Estimation of Age Using Kvaal Technique Based on Cone-beam Computed Tomography Images of Mandibular Canine Teeth in Bojnourd

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Abstract

Background and Objective: Identifying age in anthropology and forensic medicine and examining the proper development of children and adolescents is important. Age estimation techniques using teeth are of particular value. This study tends to evaluate the accuracy of age estimation by Kvaal technique using CBCT images of mandibular canine teeth in a sample of Iranian population.

Materials and Methods: In this crossvalidation study, data from 140 samples of records of patients aged 15 years and older, during 2018-2019, available at a private oral and maxillofacial radiology center in Bojnourd was used. The parameters used in Kvaal technique were measured in mandibular canine teeth on CBCT images of patients.

Results: Using multiple linear regression model to correlate parameters of Kvaal technique based on CBCT images of mandibular canine teeth and age with stepwise method showed that variables pulp length/root length, pulp width/root width in the middle, length teeth/root length were significant in predicting age ($p<0.05$ in all 3 cases). According to the above method, age = 551/5-500 (M) was obtained which was able to estimate age in 35% of the samples. The mean age of the patients was estimated to be 7.9 years, which is acceptable.

Conclusion: Kvaal formula was significant for use in Iranian population. The regression formula obtained from the control group could also be generalized to the test group.

Keywords: *Age Estimation Using Tooth, Mandibular Canine Tooth, Cone-beam Computed Tomography, Forensic Dentistry*

Introduction

Teeth are used when none of identification techniques is not satisfactorily used. In most adverse conditions, such as degradation of a cadaver or floating in the water for a long time, there is the slightest change in texture of tooth compared to other parts of the body.[1,2] The tooth is the hardest body tissue and has the highest resistance to trauma, external factors, and other factors[3] and can withstand the effects of long-term physical, chemical, mechanical damages and passage of time, and also remains intact years after death, but is at least affected by nutritional factors, environment and living conditions.[4] Forensic dentistry is a major contributor to estimation of age of corpses, immigrants and wanted criminals.[5] However, age estimation in adults is challenging in both anthropological and judicial settings compared to adolescents due to full maturity of individual teeth and bones and inaccuracy of techniques based on degenerative process.[6] Age estimation is

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still a major challenge in forensic medicine. Several methods have been employed for this purpose, and a range of results have been obtained.[7] In 1995, Kvaal invented a non-destructive technique for age estimation based on measurement of dental pulp and root space in 6 radiographic types, which have been adopted by the American Academy of Forensic Sciences.[3] This technique is completely based on measurements of radiographic images and does not depend on other factors such as root transparency and periodontal retraction and therefore no tooth extraction is required.[8,9] Based on dental ratios including tooth length, pulp length, root length and root width in three regions of CEJ, middle part of the root and between these two regions, and by examining the mean of these items, a formula can be obtained which is helpful in estimating age.[3,10] Therefore, problems with undesirable tooth angle as well as superimposition will be resolved.[11,12] Due to inconsistent results in previous studies and lack of consensus on efficacy of Kvaal technique in a sample of Iranian population as well as the lack of implementation of this project in North Khorasan province, this study tends to evaluate effectiveness of this technique in this province.

Materials and Method

Studied Population, Sample Size and Sampling

Participants included people referred to a private oral and maxillofacial radiology center in North Khorasan Province who required CBCT imaging and were older than 15 years. Based on previous studies, assuming type I error 0.05 ($\alpha = 0.05$) and type II error 0.2 ($\beta = 0.2$), i.e. 80% test power, and taking into account minimum coefficient of correlation ($r = 0.25$), the sample size was set at 110 and 30 patients were considered for the control phase (13). That is, CBCT images of 140 patients over 15 years were selected (to avoid possible confounding of age and to increase estimation accuracy, age range was set at over 15 years). After selecting the samples, CBCTs were randomly divided into two groups of 110 and 30 each. Samples were obtained from a privately owned oral and maxillofacial radiology center.

Data Collection and Validity and Reliability of Instruments

Images of all patients were analyzed using a CBCT device, Ray scan alpha 3D (LED medical diagnostics Inc., Atlanta, GA, manufactured in South Korea) previously made and exposure parameters 90 kvp, 10 mA and 14.3s with standard resolution were used. In this study, mandibular canine teeth were used to estimate age, because they had a larger pulp and a longer probability of remaining in the mouth. The relevant parameters were calculated by OnDemand 3D dental software by oral and maxillofacial radiologist. Finally, data was transmitted via DICOM format to DVD.

Method

Factors evaluated by Kvaal technique for estimating age include:

T: maximum tooth length

P: maximum pulp length

R: root length from CEJ to apex

A: root width at CEJ (level A)

C: root width at middle root level (level C)

B: root width at midpoint between CEJ and root center (level B)

By software adjustment in coronal and axial dimensions of multiple planar reconstruction (MPR) images, sagittal cut of tooth containing the entire length of the crown and root. Then, using OnDemand 3D dental software, all of the above were measured by a radiologist after reorienting and reslicing in the sagittal dimension on sample teeth. Then, by using the above 6 measurements, 6 ratios was obtained including:

T: tooth length/root length, P: pulp length/root length, R: pulp length/tooth length, A: pulp width/root width at level A, B: pulp width/root width at level B, C: pulp width/root width at level C.

The mean of all the above was calculated and included in the study as a new variable (M). First, the regression formulas first derived by Kvaal et al for age estimation using canine tooth, as age = 158/8-255/7(M), were set as template and used for the data (M mean of all ratios defined). In order to compare the results of this study with Kvaal results, mean of 6 variables mentioned above was calculated as record for each studied unit and considered as new independent variable M. This new variable was substituted in the above regression equation. By modelling the Kvaal regression model, mean of all the ratios was used; by SPSS software (version 22), the corresponding equation was obtained by using the obtained data for the Iranian population.

2.5. Ethical Considerations

In this study, CBCT images archived in a private oral and maxillofacial radiology center were used; thus, no intervention was performed for the studied patients. All information obtained from the patient records remained confidential. There was no specific ethical prohibition in this study. The plan did not contradict international treaties on medical sciences such as Nuremberg and Helsinki. All collected checklists were confidential and the results were reported only in general terms.

Results

The general regression formula for estimating age is M = a + b (x), where x is the estimated age; thus, x (age) = a + b/M. The regression equations were derived from the above equation (Table 1). Using Kvaal technique and modeling their regression equation for canine tooth, M = 0.784-0.001 (age) was set for current data; thus, age = 784 – 1000 (M). As mentioned before, M is the mean of all data. The above equation was more acceptable than the Kvaal equation but it was able to estimate age in only 21 samples (15%). Therefore, by examining the correlation tables between each variable with age, it was found that three variables were not correlated with age. Thus, the three variables B, A and R were excluded. Excluding the three variables mentioned and substituting them into the formula above, M = 1.103-0.002 (age), again yields a new regression formula: age = 551.5-500 (M). In the formula above, three variables T, P, C were used to obtain the new M (Table 2). The formula was effective in 50% (35%) of patients, indicating a higher accuracy than the original formula. The second formula, by excluding variables that did not correlate with age, had a correct estimation of age in 50 patients. By analyzing variable data of these 50 people, it was found that this formula could accurately estimate the age when these variables were in a specific range: T = 1.47-1.70, P = 1.22-1.41, C = 0.06-0.38, and M = 0.96-1.09. Outside these ranges, this formula is not responsive (Table 3).

Table 1. Components of linear regression equation in SPSS by using mean of six variables

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	**Std. Error**	**Beta**		
1	(Constant)	.784	.012		65.972	.000
	AGE	-.001	.000	-.218	-2.629	.010
a. Dependent Variable: mean of 6 items						

Table 2. Components of linear regression equation in SPSS using mean of three variables

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.103	.016		69.477	.000
	AGE	-.002	.000	-.324	-4.016	.000
a. Dependent Variable: mean2						

Table 3. Significance range of estimation of variables measures

		VAR00002	**VAR00003**	**VAR00007**	**VAR00010**
N	Valid	50	50	50	50
	Missing	0	0	0	0
Mean		1.6000	1.2916	.1912	1.0276
Std. Deviation		.05496	.03825	.05641	.02479
Range		.23	.19	.32	.12
Minimum		1.47	1.22	.06	.96
Maximum		1.70	1.41	.38	1.09

The distance between mean age of the patients and the age estimated by the formula derived from mean of three variables was 7.9 years, which is acceptable (less than 10 years). Moreover, the distance between mean age of the patients based on the formula derived from mean of 6 variables was 8.34 years (Tables 4 and 5).

Table 4. Difference in mean age estimated and real age of participants by SPSS using mean of three variables

N	Valid	140
	Missing	0
Mean		7.9929
Std. Deviation		27.27655

Table 5. Difference in mean age estimated and real age of participants by SPSS using mean of six variables

N	**Valid**	**140**
	Missing	**0**
Mean		8.3357
Std. Deviation		40.74321

Discussion

The results of our study showed that Kvaal method parameters used on human mandibular canine is effective for predicting age in adults in our studied Iranian population. Although there is a stronger correlation between age and three T, P and C variables of mandibular canine, other variables other than these variables should be considered in predicting age in Iranian population. The reason for using secondary dentin in this study is because it is surrounded not only by harder tissues such as enamel and cementum, but also by primary dentin.[13,14] Consequently, this parameter used for internal evaluation is significant due to its potential to eliminate the effect of environmental factors on human remains.[15] Given the phenomenon that due to anthropological differences between different ethnic populations, a formula devised for one population may

not be applicable to other populations, we conducted this study for the Iranian population. However, this phenomenon can be due to two-dimensional radiographic images that cannot provide accurate information about a 3D object.[14] Sakhdari et al.[16] obtained the age estimation equation by using pulp-to-surface ratio by digital panoramic radiographs from 120 patients over 12 years. They finally reported that pulp-to-surface ratio (AR) as a pure indicator cannot be used alone to determine an individual's age, but can be used in combination with other indices to estimate age.

In the present study, measurements were made on mandibular canine alone because of advantages of the mandibular canine teeth, and we used CBCT images that were more accurate than panoramic images with no magnification problems or angular limitations. In the present study, we evaluated the secondary dentin deposition in mandibular canine teeth using Kvaal parameters. Cantekin used the Demirjian classification to estimate evolution of the third molar, which is a qualitative method based on images, while the present study is based on measurement of Kvaal parameters on teeth which is a quantitative method and the operator is less involved in than in a qualitative study; this study, as our study, was efficient in age estimation. Kanchan-Talerja et al.[17] evaluated versatility of the Kvaal method for estimating dental age in the Indian population and observed that there was a large difference between actual age and the age predicted using this method. They thus argued that this large error in the Kvaal formula for estimating age in the Indian population could be due to secondary dentin deposition rate influenced by both genetic and environmental factors in Indians.[17] The present study is based on CBCT images that have higher accuracy than periapical images and especially angle bisector technique. In the present study, the results of crossvalidation in the control group showed less real and predicted age difference than the above study. Hazha star et al. (2011) investigated the estimation of human dental age by calculating a pulp/tooth volume ratio based on CBCT images obtained clinically from single rooted teeth. Finally, they found that age estimation was gender-independent, and the highest association between pulp-tooth volume ratios and age in their study was related to incisors.[18] Kvaal suggested to obtain a specific regression formula for each population.[19] Therefore, the regression formula obtained by Kvaal et al. for mandibular canine was not appropriate for estimating age in our studied population. However, since there was a significant relationship between age and P, C and T variables, there is a need for further investigation in Iranian population to identify other potential interfering factors and to include them in the regression formula. Kvaal used periapical radiography in the original study, and we used CBCT images in the present study to correct the errors of simple radiographic technique.

Conclusion

The Kvaal formula was suitable for use in the Iranian population, but it seems that other variables besides those studied here should be considered for age estimation based on application of the Kvaal formula in mandibular canine teeth.

It is recommended that this study be performed on other teeth in the future. It is also recommended to compare different imaging methods with each other and to evaluate the volume methods of pulp to tooth ratio in future studies.

Conflict of Interest: Authors have declared that no competing interests exist.

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