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Age Estimation of Korean Adults by Occlusal Tooth Wear

ABSTRACT: The aim of the present study was to evaluate the validity of the modified Kim's scoring system as a practical method of recording occlusal tooth wear and estimating age. For this purpose, 1092 pairs of maxillary and mandibular full-arch casts were randomly selected, scored, and analyzed. The results showed that the modified Kim's scoring system had excellent reliability, and that occlusal tooth wear had a positive correlation with age. Tooth wear scores of all teeth except the two lower central incisors were higher in males than in females. Calculating tables for age estimation were designed by multiple linear regression analysis. Estimated ages were within $\pm$ 5 years of actual ages in 63.5% of male subjects, and 64.0% of female subjects. The accuracy of age estimation was increased when the subjects were divided into two age groups and data were re-analyzed. Collectively, it was shown that the modified Kim's scoring system is a reliable and accurate method for age estimation, and that the data from these 1092 individuals can be used as a standard for age estimation of Korean adults.

KEYWORDS: forensic science, forensic odontology, forensic anthropology, age estimation, occlusal tooth wear, scoring system

Age estimation is of importance in the forensic sciences not only for the identification of deceased victims or human remains but also for the legal or administrative affairs of citizens. Age estimation of living persons might be required in such cases that chronological age plays a critical role, e.g., criminal responsibility, school attendance, social benefits, and so on.

Chronological age assessment based on dental factors is generally accepted as a reliable and feasible method to estimate an individual's age because teeth can be preserved for a long time after all other tissues, even bone, have disintegrated (1–3). Since Gustafson's scoring system (1) for the estimation of chronological age from human teeth, there have been several reports on improved methodologies or comparative studies in this field (4–12). However, some of those methods require tooth extraction and preparation of microscopic sections of teeth (1–3). Such invasive methods are not applicable to the estimation of a living person's chronological age. Noninvasive radiographic methods wherein age was assessed based on dental maturation or the ratio between the pulp chamber and tooth have also been reported (13–19), and have proved to be promising. Another dental factor that can be used for age estimation is occlusal tooth wear. Although age estimation from occlusal tooth wear is a very simple and practically convenient method, a low level of accuracy limits its usefulness. If a practical scoring system of occlusal tooth wear can easily be applied in a clinical environment, is reliable, and has a sufficient accuracy, it would be very useful for age estimation of living persons.

In a previous study published in 2000 (20), we reported Kim's scoring system to record the degree of occlusal tooth wear, and showed its high reliability and accuracy in estimating chronological age. Although Kim's scoring system had been proven to be applicable to age estimation for individuals of any age, it was suggested that further large-scale studies were needed to maximize its usefulness as a clinical tool. To this end, we modified Kim's scoring system to make it more applicable and conducted a study on the general population.

The aim of the present study was to evaluate the validity of the modified Kim's scoring system as a practical method of recording the degree of occlusal tooth wear and estimating chronological age. For this purpose, we examined the reliability of the modified Kim's scoring system and the relationship between chronological age and the degree of occlusal tooth wear measured by the system in a large-scale sample population.

Material and Methods

Materials

The present study was based on 1092 randomly selected pairs of maxillary and mandibular diagnostic full-arch casts obtained from individuals (587 males and 505 females) ranging from 21 to 87 years of age. Age and gender distributions are presented in Table 1. Casts from edentulous patients or patients who had severe malocclusion that could affect occlusal tooth wear were excluded.

Methods

The degree of occlusal tooth wear was evaluated with the naked eye or a magnifying glass under a light, using the modified Kim's scoring system given in Table 2. The intra- and interexaminer reliabilities of the original version of Kim's scoring system were proven in a previous study (20). In the present study, we modified the scoring system by changing the selection of teeth and degree classifications (1). We included anterior teeth and their respective scores (2). We included unsound, restored, or missing teeth on which occlusal tooth wear could not be determined, and then added the scores for those teeth. Scoring was performed by two well-trained examiners after a mutual calibration procedure. Intraexaminer concordance was evaluated by performing blind assessments on casts from 30 individuals on a randomly selected and

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TABLE 1—*Age and gender distribution of the subjects.*

	Male		Female		Total		
Age	Mean 45.2	SD 13.6	Mean 45.6	SD 14.1	Mean 45.4	SD 13.9	Percent
20s	58		53		111		10.2
30s	164		131		295		27.0
40s	157		136		293		26.8
50s	111		90		201		18.4
60s	73		64		137		12.6
70s	19		29		48		4.4
80s	5		2		7		0.6
Total	587		505		1092		100.0

SD, standard deviation.

ordered basis. Two examiners scored occlusal tooth wear using casts of 30 matched individuals independently to test interexaminer concordance.

Statistical Analysis

Intra- and interexaminer reliability was evaluated by the intraclass correlation coefficient (ICC). A sample independent *t*-test was performed to examine the gender difference in occlusal tooth wear score of each tooth. The degree differences of occlusal tooth wear of six age groups (20s, 30s, 40s, 50s, 60s, and above 70) were analyzed by Analysis of Variance (ANOVA). Linear-by-linear association was evaluated by χ^2 test with the six age groups to determine whether the newly added scores, 9 and 10, had any relationship with age. Multiple linear regression analysis based on the method of least squares was performed to evaluate the relation between age and the degree of occlusal tooth wear, and to design the calculating tables for age estimation. In the regression process, each tooth score was treated as an independent variable. SPSS 11.0 for windows was used for all statistical analyses.

Results

The intra- and interexaminer reliabilities of the modified Kim's scoring system were excellent at 0.98 ($p<0.01$) and 0.94 ($p<0.01$) in ICC, respectively. Occlusal tooth wear scores of all teeth except the two lower central incisors were higher in male subjects than in female subjects (data not shown). Occlusal tooth wear scores of all teeth showed a gradual increase with age in comparison between age groups, and the differences between age groups were statistically very significant (data not shown). The scores 9 and 10 were excluded from this mean comparison analysis because they, technically, did not represent occlusal tooth wear but some clinical state of teeth. A χ^2 test showed that the frequencies of such scores increase significantly along with age in almost all teeth (data not shown). This result indicates that the additional scores 9 and 10 are acceptable as variables of the regression analysis for the relationship between age and the modified Kim's scoring system score.

Multiple linear regression analysis was performed separately for male and female subjects due to the gender difference in occlusal tooth wear. Coefficients of determination (r^2) of occlusal tooth wear scores relative to age were as high as 0.8149 in males and 0.8407 in females. The standard errors were 7.28 and 7.16 years in male and female subjects, respectively. Based on these regression analysis results, the calculation tables for age estimation were designed (Table 3). The estimated age can be calculated by adding the constant to the sum of numerical values obtained from the table. The accuracy of estimation was evaluated by calculating the differences between estimated and actual ages. The results showed that the estimated age was within $\pm$ 5 years of the actual age in 63.5% of the male and 64.0% of the female subjects, and the accuracy increased when the subjects were divided into two groups: above and below the age of 45. The percentage of individuals whose estimated age was within $\pm$ 5 years of their actual age was 91.6% in males under age 45, 90.2% in males above age 45, 80.9% in females under age 45, and 81.9% in females above age 45 (Table 4). Moreover, the standard errors were lowered to 4.18 years in male subjects under age 45, 4.44 years in male subjects above age 45, 4.97 years in female subjects under age 45, and 6.43 years in female subjects above age 45. The calculation tables were redesigned for the four groups divided by age and gender (Tables 5 and 6).

Table 7 shows how to estimate age using the calculation table. First, a numerical value for each tooth is obtained, and then the constant is added to the sum of numerical values. The result clearly shows that the difference between estimated and actual ages is only 1.54 years.

TABLE 2—*The modified Kim's scoring system.*

Score	Incisor	Canine	Premolar	Molar
0		No visible wear		
1	L/P	L/P	1P/1L	1P/1L/2P/2L
2	S/B	S/B	2P/2L/1S/1B	3P/3L/4P/4L/1S/1B/2S/2B
3	Pc/Lc	Pc/Lc	2S/2B	3S/3B/4S/4B
4	Sc/Bc	Sc	Wear on more than 2/3 occlusal surfaces	
5		Bc	1Pc/1Lc	1Pc/1Lc/2Pc/2Lc
6			2Pc/2Lc/1Sc/1Bc	3Pc/3Lc/4Pc/4Lc/1Sc/1Bc/2Sc/2Bc
7			2Sc/2Bc	3Sc/3Bc/4Sc/4Bc
8			Concavity on more than 2/3 occlusal surfaces	
9		Filling,* Caries,* Crown (all teeth)		
10		Missing, stump of tooth, pontic, denture (all teeth)		

*If the extent of filling materials or caries does not exceed 1/3 of the occlusal surface so that the degree of occlusal tooth wear can be determined, the pertinent score should be given.

P, point-like wear facet less than *c*. 1 mm in diameter; L, linear wear facet less than *c*. <1 mm in width; S, surface-like wear facet greater than *c*. 1 mm in diameter; B, band-like wear facet greater than *c*. 1 mm in width or wear facet involving more than two surface-like wear facets.

'/' means 'or.'

'c'(concavity), the wear of dentin.

In the situation where a tooth has several different degrees of occlusal tooth wear, the highest degree should be selected as the occlusal tooth wear score.

TABLE 3—*Calculation table for age estimation of all subjects.*

Tooth No.*	Scores																					
	0		1		2		3		4		5		6		7		8		9		10	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
11			19.69	−18.99	−1.99	−3.13			−1.09	1.27									−0.32	−3.23	−3.12	−2.10
12			−5.30	4.63			−0.28	2.00	−0.94	0.94									2.94	0.79	−0.02	3.90
13			16.66	−1.81			−0.38	0.02	−0.84	0.30	−2.63	−1.06							0.34	−0.56	0.59	0.03
14			−1.83	−22.55	−0.76	−0.12			−0.88	3.49	−0.54	3.75	−3.33	4.02	4.05		−7.66		−2.87	7.49	−2.70	11.11
15			8.22	9.25	3.86	2.82	0.99	1.02			−0.20	0.62	−1.40	2.69	−1.20	1.27	4.91	−5.96	−1.15	0.08	3.89	1.58
16					−3.44	0.08	−2.89			1.22	0.18	0.61	1.20	1.71	5.84	2.12	10.12	−2.51	1.01	0.31	1.02	0.66
17					−5.39	−2.06	−0.77	−0.99			1.13	2.72	3.23	4.36	5.64	−5.61	1.56		0.85	2.72	0.92	2.94
21				4.82	−3.88		−3.42	0.22		3.87									−4.95	2.89	−4.87	0.54
22		8.08	5.41	−0.02			−0.44	0.27	0.88	−1.52									1.49	0.63	0.53	2.27
23			−17.93	2.30	−1.36	−0.22	0.85		2.78	0.45	5.03	3.51							3.04	4.28	2.23	3.79
24			3.04	−16.93	−2.53	1.95			2.08	0.17	0.46	0.44	−0.89	1.61	−7.61	2.90	15.10		3.69	−3.33	6.57	−1.41
25			−6.51	13.59	0.37	−2.13	−0.29	−0.31			1.99	−1.09	7.02	1.95	4.71		13.33		1.49	0.16	1.26	2.49
26			3.88	7.48	−1.33	0.82	−2.77	0.41	−1.06		−1.98	1.91		4.47	4.04	6.47	−1.57	−6.01	1.13	2.03	1.00	1.73
27					0.16	1.39	0.49	−0.04			2.36	1.36	0.95	1.19	4.58		−1.51	−10.43	2.40	−0.79	4.05	2.40
31			2.20	12.38	1.13	0.98	2.66			−0.24									−0.61	−3.51	−1.38	1.73
32			−4.95	0.20	−1.47	1.09	−0.06			3.55									−3.65	5.44	−2.89	−3.57
33			22.21	1.95	11.01	−0.40	11.79		10.95	0.07	11.86	0.72							10.16	−3.79	24.19	−5.18
34		1.46	0.49	−0.50			2.04	2.30	1.72	1.52	2.31	1.17	5.57	0.23	8.32	5.16	12.64		7.03	2.75	5.98	2.71
35			−4.30	0.65		−2.94	−0.59	−1.63	0.84		−0.02	1.04	−2.00	−2.11	−7.29	10.65	−12.53	14.03	−2.08	−0.05	−0.62	0.23
36					3.51	1.24	2.40	−2.31	1.02	−0.07		1.83	1.31	1.00	−0.58	1.40	−1.19		−0.20		3.02	−1.00
37					0.77	−3.75	0.93	−1.81			2.61	0.17	1.74	3.99	−0.03	1.29	3.37		−0.02	−1.44	2.92	−0.76
41			−4.29	−10.23	1.39	−1.51		−1.20	1.23										4.76	15.74	4.15	3.75
42			3.82	−0.56	−3.28		−1.72	0.01		2.15									−0.46	1.06	0.35	5.51
43			−15.40	−0.82	0.82	1.87			1.47	2.44	3.80	−1.68							2.43	7.28	−13.54	14.80
44	7.03		−3.52	1.43			−0.29	−0.82	−0.28	2.32	−1.80	−1.33	2.30	−3.74	6.68	10.81	−1.52	7.83	1.24	5.25	−1.19	−3.56
45	−17.86		−2.15	−6.06	−2.86			1.77	2.32	1.25	1.25	3.64	0.87	10.86	12.61		3.40	−5.50	1.24	3.13	−1.55	0.02
46					3.56	−5.53	1.51	−5.64	−0.98	−4.16	0.61			−2.27	0.48	−2.04	3.93	−1.56	0.71	−1.77	0.06	−1.71
47			−5.21		−4.70	−4.24	−3.38	0.89			0.90	1.71	−0.66	4.11	5.12	0.66	3.52	9.13	1.66	−2.47	0.15	−1.18

*Two-digit system was used for numbering of teeth (e.g., 14 denotes the right maxillary first premolar).
Constant = 27.96 (male), 36.29 (female).
r^2 (coefficient of determination) = 0.8149 (male), 0.8407 (female), Standard error = 7.28 (male), 7.16 (female).
M, male; F, female.

Discussion

Occlusal tooth wear is widely accepted as a physiological consequence of aging. Nevertheless, it is evident that age estimation based only on occlusal tooth wear has to be avoided, if possible, because the process of occlusal tooth wear is affected by various factors such as eating and chewing habits, the hardness of dental tissues, bite force, gender, geographical location, environmental conditions, and parafunctions like bruxism (4,21–23). However, in some cases, especially in living persons over 20 or 30 years of age, age estimation has to be carried out inevitably with limited information. It has been emphasized that such a problem in Europe appears to be growing because of increasing immigration, both legal and illegal, due to economic globalization and European integration (24,25). Because of the tide of globalization worldwide, it could be the same in any region of world.

Occlusal tooth wear is one of the degenerative changes related to age, and can be used to estimate the chronological age of living persons with no proof of their date of birth. Although several scoring systems for the evaluation of occlusal tooth wear have been reported (7,26–29), there is no universally applicable occlusal tooth wear scoring system. Kim's scoring system was presented first in 2000, and its reliability and accuracy were proven (20). However, its focus was on the scoring system itself, in the manner of selecting a limited number of sound teeth to prove its validity, as with other previous studies. Although variability inevitably increases, it is necessary that a scoring system cover the widest range of dental states that can be observed in the general population, such as missing, fractured, decayed, and restored teeth, in order to be effectively applied in the field. This is the reason why the previously described Kim's scoring system was modified. All kinds of teeth, except third molars, were included for study and scores for unsound, restored, or missing teeth on which occlusal tooth wear could not be determined were added (Table 2). The results showed that the frequencies of such additional scores, besides occlusal tooth wear, have a correlation with age; thus the modification is acceptable for the regression process. As every score of each tooth was treated independently in the process of regression analysis, the order of scores did not matter; thus, the additional scores were added to the end of the series of scores. The modified Kim's scoring system showed excellent reliability in the intra- and interreliability tests performed with 30 pairs of dental casts, as the original Kim's scoring system had been.

TABLE 4—*Accuracy of age estimation.*

Age	Gender	Range of Error (Years)				
		Within ± 2 (%)	Within ± 3 (%)	Within ± 5 (%)	Within ± 10 (%)	Above 10 (%)
Total	M	30.5	41.4	63.5	91.1	100.0
	F	33.5	44.0	64.0	91.9	100.0
Under age 45	M	59.5	75.3	91.6	99.7	100.0
	F	54.3	70.3	90.2	100.0	100.0
Above age 45	M	39.9	55.6	80.9	98.3	100.0
	F	47.4	64.3	81.9	99.2	100.0

M, male; F, female.

TABLE 5—*Calculation table for age estimation of subjects under age 45.*

Tooth No.*	Scores 0		1		2		3		4		5		6		7		8		9		10	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
11			18.18	−6.76			2.03	2.29	−0.86	−2.03									0.94	4.36	−7.65	4.37
12			−3.91	2.62		−1.06	−0.11		−2.82	−5.07									5.05	2.16	4.58	21.87
13			16.72	0.29			0.41	0.63	0.38	1.67	3.50	16.27							4.15	−10.73	−19.96	−8.36
14			2.54	−9.14	−3.16	−3.27		−0.66	−0.27		−0.37	−0.98	−4.76	9.15					−1.98	3.45	−5.87	12.95
15			14.05	6.45	6.50	2.45	3.53	1.64			1.90	2.87	−1.94	0.42					0.28	−2.93	2.40	−0.42
16					−4.57	0.38	−2.38		−0.58	−0.47		−1.57	−7.58	8.09					−1.46	−2.72	2.56	−0.14
17					−2.64	−2.68	−1.20	−0.54			−3.73	3.49	2.27						−3.34	−0.04	0.52	0.61
21					−2.16	0.32			1.54	−1.30									−0.22	−4.40	7.31	3.12
22		1.04	5.10	−0.59			0.46	0.11	1.35	11.57									−2.55	−8.74	0.73	6.76
23			−16.75	−2.92			2.01	0.07	0.73	0.81	3.00	11.93							2.75	27.69	1.53	
24			−10.08	−6.54	2.74	2.96			2.95	−0.62	2.31	−0.05	4.01	4.85					5.59	−1.62		−6.51
25			0.11	7.54	−0.50	−1.03			−0.07	1.29	1.87	1.77		−13.29					−0.87	1.68	−1.10	−38.90
26			3.09	11.79	−3.06	−3.22	−0.75	−1.48			0.42	−0.21	2.39	−1.42					2.40	1.52	1.62	−3.36
27					0.15	2.47	0.09	−0.38			2.01	−4.09	−1.10	3.12					0.89	−2.44	−3.77	1.55
31				−0.25	−1.26	−2.11			−1.47	4.98									−13.34		−6.83	
32			−3.52	2.49		−0.28	0.53		−2.37	2.14									−5.81		−7.79	10.65
33			9.08	2.02	−1.08	−0.54			−0.65	2.40	−2.82	7.72										−4.92
34		3.28	−2.06	−2.10			0.93	1.94	−0.58	0.98	1.98	5.57	4.73	−32.59					3.01	−7.15	−9.54	
35			1.13	1.77			1.93	−0.27	6.11	2.48	1.06	5.88	4.82	30.50					−4.19	5.67	−1.88	5.47
36					0.19	5.21			0.39	2.94	−0.69	3.25	0.52	2.83	−0.27	11.42			−1.19	3.36	4.37	0.54
37					−1.02	−1.28	−0.01			0.03	0.93	0.71	−2.40	−1.77	−21.08				1.05	1.76	−2.35	0.94
41			−6.58	−0.61			−1.11	−1.57	3.13	−3.04									5.20		11.18	8.17
42			7.23	1.93			−1.08	−0.81	−0.50	−0.18									−0.07	−16.03	−0.58	−3.45
43			−14.72	−0.04			−0.94	−1.51	2.33	0.07	0.95	−4.35							4.54			
44	5.12		−0.88	−4.57			0.18	−1.20	−1.90	−0.87	−2.60	−2.51	−1.39	−6.09					7.61	6.72	23.49	−4.43
45	−5.80		−3.52	−4.36			2.19	1.19	1.62	0.51	2.32	2.45	11.27						1.41	−0.20	−4.11	−10.13
46					1.96	−1.35			−2.31	4.62	−3.34	2.92	−3.62	0.46		−17.45			−1.04	2.35	−1.04	2.50
47			−4.09		−3.34	−3.67	−3.55			−1.63	−0.55	2.37	2.16	10.33					0.16	−0.95	0.14	−0.61

*Two-digit system was used for numbering of teeth (e.g., 14 denotes the right maxillary first premolar).
Constant = 31.68 (male), 30.42 (female).
r^2 (coefficient of determination) = 0.8087 (male), 0.7934 (female), standard error = 4.18 (male), 4.97 (female).
M, male; F, female.

TABLE 6—*Calculation table for age estimation of subjects above age 45.*

Tooth No.*	Scores 0		1		2		3		4		5		6		7		8		9		10	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
11					−0.33	−5.11			−0.67	6.85									−1.28	3.08	−0.91	−1.37
12						−3.12	1.53		0.94	1.33									2.17	6.25	0.29	−2.05
13					5.14	−1.24	5.94		5.09	1.21	−2.22	2.67							1.80	−6.02	7.01	−3.94
14					−17.85	19.53	−0.78	−5.97	−2.69		2.09	2.14		1.29	8.52		−9.06		0.03	10.25	−1.89	11.59
15					7.46	−26.91	−0.27	−3.39			−1.16	−1.50	−3.73	−3.37	−7.91	−4.46	9.72	−11.33	−0.12	−7.89	1.00	−8.38
16							−0.16	−23.15		−1.88	−0.94		1.94	−3.11	6.62	−4.31	10.22	−18.98	2.40	1.38	3.76	0.22
17						−3.22	−0.46	7.14			−2.48	2.33	0.13	7.69	3.70	−3.09	4.01	−16.09	−0.62	4.68	−1.18	6.70
21				−7.00	−0.48	4.66		1.74	0.69										−1.61	−0.77	−10.80	−0.03
22		12.72		−8.88	0.04		−2.46	−3.05		−6.57									4.74	−5.04	2.70	−1.56
23				6.51	−1.80	2.03	−5.57		−4.55	0.16		2.76							−3.25	1.07	−3.81	−4.27
24			19.36		−8.25	−10.72	4.56	9.72	1.14			1.16	−1.62	1.71	−6.57	6.11	18.71		4.58	−0.87	8.32	−0.47
25					−0.65	19.36	−1.17	0.32		2.36	−0.22		3.29	2.57	2.79		8.08		2.99	0.90	−4.17	6.41
26							19.91	18.34	−1.93		−3.66	4.79	−0.10	4.73	2.16	10.56	−6.53			2.96	−2.66	−0.03
27							−1.26	1.53			1.45	1.16	−0.24	3.75	4.85		−5.97	−20.19	0.72	0.42	5.02	5.04
31				13.84	0.51	−5.33	3.61	−0.60											8.39	13.24	8.09	18.39
32			18.09		−2.59	−3.59	−0.70	−5.70											2.10	−7.99	−5.23	−25.70
33			24.85		19.56	−3.95	18.98	2.42	17.74		18.20	0.65							7.66	−4.61	31.05	18.58
34					−8.09	−4.93	−3.10		−3.52	1.22	−2.94	2.19		2.06	4.62	4.93	5.35		0.61	7.53	−3.73	9.43
35					−0.51	1.19	−4.79			2.31	−1.65	1.80	−4.10	4.15	−7.49	11.43	−14.97	11.11	0.56	2.76	−2.77	−0.25
36					1.86		−13.92	4.33	5.11	−2.64	3.06		2.15	−3.03	1.66	−10.72	−1.43		−0.72	−3.95		−2.93
37							16.35	3.91			4.22	1.16	2.58	4.68	3.97	−6.75	3.80		−1.03	−3.16	3.24	1.26
41					−1.31	1.61	−2.91			−1.53									0.84	8.37	0.35	−0.11
42			−18.38		−1.65	−5.12	−2.19	0.34											−2.57	4.41	1.27	2.73
43				27.34	−4.93	4.67	−4.35		−2.72	2.23		−3.76							−5.26	4.16	−42.65	4.91
44				24.05	4.96	13.11	4.78	6.47	2.47	7.44		5.66	3.49		7.36	41.61	0.78	25.03	4.87	10.91	3.49	−5.12
45					1.93	9.00		2.94	2.60		1.46	4.71	2.94	15.33	4.20		10.96	−2.60	5.72	3.01	1.07	−4.75
46							−10.48	−10.49	−2.87	4.41	−0.96			−0.02	−0.14	4.18	4.20	−5.15	4.93	−1.12	3.58	0.07
47						−3.92	−10.99	−10.75			0.29	−1.03	−2.86	1.42	0.81	−0.52	−2.24	3.70	−1.11	−2.49	−4.88	−5.59

*Two-digit system was used for numbering of teeth (e.g., 14 denotes the right maxillary first premolar).
Constant = 36.51 (male), 44.54 (female).
r^2 (coefficient of determination) = 0.8063 (male), 0.8470 (female), standard error = 4.44 (male), 6.43 (female).
M, male; F, female.

TABLE 7—*A practical example of age estimation for a male subject under 45 years of age.*

Tooth No.*	Score	Numerical Value†
11	2	
12	2	
13	3	0.41
14	4	− 0.27
15	4	
16	4	− 0.58
17	4	
21	2	− 2.16
22	2	
23	3	2.01
24	4	2.95
25	4	− 0.07
26	5	0.42
27	9	0.90
31	2	− 1.26
32	2	
33	2	− 1.08
34	9	3.01
35	4	6.11
36	7	− 0.27
37	9	1.05
41	2	
42	2	
43	3	− 0.94
44	4	− 1.90
45	4	1.62
46	5	− 3.34
47	6	2.17

*Two-digit system was used for numbering of teeth (e.g., 14 denotes the right maxillary first premolar).

†Numerical values and the constant are pertinent values from Table 5.
Sum of numerical values = 8.78.
Constant = 31.68.
Estimated age = 40.46.
Actual age = 42.
Difference of ages = 1.54.

It was also proposed in the previous study that Kim's scoring system had to be supported by a large-scale study on the general population in order to maximize its usefulness. In the present study, 1092 pairs of dental casts were analyzed. The results showed that the degrees of occlusal tooth wear were higher in males than in females, and higher degrees of occlusal tooth wear were observed in the older age group. Gender difference in the degree of occlusal tooth wear was in agreement with that of previous studies (20,23,30–34). These differences may be explained by stronger masseter muscle function in males (32). It is now beyond doubt that the degree of occlusal tooth wear increases with age, which has been confirmed by previous studies (20,30,31,33–35). Up to now, only one study did not find a correlation between age and attrition (32), but the study was not performed with a randomly selected sample group comprised of different age strata (23).

The accuracy of age estimation using calculation tables is shown in Table 4. Estimated ages were within $\pm$ 3 years of the actual age in 41.4% of the male subjects and 44.0% of the female subjects. Accuracy increased when the subjects were divided into two groups. In the group under 45 years of age, the estimated age was within $\pm$ 3 years of actual age in 75.3% of the males and in 70.3% of the females. In subjects above 45 years of age, the estimated age was within $\pm$ 3 years of actual age in 55.6% of the male subjects, and 64.3% of the female subjects. The reason for this is that the degree of occlusal tooth wear correlates with age, but not exactly in a proportional manner. For practical use, however, we need age estimation (under age 45 or above age 45) before applying Tables 5 and 6. If some sort of information about a subject's age is available, we can restrict the age range and increase the accuracy of age estimation. If this kind of classification is impossible in certain situations, simply total values can be applied.

These overall results show that age estimation by the modified Kim's scoring system is as accurate, despite the modification, as the original Kim's scoring system published in 2000. This result may be explained by the increase of statistical power due to the larger sample size, and the statistical correlation of the frequencies from the added scores 9 and 10 with age. The results of the age group under 45 years were more accurate than that of the group above 45 years of age. This result might be due to a decrease of the number of teeth, which is known to affect the degree of occlusal tooth wear (23,36).

Collectively, the present study demonstrates that the modified Kim's scoring system is a very reliable and accurate method for age estimation of the general Korean population at any age above 20 years. Using only the simple procedure of taking a dentition impression, the data of 1092 individuals can be used as a standard for age estimation of Korean adults. Hereafter, the more the data accumulated, the more useful the modified Kim's scoring system will be to estimate the age of a living person.

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