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Age Estimation by Occlusal Tooth Wear

ABSTRACT: The purpose of the present investigation was to test the accuracy of a new scoring system in recording tooth wear for age estimation. The material consisted of dental stone casts of 383 volunteers who had sound premolars and molars with normal occlusion. The degree of occlusal wear for all premolar and molar teeth was scored with the new system. The high intra- and inter-examiner concordances showed that the new score system was very reliable. The degree of tooth wear showed a significant positive correlation with age in each and every examined tooth of both males and females. Tooth wear scores of males were higher than those of females. Calculating tables for age estimation were designed and the accuracy of age estimation was obtained with the General Linear Models procedures. Our system could provide estimation of an individual's age within ±3 years in 42.4% of males and 49.4% of females, within ±5 years in 61.8% of males and 63.3% of females. When the subjects were divided into two age groups and data were re-treated, the accuracy of age estimation was increased. Collectively, it was shown that our new system for scoring tooth wear is a reliable and accurate method for age estimation.

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

Tooth wear has been frequently used as a tool of age estimation (1–4). Teeth can be preserved for a long time after all other tissues, even bone, have disintegrated (1,2,5). Dentition can be also examined directly in live individuals. Tooth development follows a typical chronological pattern and fully formed teeth show aging changes. Thus, examination of dentition can provide valuable information on an individual's growth and development. Teeth can also act as a biological marker of aging and can be used to estimate an individual's age for forensics and anthropology.

The mechanisms by which teeth wear include attrition, abrasion and erosion. Tooth attrition is defined as gradual and regular loss of tooth substance as a result of chewing activity. Tooth abrasion means the pathologic wearing away of dental hard tissue by the friction of a foreign body, independent of dental occlusion. Dental erosion is superficial loss of dental hard tissue by a chemical process that does not involve bacteria (6). These mechanisms, however, seldom operate singly. Overlapping of two or more different processes, at different times, adds to the complexity of the phenomenon of tooth wear. The factors that may influence these processes include functional or parafunctional habits, patterns of mandibular movement, bite force, saliva, diet, medication, diseases, and occupational and habitual environment (7).

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 (8–15). However, some methods require tooth extraction and preparation of microscopic sections of tooth (1,2,5). These methods are also time-consuming and cost-inefficient. In addition, this invasive approach may not be practical for ethical, religious, cultural or scientific reasons. Although even sophisticated techniques such as computer-graphics (16) and scanning electron microscopy (17) are available, their usefulness in clinical situations is still questionable. Estimation of an individual's age from tooth wear is a very simple and convenient method. This method does not need any invasive process such as tooth extraction or tissue preparation. However, a low level of accuracy is a factor to limit its usefulness.

The purpose of this study was to evaluate the accuracy of Kim's new scoring system as a method of recording the degree of tooth wear and determining an individual's age. For this goal, we examined the reliability of the new scoring system and the relationship between age and the degree of tooth wear by the new system.

Materials and Methods

Subjects

The present study was based on the data from 383 individuals (217 males and 166 females) whose ages range from 13 to 79 years. The gender and age distributions are presented in Table 1. Individuals who had no distinct dental malocclusion were included. Subjects who had a history of any operative or prosthetic treatments, or missing a tooth on their premolar and molar areas, were excluded.

Methods

Maxillary and mandibular dental study models (four casts: right maxillary, right mandibular, left maxillary and left mandibular) were obtained from each subject. A dental impression was taken with a bite tray on both jaws simultaneously to reduce chair time. To get a more precise duplication, silicon rubber impression material (vinyl polysiloxane impression material: Perfect VPS, J.P. Korea Ltd., Seoul, Korea) was used.

Sixteen permanent teeth (first and second premolars and molars) were selected to examine the degree of tooth wear. Tooth wear of anterior teeth (from canine to canine) was disregarded because of very wide individual variations in their vertical angles and rotations. The degree of tooth wear for each tooth was evaluated with the naked eye or a magnifying glass under a light using the Kim's scoring system of tooth wear given in Table 2. Scoring was performed by two well-trained examiners after a period of mutual calibration procedure. Intra-examiner concordance was evaluated by performing blind assessments on casts of 150 subjects on a randomly selected and ordered basis. Two examiners scored tooth

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

Gender	−19	20–29	30–39	40–49	50–59	60–69	70–79	Total
Males	20	21	39	68	44	11	14	217
Females	22	20	28	47	24	15	10	166
Total	42	41	67	115	68	26	24	383

(Age, years — column header spanning the numeric age columns)

TABLE 2—*The Kim's scoring system of tooth wear.*

Score	Premolar	Molar
0	**No visible wear**	
1	1P/1L	1P/1L/2P/2L
2	2P/2L/1S/1B	3P/3L/4P/4L/1S/1B/2S/2B
3	2S/2B	3S/3B/4S/4B
4	**Wear on more than 2/3 occlusal surface**	
5	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 surface**	

P = Point-like wear facet less than approximately 1 mm in diameter.
L = Linear wear facet less than approximately 1 mm in width.
S = Surface-like wear facet more than approximately 1 mm in diameter.
B = Band-like wear facet more than approximately 1 mm in width or wear facet involving more than two surfaces.

NOTES
'/' means 'or'.
'c'(concavity) means the wear of dentin.
In the situation where a tooth has several different degrees of tooth wear, the highest degree should be selected as tooth wear score.

wear on casts of 150 matched subjects independently to test inter-examiner concordance.

Statistical Analysis

Intra- and inter-examiner reliabilities were tested by checking the concordance of tooth wear score. Means and standard deviations of tooth wear score in each age group were obtained using SAS. The t-test was used to examine gender difference. The correlation analysis was used to examine the relationship between tooth wear scores of different teeth. The ANOVA and linear regression analysis of age against tooth wear score were done to examine the relationship between age and tooth wear score. Finally, calculating tables for age estimation were designed and the accuracy of age estimation was obtained with the GLM (General-Linear Models) procedures.

Results

The intra- and inter-examiner concordances by the Kim's scoring system were 92.9 and 93.9%, respectively, which means our new scoring system is a very reliable method. Table 3 shows mean values and standard deviations of tooth wear and gender difference for each tooth. There was a gradual increase in tooth wear score with aging in each and every tooth in both males and females ($p < 0.01$). Generally, the degrees of tooth wear in males were higher than those in females. In the groups under the age of 30, males showed higher scores than females but there was no statistical significance. Gender differences with statistical significance were observed mostly at the age ranges in the thirties and fifties. The correlation analysis showed that the degrees of correlation were relatively strong between tooth wear scores of all examined teeth (coefficient of determination, $r^2 = 0.4199 - 0.7465$). The correlation between tooth wear scores of molars ($r^2 = 0.5256 - 0.7465$) was greater than premolars ($r^2 = 0.4238 - 0.6642$).

TABLE 3—*Mean values and standard deviations of tooth wear score for each tooth and levels of statistical significance between tooth wear scores of males and females.*

Tooth No.†	−19 (years) M Mean	M S.D.	F Mean	F S.D.	Sig.	20–29 (years) M Mean	M S.D.	F Mean	F S.D.	Sig.	30–39 (years) M Mean	M S.D.	F Mean	F S.D.	Sig.
14	1.45	0.60	1.66	0.58		2.52	1.16	2.05	0.91		3.33	1.20	2.54	1.07	**
15	1.25	0.55	1.27	0.63		1.81	0.75	1.45	0.69		2.74	0.82	2.32	0.94	
16	1.84	0.83	1.64	0.58		2.33	0.58	2.10	0.91		3.28	1.10	2.89	0.89	
17	1.42	0.84	1.27	0.83		2.10	0.54	2.00	0.65		3.03	0.84	2.68	0.72	
24	1.55	0.60	1.45	0.51		2.38	0.86	2.05	0.91		3.41	1.09	2.82	1.06	*
25	1.47	0.51	1.45	0.51		1.57	0.68	1.40	0.68		2.85	0.81	2.29	0.71	**
26	2.00	0.79	1.91	0.61		2.24	0.70	2.25	0.97		3.38	0.88	2.89	0.79	*
27	1.63	0.96	1.29	0.72		2.15	0.75	2.05	0.69		3.18	0.85	3.00	0.98	
34	1.37	0.50	1.23	0.61		1.71	0.56	1.53	0.61		2.51	1.19	1.96	0.84	*
35	1.20	0.62	1.24	0.54		1.71	1.10	1.40	0.68		2.67	1.01	2.23	0.65	*
36	1.84	0.76	1.86	0.65		2.43	0.97	2.55	1.32		4.31	1.24	3.57	1.23	*
37	1.88	0.60	1.50	0.71		2.42	0.93	2.15	0.67		3.61	1.17	2.54	0.58	**
44	1.25	0.64	1.36	0.58		1.76	0.54	1.63	0.60		2.61	1.20	1.96	0.84	*
45	1.35	0.59	1.29	0.64		1.48	0.68	1.50	0.61		2.47	0.83	2.00	0.77	*
46	2.20	0.62	1.90	0.54		2.29	1.10	2.45	1.36		3.76	1.40	3.11	1.29	
47	1.84	0.69	1.85	0.75		2.19	0.60	2.00	0.73		3.18	1.01	2.54	0.74	**

*p < 0.05.
**p < 0.01.
S.D. = Standard deviation.
Sig. = significance.
† Two-digit system was used for numbering of teeth. (Example: 14 means upper right first premolar.)

TABLE 3—*(Continued.)*

40–49 (years) M		F		Sig.	50–59 (years) M		F		Sig.	60–69 (years) M		F		Sig.	70–79 (years) M		F		Sig.
Mean	S.D.	Mean	S.D.		Mean	S.D.	Mean	S.D.		Mean	S.D.	Mean	S.D.		Mean	S.D.	Mean	S.D.	
3.88	1.33	3.49	1.30		4.67	1.23	4.04	1.20	*	4.82	1.17	4.40	1.12		5.76	0.58	4.80	1.14	*
3.38	1.01	3.11	0.85		4.19	1.33	3.75	1.03		4.00	1.18	3.93	0.80		5.36	1.01	5.20	1.32	
4.26	0.97	4.02	1.03		5.35	1.53	4.46	0.93	**	5.73	1.19	5.20	0.56		6.14	1.17	5.40	1.17	
3.79	0.84	3.61	0.88		4.69	1.51	4.04	0.77	*	5.36	1.43	4.27	0.80	*	5.71	1.68	4.89	0.78	
4.16	1.23	3.43	1.35	**	4.55	1.15	4.00	1.06		4.55	1.13	4.47	1.06		5.50	0.65	4.80	0.92	*
3.43	1.16	3.06	0.79	*	3.95	1.20	3.63	0.92		3.91	1.30	3.87	0.92		5.31	0.95	4.78	1.09	
4.42	1.10	3.96	1.04	*	5.20	1.34	4.46	0.93	*	5.45	1.13	5.40	0.63		6.14	1.23	5.70	0.82	
3.89	0.91	3.55	0.83	*	4.77	1.44	3.95	0.74	**	5.33	1.22	4.53	0.83		6.00	1.41	5.10	1.29	
3.22	1.41	3.19	1.50		4.30	1.34	3.58	1.47	*	4.40	1.51	4.27	1.33		5.64	1.01	4.20	0.92	*
3.01	1.04	2.98	0.94		3.67	1.27	3.21	0.93		3.80	1.14	4.07	1.33		5.23	1.64	4.60	0.84	
4.94	1.13	4.72	0.97		5.56	1.08	4.75	1.11	**	6.30	0.95	5.47	0.83	*	6.38	1.04	6.00	1.05	
3.74	1.01	3.60	0.74		5.12	1.38	3.91	0.90	**	5.67	1.22	4.93	0.92		6.08	1.44	5.40	1.17	
3.19	1.35	3.09	1.40		4.18	1.50	3.38	1.24	*	4.60	1.84	4.33	1.35		5.92	1.55	4.67	1.22	
3.07	1.16	3.11	1.06		3.64	1.22	3.50	1.06		3.70	1.16	4.00	1.11		5.38	1.85	4.88	0.99	
4.70	1.04	4.82	0.96		5.73	1.35	4.71	1.12	**	5.80	0.79	5.33	0.49		6.43	1.09	5.78	0.67	
3.85	1.04	3.61	0.89		5.09	1.56	3.88	1.03	**	5.11	1.69	5.21	1.31		6.15	1.57	5.38	0.92	

The results of regression analysis for each tooth are given in Table 4. The ranges of r^2 were 0.4416 to 0.5755 in males and 0.4084 to 0.6714 in females. Calculation tables were designed for age estimation from the degrees of tooth wear in total male and female subjects, respectively (Tables 5, 6). The estimated age can be calculated by adding an intercept to the sum of numerical values obtained from the table. The percentage error that means the difference between estimated and actual ages is given in Table 11. The estimated age was within ±5 years of actual age in 61.8% of male and 63.3% of female subjects.

When the subjects were divided into two groups, the accuracy of estimation increased. Tables 7–10 give redesigned calculation tables for the divided groups. In the group under the age of 49 years, age can be estimated within ±5 years in 80.4% of males and 76.1% of females. In the group above the age of 40 years, the estimated age was within ±5 years of actual age in 77.4% of males and 76.0% of females (Table 11).

Table 12 shows how to estimate age by using Table 7. First, a numerical value for each tooth is obtained, and then the number of intercept is added to the sum of numerical values. The result shows clearly that the difference between estimated and actual ages is only 1.52 years.

Discussion

Tooth wear is widely accepted as a physiological consequence of aging. Therefore, the evaluation of tooth wear can be a simple tool to estimate age. Because the process of tooth wear is affected by various factors such as eating and chewing habits, the hardness of dental tissues, bite force, gender, geographical location, and environmental conditions, (7), age estimation based solely on tooth wear is not reliable (18). However, Hongwei et al. (19) showed that results could be improved if a large number of teeth from the same person were sampled.

TABLE 4—*Regression analysis of age against tooth wear score for each tooth.*

Tooth No.†	Males a	b	r^2	Females a	b	r^2
14	6.34	19.35	0.4629	7.13	19.10	0.4195
15	7.33	19.46	0.5162	9.00	16.04	0.6026
16	6.60	16.25	0.5646	8.66	10.85	0.6430
17	6.85	18.17	0.5492	9.66	10.93	0.6296
24	6.80	17.36	0.4623	7.57	17.62	0.4635
25	7.19	20.04	0.4837	9.94	13.81	0.6012
26	6.96	14.53	0.5755	8.89	9.42	0.6461
27	6.97	16.70	0.5676	9.28	11.53	0.6145
34	6.06	23.71	0.4668	6.63	23.34	0.4084
35	6.72	23.04	0.4425	9.28	16.87	0.5624
36	6.50	13.31	0.5692	7.31	12.01	0.5416
37	6.36	18.00	0.4989	9.60	10.51	0.6714
44	5.80	24.48	0.4655	7.18	21.70	0.4421
45	6.65	23.53	0.4416	8.58	17.89	0.5492
46	6.26	15.38	0.5390	7.25	12.82	0.5425
47	6.21	19.15	0.5055	8.45	13.70	0.5687

$p < 0.001$ in all teeth.
$Y = aX + b$ [Y = estimated age (years), X = tooth wear score].
r^2 = Coefficient of determination.
† Two-digit system was used for numbering of teeth.

Methods of age estimation based on the morphological changes of teeth can be divided into a scoring system (1,20) and direct measurement (21,22) of age-related changes in dental hard tissues. Several scoring systems for the evaluation of degree of tooth wear have been presented in the literature (11,19,23–25). However, there is no universally applicable tooth wear scoring system. Although scientific quantification of tooth wear is a more desirable determinant for age estimation, attempts to measure actual

TABLE 5—*Calculation table for age estimation in all male subjects.*

Tooth No.†	Degree of Tooth Wear								
	0	1	2	3	4	5	6	7	8
14	27.11	9.33	10.77	9.61	11.97	9.68	−1.78	0.00	...
15	−7.42	−11.74	−10.45	−8.85	−10.10	−8.30	−12.38	0.00	...
16	−18.71	−8.29	−3.59	−7.29	−2.27	−4.65	−4.49	−4.37	0.00
17	−4.73	6.41	10.44	16.20	15.94	15.50	5.19	6.47	0.00
24	0.00	12.58	20.66	22.58	18.78	21.61	21.49	0.00	...
25	...	−1.48	−2.92	−4.34	−2.07	0.32	1.20	0.00	...
26	...	32.73	33.59	34.60	33.68	37.55	30.47	7.48	0.00
27	−30.38	−26.03	−32.75	−30.53	−29.56	−28.59	−16.49	0.00	0.00
34	...	10.08	6.98	10.45	4.21	9.38	13.09	0.00	...
35	−40.99	−37.46	−38.02	−36.82	−29.94	−38.59	−53.95	0.00	...
36	...	−38.65	−38.79	−38.81	−24.47	−38.69	−38.46	−35.41	0.00
37	...	−23.50	−20.99	−17.50	−16.89	−21.57	−12.50	−16.07	0.00
44	−40.86	−46.52	−40.90	−40.46	−49.35	−38.35	−26.36	−13.87	0.00
45	−10.42	−11.18	−5.72	−7.57	−15.41	−7.58	0.00	0.00	0.00
46	...	4.84	0.20	−0.62	−4.61	2.13	0.96	8.41	0.00
47	...	−12.15	−14.98	−11.13	−12.26	−12.85	−9.69	−12.15	0.00

Intercept = 152.35.
r^2 (coefficient of determination) = 0.8815.
† Two-digit system was used for numbering of teeth.

TABLE 6—*Calculation table for age estimation in all female subjects.*

Tooth No.†	Degree of Tooth Wear								
	0	1	2	3	4	5	6	7	8
14	...	−2.39	−3.17	−10.14	−0.15	−9.25	0.00	...	...
15	37.67	37.47	37.02	37.69	33.26	35.11	0.00	...	...
16	...	−50.57	−51.11	−47.21	−45.24	−38.79	0.00	...	...
17	−12.94	−3.03	−3.13	1.63	4.50	9.40	0.00	...	...
24	...	16.82	17.22	21.77	−4.09	17.61	0.00	...	...
25	−17.64	−19.44	−14.45	−8.92	3.64	−9.56	0.00	...	...
26	...	6.71	4.25	2.50	−6.08	−6.63	8.57	0.00	...
27	−6.73	0.57	11.57	7.80	11.88	3.87	0.00	...	...
34	−26.08	−15.08	−13.65	−11.36	...	−8.09	0.00	...	...
35	−88.55	−80.81	−78.85	−82.14	−83.81	−100.42	0.00	...	...
36	...	−9.23	−6.87	−3.85	17.31	−2.91	−1.44	−85.00	0.00
37	0.00	−19.93	−19.34	−13.51	−11.24	−2.64	0.00	...	...
44	...	11.19	10.16	6.33	−6.84	2.60	0.00	...	...
45	18.81	15.86	14.42	20.59	20.07	29.47	0.00	...	...
46	...	−8.72	−14.30	−14.73	−7.40	−15.04	−27.21	0.00	...
47	0.00	−0.41	−5.23	−5.70	−9.88	−7.77	−23.86	0.00	0.00

Intercept = 143.69.
r^2 (coefficient of determination) = 0.9283.
† Two-digit system was used for numbering of teeth.

areas of tooth wear are complicated by such structures as cusps and ridges on a tooth crown where sites of tooth wear are angled and not even and flat.

In the present study, tooth wear score is classified into a 0-to-9-point scale based on the pattern, number and amount of tooth wear. Tooth wear can be evaluated by two different types of criteria (22). One is the area of tooth wear, which may be termed as a horizontal factor. The other is the degree of dentin exposure, which may be termed as a vertical factor. The combination of both horizontal and vertical factors should be considered to obtain a more accurate estimation of age. Our scoring system, designed to consider both factors, is divided into two categories according to the presence or ab-

sence of dentin exposure, the vertical factor. Then, each category is divided into 4 degrees according to the pattern, number and amount of tooth wear, the horizontal factor.

The scoring system for age estimation should be developed to have good reliability, leaving only unavoidable individual variability. To minimize the influence of intra- and inter-examiner variations, well-defined criteria and careful calibration among examiners are essential. An analysis of observation error, in the form of a concordance test, was done with our new system and its intra- and inter-examiner agreements were excellent.

According to the results of the present study, the degree of tooth wear was increased with aging in each and every tooth in both

TABLE 7—*Calculation table for age estimation in males under age 49.*

Tooth No.†	Degree of Tooth Wear								
	0	1	2	3	4	5	6	7	8
14	−9.28	−3.59	−2.44	−3.11	−2.88	−3.48	0.00	...	...
15	10.62	6.72	9.36	8.16	5.00	11.41	0.98	0.00	...
16	−18.47	−6.54	−2.54	−5.99	−1.42	−3.01	0.00	...	...
17	−6.01	5.03	8.93	13.39	14.10	15.37	14.87	0.00	...
24	0.00	−9.00	−1.40	−0.49	−2.68	−1.34	0.00	0.00	...
25	...	−8.67	−9.17	−8.04	−4.65	−5.91	0.00	0.00	...
26	...	−4.91	−4.52	−2.46	−0.37	−4.06	0.00	...	...
27	3.59	9.10	2.54	5.40	6.15	7.71	0.00	...	...
34	...	9.38	6.51	7.74	2.64	9.88	0.00	...	...
35	2.07	4.26	4.13	4.37	−13.68	0.00	0.00	...	...
36	...	−6.97	−7.43	−8.19	1.07	−5.66	−3.71	0.00	...
37	...	12.01	15.07	18.61	16.13	12.91	15.34	0.00	...
44	5.99	0.95	5.83	6.62	19.20	6.34	0.00	...	...
45	−6.15	−7.57	−3.65	−6.02	0.00	−1.92	0.00	...	...
46	...	3.30	−2.06	−1.68	−2.93	−0.78	0.00	...	...
47	...	0.18	−1.08	1.82	2.84	2.74	0.00	...	...

Intercept = 7.40.
r^2 (coefficient of determination) = 0.8961.
† Two-digit system was used for numbering of teeth.

TABLE 8—*Calculation table for age estimation in females under age 49.*

Tooth No.†	Degree of Tooth Wear								
	0	1	2	3	4	5	6	7	8
14	...	−37.57	−38.80	−44.59	...	−31.33	0.00	...	...
15	7.14	5.33	5.69	3.11	1.32	−2.33	0.00	...	...
16	...	−4.98	−5.49	0.36	−13.72	−7.07	0.00	...	...
17	−17.12	−6.90	−7.07	−3.50	−0.78	15.64	0.00	...	...
24	...	3.05	3.18	8.24	...	0.00	0.00	...	...
25	−55.38	−53.32	−48.25	−44.70	−37.40	0.00	...	...	...
26	...	−6.16	−8.94	−9.12	−0.86	0.00	0.00	...	...
27	34.41	−3.51	5.89	2.45	0.02	0.00	0.00	...	...
34	−20.54	−10.76	−9.28	−10.52	...	0.00	0.00	...	...
35	16.09	22.55	24.36	23.99	31.48	0.00	...	...	...
36	...	−14.80	−12.45	−12.55	...	−10.11	0.00	...	...
37	0.00	5.65	6.41	12.25	11.99	0.00	0.00	...	...
44	...	9.17	8.35	3.53	...	0.00	...	...	...
45	−8.00	−11.79	−12.73	−7.20	20.12	0.00	...	...	...
46	...	−12.27	−19.40	−16.00	...	−18.81	−52.06	0.00	...
47	0.00	20.26	18.29	15.59	10.13	12.31	...	...	...

Intercept = 119.08.
r^2 (coefficient of determination) = 0.9159.
† Two-digit system was used for numbering of teeth.

males and females. This fact agrees with the results by Tochihara (26) and Ekfeldt et al. (27). It is natural that the degree of tooth wear is proportional to time of exposure of teeth to oral cavity. In the present study, tooth wear scores in males are higher than those in females. This result agrees with that of Seligman et al. (28). They suggested that males show better development of masticatory muscles than females. Thus, males could exert a stronger bite force than females (29).

The method described here can provide a high level of accuracy. In 42.4% of males and 49.4% of females, age can be estimated within ±3 years of actual age. The accuracy is increased if the sub-jects are divided into two groups. After retreating data in the group under the age of 49 years, age can be estimated within ±2 years in 53.4% of males and 50.4% of females, within ±3 years in 62.8% of males and 59.0% of females. In the group above the age of 40 years, age can be estimated within ±2 years in 48.9% of males and 58.3% of females, within ±3 years in 62.0% of males and 67.7% of females. These data have important significance. Once an individual is classified into the young or old age group, age can be estimated with a higher level of accuracy by our scoring system. Hitherto it has been assumed that age estimation with a high level of accuracy within a range of ±2 or ±3 years was possible only in

TABLE 9—*Calculation table for age estimation in males above age 40.*

Tooth No.†	Degree of Tooth Wear								
	0	1	2	3	4	5	6	7	8
14	...	...	18.81	19.20	14.69	20.51	3.37	0.00	...
15	...	...	63.33	66.78	67.60	65.25	53.37	0.00	...
16	...	...	−33.78	22.02	26.95	23.82	20.32	26.24	0.00
17	...	...	113.49	79.17	76.04	77.35	69.62	76.20	0.00
24	...	...	30.21	42.02	43.65	42.63	47.96	0.00	...
25	...	−82.13	−93.39	−94.36	−93.22	−87.86	−92.26	0.00	...
26	...	...	44.60	30.61	29.62	27.90	18.80	6.87	0.00
27	...	...	−54.21	−48.96	−48.42	−47.94	−34.00	0.00	0.00
34	...	−11.35	−5.69	−1.90	...	−4.72	−0.28	0.00	...
35	...	−60.21	−48.00	−44.53	−47.85	−38.50	−57.25	...	...
36	...	...	8.33	−9.82	11.34	−13.30	−14.89	−5.80	0.00
37	...	...	−97.31	−87.03	−82.27	−82.85	−78.16	−64.92	0.00
44	...	−40.44	−35.84	−34.93	−63.77	−29.94	−25.67	−30.37	0.00
45	...	0.00	−14.42	−22.67	−24.12	−26.65	0.00	0.00	0.00
46	...	...	−63.88	−46.73	−49.66	−45.89	−44.53	−41.06	0.00
47	...	...	14.18	15.68	14.49	11.65	14.49	−23.26	0.00

Intercept = 163.80.
r^2 (coefficient of determination) = 0.8608.
† Two-digit system was used for numbering of teeth.

TABLE 10—*Calculating table for age estimation in females above age 40.*

Tooth No.†	Degree of Tooth Wear								
	0	1	2	3	4	5	6	7	8
14	...	−5.34	−1.93	−9.17	5.36	−12.01	0.00	...	...
15	...	...	53.56	53.06	53.07	62.58	0.00	...	...
16	...	...	−14.81	−10.48	−16.85	−3.04	0.00	...	...
17	...	...	5.47	9.77	9.24	12.06	0.00	...	...
24	...	50.13	9.68	28.81	90.08	40.88	0.00	...	...
25	...	...	−74.93	−75.46	−84.66	−74.28	0.00	...	...
26	...	...	−216.67	−218.13	−220.40	−224.33	−198.32	0.00	...
27	...	...	−15.44	−31.51	−34.26	−26.72	0.00	...	...
34	...	44.47	11.12	2.97	...	10.66	0.00	...	...
35	...	0.00	84.37	87.25	80.25	106.17	0.00	...	...
36	...	...	...	36.04	45.09	23.91	6.88	41.63	0.00
37	...	...	...	−0.64	4.51	22.07	0.00	...	...
44	...	5.70	−18.33	−11.12	12.84	−15.30	0.00	...	...
45	...	−12.32	−27.43	−13.28	−29.46	−25.28	0.00	...	...
46	...	...	9.04	−14.65	−29.75	−5.49	7.62	0.00	...
47	...	...	33.01	54.34	43.09	37.47	2.21	0.00	0.00

Intercept = 170.01.
r^2 (coefficient of determination) = 0.9467.
† Two-digit system was used for numbering of teeth.

TABLE 11—*Accuracy of age estimation.*

Age	Gender	Range of Error (years)				
		Within ±2	Within ±3	Within ±5	Within ±10	10 or above
Total	M	31.3%	42.4%	61.8%	83.4%	100.0%
	F	41.6%	49.4%	63.3%	79.5%	100.0%
Below 49 years	M	53.4%	62.8%	80.4%	91.2%	100.0%
	F	50.4%	59.0%	76.1%	83.8%	100.0%
Over 40 years	M	48.9%	62.0%	77.4%	85.4%	100.0%
	F	58.3%	67.7%	76.0%	80.2%	100.0%

TABLE 12—*Practical example of age estimation using Table 7.*

Tooth No.†	Degree of Tooth Wear	Numerical Value
14	3	−3.11
15	4	5.00
16	4	−1.42
17	4	14.10
24	5	−1.34
25	5	−5.91
26	5	−4.06
27	4	6.15
34	5	9.88
35	3	4.37
36	5	−5.66
37	3	18.61
44	3	6.62
45	3	−6.02
46	4	−2.93
47	4	2.84

Sum of numerical values = 37.12.
Intercept = 7.40.
Estimated age = 44.52 (years).
Actual age = 43 (years).
Error = 1.52 (years).
† Two-digit system was used for numbering of teeth.

individuals up to the age of about 25 years (30). It is clear that regardless of the subjects' age ranges, our new scoring system can provide age estimation with much greater accuracy.

Collectively, the results demonstrate that our new scoring system is a very simple and reliable method which can be applied to age estimation of individuals at any age ranges with excellent accuracy. In order to maximize the usefulness of this method as a clinical tool for age estimation, further large-scale studies should be continued.

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