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[UCI]I804:24011-200000276414

2014년 8월 석사학위 논문 한국인집단에 대한 Kvaal과 Paewinsky 방법의 적용성: 한국인 특화된 추정식 개발 노 병 윤

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석사학위 논문

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The applicability of Kvaal's and Paewinsky's methods to Korean population: Development of a estimating formulae specialized for Koreans

2014년 8월 25일

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이 논문을 치의학 석사학위신청 논문으로 제출함.

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초록

한국인집단에 대한 Kvaal과 Paewinsky 방법의 적용성: 한국인 특화된 추정식 개발

노 병 윤
지도교수: 윤 창 륙
조선대학교 대학원 치의학과

살아있는 사람에 있어서 치과적 연령감정은 매우 제한되어 있는데, 치과 방사선사진에서 2차 상아질의 침착에 따른 치수의 크기를 계측하여 연령을 추정하는 연구가 보고되어 왔으며, Kvaal의 연구가 대표적이다. 이번 연구는 한국인의 digital panoramic radiograph에 Kvaal의 방법을 적용하였을 때, validity를 평가하고, 한국인에게 적용할 수 있는 회귀식을 확인하는 것이다. 조선대학교 치과병원에 내원한 21-69세 사이의 266명 환자의 digital panoramic radiogrpah를 대상으로 연구가 이루어졌다. Kvaal의 연구에서 이루어진 것과 같이 상악 중절치, 측절치, 제2소구치, 하악 측절치, 견치, 제소구치 6개의 치아에 대한 치아, 치수의 길이와 폭에 대한 계측이 이루어졌다. 계측값들이 재현성을 갖는지 inter-/intra-observer reliability를 측정하여 보았으며, 각 계측비들과 연령간의 상관관계를 통계적으로 분석하여 보았다. Kvaal의 방법과 이를 수정한 Paewinsky의 방법으로 추정한 연령과 실제 연령간의 차이를 분석하여 보았으며, 이 연구를 바탕으로한 연령 추정식을 도출하여 보았다. Kvaal의 연구에서 측정된 계측비들은 Kvaal의 연구보다는 낮았지만, 실제 연령과 어느정도 연관성을 나타냈으며, 특히 6개의 모든 치아를 적용하였을 경우 연관성이 높게 나타났다. 하지만 Kvaal의 추정식을 그대로 적용할 경우 실제 연령과 차이는 많이 나타났으며, 이번 연구를 바탕으로 한

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국인에게 적용할 수 있는 수정된 Kvaal의 공식을 도출해보았다. 이는 추후 연구를 통하여 검증되어야 할 것으로 사료된다. 한편 Paewinsky의 방법은 오차가 커 한국인에게 적용은 어려울 것으로 판단된다.

Keywords: Dental age estimation, Panoramic radiographs, dental pulp, secondary dentin

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Ⅰ. Introduction

Age estimation plays an important role for identification in forensic science. Especially, estimation with teeth has been actively studied so far. The Romans are believed to historically have utilized eruption of second molar tooth to decide draft age, but age estimation has been scientifically researched and applied from early the 19th century.[1] In 1836, Thomson, a forensic doctor, reported that eruption time of first molar teeth was used to identify 7 years old children. And, Sounders suggested age estimation for 1000 children to apply Factory Act in 1837. Lacassagne estimated age with adult teeth from a dead body in 1889.[2] In 1950, Gustafson reported age estimation method with age-related 6 different structural changes(secondary dentin apposition, attrition, periodontitis, cementum apposition, root resorption and root transparency).[3] In 1971, Johanson subdivided the Gustafson' method and brought a new equation for estimation, and it has been widely used for age estimation of the deceased.

Some studies utilized root transparency, secondary dentin formation, periodontal recession and tooth attrition for age estimation of adult respectively. In 1970, Band and Ram introduced an age estimation method using root transparency only. It is known that intratubular calcification increases and diameter of dentinal tubule decreases in accordance with its aging. As a result, a root increases transparency in the direction of the tip of root to coronal. They introduced an age estimation method by measuring the length of root translucency from the apex of an intact tooth and longitudinal sectioned teeth.[4]

Maple reported an age estimation method using root transparency and secondary dentin formation in 1978. He noted that it could decrease an observer error with reduction of variables and be used on other population

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with some confidence.[5)]

In 1992, Lamendin et al.[6)] reported an age estimation using root transparency and periodontal recession. This method can be performed without tooth sectioning, and has the advantage of not requiring special equipment or training.

Tooth wear according to aging has been studied for age estimation. Yun et al.[7)] reported age estimation method using a new scoring method evaluating tooth wear for Korean populations in 2007.

On the other hand, an biochemical method using amino acid racemization of tooth has been reported. L-form of amino acids are gradually converged to D-form of amino acids. Some age estimation methods have been studied using racemization conversion rates of aspartic acid in dentin, and these method had quite high accuracy. [8, 9)]

However, they demand extraction of the teeth except for the method using tooth attrition, and it is impossible for a living person. Therefore, non-invasive methods using dental radiographs have been tried for age estimation, and they utilize the decrease in pulp cavity by continuous secondary dentin apposition.

In 1995, Kvaal et al had reported a new age estimation method using Norwegian sample with periapical radiographs. Kvaal et al measured the length and width of tooth and pulp, investigated correlation between age and the values, and derived a regression equation.[4)]

Since then some studies have been applied Kvaal et al's study to parnoramic radiographs, but they reported confliction results.[5) -9)] Particularly, Paewinsky reported a new age estimation equation using the width of pulp cavity by modifying Kvaal's study. The purpose of this study is to evaluate the validity of Kvaal's and Paewinsky's methods with Korean digital panoramic radiograph and assure a regression equation which can be applied to Korean.

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Ⅱ. Methods & materials

The subjects were 266 patients who visited in Dental hospital Chosun University, and they were randomly selected according to their ages every 10 years old. This study received approval from Institutional Review Board of the Chosun University dental Hospital (No. CDMDIRB153).

As Kvaal's study, 6 kinds of teeth(maxillary incisor, maxillary lateral incisor, second premolar, mandibular lateral incisor, canine, and second premolar) were measured, but the cases having severe caries, pathological lesion on jawbone, malposition, superimposition, treated by root canal therapy and restoration, and impossible to measure due to low sharpness.

According to Kvaal et al, there was no difference between left and right side, so 6 kinds of teeth were selected by their sharpness.

Images were converted into JPG on PiViewSTAR (INFINITT, Korea), Pacs program, and measured with Adobe Photoshop cs 5 (Adobe Systems Incorporated, San Jose, CA, USA). Measuring points were determined on 200% magnified images, and the number of pixel between points were calculated. In cases of inclined tooth with mesio-disto direction, images were adjusted CEJ line to be horizontal, then the length and width of the teeth were measured.

In terms of tooth length, maximum tooth length (T), maximum pulp length (P), and root length on the mesial surface from the CEJ to the root apex (R) have been measured. In terms of tooth width, the root and tooth width both at the CEJ (level A), at the midroot level (level C) and at midpoint between the ECJ and midroot level (level B) have been measured.(Fig. 1)

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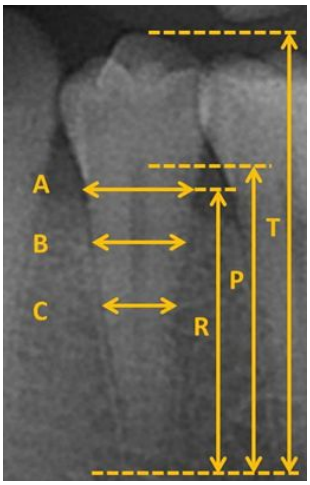

Fig. 1 measurements on the radiographs according to Kvaal et al. (1995) : T maximum tooth length, R root length on the mesial surface, P maximum pulp length; A root and pulp width at the CEJ, B root and pulp width midway between measurement levels A and C, C root and pulp width midway between apex and ECJ

To compensate for measurement errors in magnification and angulation on panoramic radiographs, the following ratios were calculated: pulp/root length (P), pulp/tooth length (R), tooth/root length (T) and pulp/root width at the three levels (A, B and C).

All measurements were carried out by one observer. To verify reproducibility, remeasurement was performed for 25 subjects after 3 months by the same observer. Another observer measured other 25 subjects to evaluate inter-observer reliability.

Collected data was statistically analysed by SPSS software (ver. 20.0; SPSS Inc., Chicago, IL, USA). Inta-observer reliability & inter-observer reliability of the measurements was evaluated with intra-class correlation coefficient. Pearson correlation between each value and chronological age was acquired, and the difference between estimated age by Kvaal's and Paewinsky's methods and real age was statistically analyzed .

Based on the study, modified Kvaal's and Paewinsky's age estimation

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equation for Koreans were derived, and each coefficient of determination(r^2) and standard error of the estimate in years was analyzed.

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Ⅲ. Results

Age and gender distribution of the subjects studied is shown in Table 1.

Table 1. Age and gender distribution of subjects

Age(years)	Male	Female	Total
20-29	25	27	52
30-39	25	25	50
40-49	25	28	53
50-59	28	29	57
60-69	28	26	54
total	131	135	266

Measurement consistency of Inter-observer was over 98%. Intra-observer reliability on maxillary lateral incisor was 90%, and those of other teeth were over 99%. This means that the technique on digital panoramic radiographs is highly reproducible.

Correlation coefficients between the age and the ratios of measurements and their mean values appeared on Table 2. Correlation coefficients of this study was relatively less than that of Kvaal et al's study. Comparing to correlation of each tooth, the mean value of maxillary/mandible/maxillary and mandible teeth showed higher correlation coefficients. Correlation between the age and the length of tooth was not significant or minor.

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Table 2. Correlation coefficients between chronological age and ratios of measurements from the digital panoramic radiographs and their mean values for each tooth, three maxillary teeth, three mandibular teeth and all six teeth from both jaws. (n=266)

	11/21	12/22	15/25	32/42	33/43	34/44	Mx.	Mn.	Both Jaw
P	-0.04 (NS)	0.08 (NS)	0.13*	0.00(NS)	0.10 (NS)	0.20**	0.08(NS)	.12(NS)	0.13*
T	-0.15*	-0.12*	-0.28**	-0.29**	-0.31**	-0.18**	-0.25*	-0.37*	-0.38**
R	0.14*	0.15*	0.38**	0.28**	0.30**	0.11(NS)	0.30*	0.30*	0.37**
A	-0.39**	-0.37**	-0.34**	-0.27**	-0.31**	-0.30**	-0.49**	-0.43**	-0.54**
B	-0.56**	-0.49**	-0.50**	-0.33**	-0.28**	-0.31**	-0.66**	-0.43**	-0.64**
C	-0.42**	-0.58**	-0.37**	-0.29**	-0.30**	-0.27**	-0.62**	-0.43**	-0.63**
M	-0.47**	-0.46**	-0.43**	-0.31**	-0.31**	-0.22**	-0.59**	-0.41**	-0.58**
W	-0.56**	-0.58**	-0.50**	-0.36**	-0.35**	-0.34**	-0.70**	-0.48**	-0.67**
L	0.07(NS)	0.14*	0.33**	0.15*	0.25**	0.17**	0.26**	0.28**	0.33**
W-L	-0.47**	-0.51**	-0.55**	-0.36**	-0.40**	-0.32**	-0.68**	-0.52**	-0.70**

P: ratio between length of pulp and root; T: ratio between length of tooth and root; R: ratio between length of pulp and tooth; A: ratio between width of pulp and root at CEJ (level A); B: ratio between width of pulp and root at midpoint between level C and A (level B); C: ratio between width of pulp and root at midroot level (level C); M: mean value of all ratios; W: mean value of width ratios from levels B and C; L: mean value of the length ratios P and R; W - L: difference between W and L

NS: No significance $P>0.05$.

* $P<0.05$, ** $P<0.01$

With Kvaal′ and Paewinsky′s equation, the mean, SD, and Standard error of the estimate appeared on Table 3 and 4. There was a huge difference between real age and estimated age on both methods.

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Table 3. Difference between real age & estimated age, and standard error of the estimation by regression equation of Kvaal's method

Model	Difference				Standard error of the estimate
	mean	SD	Min	Max	
All	66.70	10.67	43.50	91.44	67.8
Mx	57.21	11.08	28.73	85.06	58.49
Mn	70.91	12.17	37.58	101.33	72.21
11/21	43.26	12.43	9.94	70.39	45.17
12/22	48.83	11.93	15.99	75.46	50.45
15/25	66.86	12.62	34.65	101.63	68.3
32/42	54.99	13.34	21.01	92.51	56.8
33/43	46.10	14.00	11.90	86.47	48.35
34/44	61.50	14.18	24.62	93.35	63.35

Table 4. Difference between real age & estimated age, and standard error of the estimation by regression equation of Paewinsky's method

Model		Difference				Standard error of the estimate
		mean	SD	Min	Max	
11/21	A	-7.48	14.70	-50.69	41.12	16.53
	B	-8.60	12.49	-41.71	25.81	15.20
	C	-10.60	13.96	-49.10	35.72	17.57
12/22	A	-0.03	18.58	-45.53	54.70	18.62
	B	-4.46	16.43	-58.19	48.07	17.06
	C	-10.70	14.70	-51.15	27.10	18.23
15/25	A	-7.73	18.23	-56.82	47.47	19.85
	B	-12.8	16.51	-51.73	30.88	20.97
	C	-16.03	18.10	-69.12	34.05	24.25
32/42	A	-3.05	20.23	-58.46	78.91	20.50
	B	-11.75	19.99	-71.17	49.99	23.24
	C	-22.32	20.90	-70.89	41.71	30.67
33/43	A	-6.15	14.96	-41.85	25.50	16.21
	B	-5.02	16.60	-48.47	40.74	17.38
	C	-9.89	17.48	-50.42	126.23	20.14
34/44	A	-13.53	17.47	-64.91	35.65	22.15
	B	-12.00	17.84	-61.09	36.49	21.55
	C	-17.14	18.50	-63.83	29.03	25.29

Regression equation through multiple linear regression analysis from the samples of the study was obtained. Regression equation was derived using each variable, and it showed on Table 5. Regression equations for each gender were obtained.(Table 6 & Table 7)

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Table 5 Regression formulae derived from this study (all subjects)

	Regression fomula	r	r^2	SEE
All	Age = 78.81 - 100.55(W-L) - 415.74(M) + 141.8(P)	0.758	0.569	9.60
Mx	Age = 42.73 - 221.91(W) + 66.65(R) - 49.04(A)	0.731	0.534	10.04
Mn	Age = 137.11 + 70.26(WL) - 609.35(M) +255.05(P) + 89.31(R)	0.665	0.442	11.00
11/21	Age = 78.74 - 156.66(W) - 46.66(A)	0.596	0.355	11.79
12/22	Age = 50.40 - 51.73(W) - 42.29(A) - 75.58(C) - 31.93(WL)	0.627	0.393	11.99
15/25	Age = 22.48 - 141.96(WL) - 148.33(M) + 64.01(C)	0.301	0.361	12.28
32/42	Age = 69.66 - 92.64(W-L) - 150.69(M)	0.488	0.239	13.38
33/43	Age = 50.22 - 64.25(W-L) - 83.31(A) - 29.26(T)	0.505	0.255	13.26
34/44	Age = 97.53 + 180.81(P) - 291.58(M) - 47.30(T)	0.557	0.310	12.76

r^2: coefficient of determination. SEE: standard error of the estimate in years

Table 6 Regression formulae derived from this study (Male)

	Regression fomula	r	r^2	SEE
All	Age = 74.50 - 94.08(W-L) - 44.99(L) + 165.76(P)	0.740	0.547	10.00
Mx	Age = 25.06 - 157.40(W) - 74.80(W-L) - 49.84(A)	0.687	0.472	10.80
Mn	Age = 131.01 - 93.83(W-L) - 142.41(A) - 100.44(T) - 91.38(R) + 75.30(P)	0.693	0.480	10.80
11/21	Age = 75.83 - 131.58(B) - 37.71(A)	0.571	0.326	12.15
12/22	Age = 77.89 - 129.525(C) - 58.61(A)	0.605	0.367	11.78
15/25	Age = -55.58 - 168.75(W-L) - 74.52(C) -23.35(T)	0.606	0.368	11.82
32/42	Age = 66.81 - 82.46(W-L) -133.84(M)	0.474	0.224	13.04
33/43	Age = 74.90 - 63.90(W-L) - 115.07(A) - 41.50(T)	0.599	0.359	11.90
34/44	Age = 72.94 + 206.99(P) - 296.52(M) - 47.62(T)	0.615	0.378	11.72

Table 7 Regression formulae derived from this study (female)

	Regression fomula	r	r^2	SEE
All	Age = 2.19 - 289.01(W) + 118.53(R)	0.774	0.598	9.33
Mx	Age = 39.04 - 225.31(W) + 72.20(R) -52.62(A)	0.782	0.612	9.21
Mn	Age = 0.34 - 174.80(W) + 108.06(R) -69.09(A)	0.637	0.405	11.39
11/21	Age = 159.71 - 129.24(W) - 146.09(M)	0.637	0.405	11.35
12/22	Age = 1.05 - 101.99(W) - 83.28(W-L)	0.703	0.494	10.47
15/25	Age = 35.99 - 152.95(W) - 59.21(A) + 54.71(R)	0.674	0.454	10.92
32/42	Age = 10.31 - 189.08(W) + 85.57(R)	0.561	0.315	12.19
33/43	Age = 69.68 - 68.47(W-L) - 127.13(M)	0.480	0.230	12.92
34/44	Age = 57.10 - 181.14(W-L) - 288.00(M) + 180.77(W)	0.552	0.304	12.33

Also, Regression formulae using variations of Kvaal's method was

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calculated (Table 8), and it is separatively obtained by gender.

Table 8. Regression formulae using variations of Kvaal's method (All subject)

	Regression fomula	r	r^2	SEE
All	Age = 54.42 - 230.80(M) - 182.10(W-L)	0.749	0.561	9.73
Mx	Age = 48.18 - 177.98(M) - 152.13(W-L)	0.720	0.519	10.19
Mn	Age = 75.22 - 210.08(M) - 131.03(W-L)	0.613	0.375	11.60
11/21	Age = 83.17 - 151.51(M) - 83.82(W-L)	0.560	0.314	12.16
12/22	Age = 85.18 - 157.72(M) - 86.15(W-L)	0.590	0.348	12.38
15/25	Age = 37.39 - 118.21(M) - 107.96(W-L)	0.585	0.342	12.44
32/42	Age = 69.66 - 150.69(M) - 90.64(W-L)	0.488	0.239	13.38
33/43	Age = 65.13 - 128.43(M) - 76.24(W-L)	0.467	0.218	13.56
34/44	Age = 82.71 - 135.40(M) - 59.56(W-L)	0.405	0.164	14.02

Table 9. Regression formulae using variations of Kvaal's method (Male)

	Regression fomula	r	r^2	SEE
All	Age = 52.56 - 230.24(M) - 185.15(W-L)	0.719	0.517	10.29
Mx	Age = 58.43 - 181.20(M) - 141.97(W-L)	0.666	0.443	11.05
Mn	Age = 68.96 - 199.31(M) - 131.11(W-L)	0.588	0.346	11.98
11/21	Age = 49.34 - 109.11(M) - 92.35(W-L)	0.502	0.252	12.81
12/22	Age = 112.84 - 170.84(M) - 60.97(W-L)	0.543	0.295	12.43
15/25	Age = -6.43 - 61.25(M) - 120.07(W-L)	0.556	0.309	12.31
32/42	Age = 66.81 - 133.84(M) - 82.46(W-L)	0.474	0.224	13.04
33/43	Age = 68.82 - 144.34(M) - 86.01(W-L)	0.505	0.255	12.78
34/44	Age = 92.48 - 131.17(M) - 44.77(W-L)	0.358	0.128	13.83

Table 10. Regression formulae using variations of Kvaal's method (Female)

	Regression fomula	r	r^2	SEE
All	Age = 62.36 - 239.78(M) - 178.15(W-L)	0.781	0.609	9.20
Mx	Age = 41.26 - 178.43(M) - 161.01(W-L)	0.774	0.599	9.32
Mn	Age = 82.24 - 222.17(M) - 131.04(W-L)	0.639	0.408	11.32
11/21	Age = 114.64 - 193.23(M) - 77.83(W-L)	0.624	0.389	11.51
12/22	Age = 9.79- 99.42(M) - 137.79(W-L)	0.705	0.497	10.44
15/25	Age = 69.68 - 163.11(M) - 101.45(W-L)	0.658	0.433	11.09
32/42	Age = 73.54 - 175.40(M) - 108.74(W-L)	0.569	0.323	12.11
33/43	Age = 69.68 - 127.13(M) - 68.47(W-L)	0.480	0.230	12.92
34/44	Age = 53.68 - 131.86(M) - 93.02(W-L)	0.517	0.267	12.60

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Coefficient of determination from regression fomula using Paewinsky's variations was 0.073 - 0.330, and standard error of estimate(SEE) was a range of 12.1 ~ 14.74(Table 11).

Table 11 Paewinsky's model을 이용한 회귀식

Model	Regression fomula	r	r^2	SEE
11/21 A	Y = 60.83 + (-79.44)x	0.385	0.148	13.52
B	Y = 70.27 + (-148.15)x	0.555	0.308	12.19
C	Y = 62.82 + (-130.66)x	0.418	0.175	13.31
12/22 A	Y = 61.89 + (-86.33)x	0.368	0.136	14.23
B	Y = 066.97 + (-124.92)x	0.485	0.235	13.38
C	Y = 69.97 + (-165.23)x	0.575	0.330	12.52
15/25 A	Y = 60.00 + (-91.81)x	0.335	0.112	14.42
B	Y = 63.86 + (-134.66)x	0.496	0.246	13.29
C	Y = 57.83 + (-105.49)x	0.368	0.136	14.23
32/42 A	Y = 57.82 + (-73.94)x	0.270	0.073	14.74
B	Y = 61.52 + (-111.09)x	0.329	0.108	14.45
C	Y = 56.13 + (-94.76)x	0.289	0.083	14.65
33/43 A	Y = 62.06 + (-107.23)x	0.314	0.099	14.53
B	Y = 57.75 + (-85.06)x	0.284	0.081	14.67
C	Y = 53.70 + (-71.59)x	0.296	0.088	14.62
34/44 A	Y = 59.56 + (-99.22)x	0.303	0.092	14.58
B	Y = 58.60 + (-93.35)x	0.308	0.095	14.56
C	Y = 54.64 + (-79.37)x	0.273	0.074	14.72

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Ⅳ. Discussion

Dental age estimation is usually carried out to identify the dead, but it is also done with a living person. Age estimation for the living is mostly performed by reason of social benefit, contract law, criminal prosecution, and undocumented immigration,[1] and the demand has been increased in Korea due to the expansion of National Pension Service.[16] However, its methods are limited compared to that for the dead.

Age estimation with dental radiographs is non-invasive and can be simply used for both the living and dead. The decrease in pulp cavity by aging is used in most age estimation with dental radiographs, and the study by Kvaal et al[10] using periapical radiograph(1995) is well-known.

Many studies on the precision(accuracy) of Kvaal's method have been tried, and some of them using panoramic radiograph reported conflicting results. Bosmans et al[11] had reported that age estimation with digital panoramic radiographs could get similar results with original method from their study subjecting 197 Belgians in 2005. Paewinsky et al.[12] brought a new regression equation with the width of only tooth and pulp on panoramic radiographs of 168 Germans, and they insisted it had higher accuracy than Kvaal's method. On the other hand, Meinl et al[13] reported Kvaal's method had a huge difference from real age on their study with 44 Austrian young adults in 2007. In 2008, Landa et al.[14] reported that there was a significant difference between estimated age and real age from the study with 100 Spanish people. Erbudak et al.[15] reported in 2012 that both Kvaal's and paewinsky's mehtods were difficult to be applied because they had a huge difference with panoramic radiographs from their study with 123 Turkish people.

The evaluation on the accuracy of age estimation of Kvaal's method for Koreans has not been studied yet, therefore, validation of Kvaal's and Paewinsky's method were performed to evaluate availability for Koreans

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with digital panoramic radiographs. Panoramic radiograph is generally taken at a dental clinic and can acquire all images of 6 kinds of teeth at once. In this study, correlation between the calculated ratios and chronological age were lower than those of Kvaal's original study, but they had significant correlation coefficient in general. However, there was a huge difference between estimated age and chronological age when Kvaal's original method was applied to Koreans. Estimated age by Kvaal's equation was consistently underestimated compared to real age, hence by Paewinsky's equation was overestimated. This tendency was similar to the results from the studies of Meinl et al in 2007 and Erbudak et al. in 2012.[13, 14)]

Based on the results of the study, estimation equation for Korean was derived. From regression equation by Kvaal's original method, coefficient of determination (r^2) was 0.164~ 0.561, and standard error of the equation was 9.73~ 14.02. The mean value of 6 kinds of teeth provided more accurate results. Regression equations for male and female were separatively acquired because there could be difference by gender.(Table 9 & Table 10) There was no significant difference from the values by stepwise method using all measurement ratios. This study suggested that Kvaal's method should be modified in age estimation for Korean as Table 8-10.

On the other hand, from regression equation by Paewinsky's method, coefficient of determination was 0.073~0.330, and standard error of the equate was 12.19~14.72. It is considered that this method can not be used in practical age estimation.

The differences between the results of previous Kvaal's method and this study could be affected by various factors. It is thought that population difference had major effect on the results. It is known that there are differences in tooth development, tooth size, and pulpal shape by human population, and it affects the size of pulp cavity as well.[17-19)] Diet could influence the secondary dentin apposition. For this reason, this study had

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a huge difference from the studies on Norwegian, German, and Belgian.[10-12)]

Panoramic radiograph was used in this study whereas standard apical radiograph was used in Kvaal's study. This can be a reason making differences. Panoramic radiograph generally has less fine anatomic detail than intraoral periapical radiograph, typical overlap on premolar area, unequal magnification, and distortion.[20)] It is considered that these factors cause each parameter to have less correlation with real age. The way of measurement could have influence on the results. Some studies reported that digital measurement is less accurate than manual measurement, [21, 22)] but recent studies have reported digital measurement has high reproducibility.[11, 14, 15)] This study also had high level of intra-/inter-observer reliability.

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Ⅴ. Conclusion

From the result of the study, each parameter measured by Kvaal's study on Korean digital panoramic radiograph has less correlation than Kvaal's study, but it indicated a certain correlation with real ages. Especially, it had higher correlation when all 6 kinds of teeth were applied. However, there was significant difference when Kvaal's original regression formulae was applied intactly for Koreans. So regression formulae modifying Kvaal's method for Koreans was brought based on this study.

It is considered that Kvaal;s method can be applied for Koreans but, Peawinsky's method modified from this study still had a huge error between real age and estimated age, so it can not be used in practical age estimation.

Kvaal's regression equation for Koreans derived from the study should be verified by further independent study.

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