Original Article

Age Estimation using Segmented Pulp/Tooth Area Ratio Method in Thai Population

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Abstract

The aims of this study were to develop an age estimation equation in Thai population using segmented pulp/tooth area ratio (sPTR) and to test the reliability of that equation. The sample consisted of 400 digital periapical images of right maxillary central incisors derived from 163 men and 237 women aged between 10.03 and 81.61 years (mean=32.38 years). sPTR measurement modified from the Cameriere's method was performed in the 400 samples. Subsequently, statistical analysis was performed in order to generate a regression model for age estimation. Then, another 103 samples were tested for the accuracy of the regression model. The difference between the chronological age and the estimated age was statistically calculated. The correlation coefficient was statistically significant, with r=-0.86 (p<0.05). The power regression model for the Thai sample yielded the following equation: $Age=0.790\times sPTR^{(-2.059)}$. The coefficient of determination (R^2) was 0.82. The mean difference value between the estimated and the chronological ages was -0.80. The mean absolute error (MAE) was 4.26 years. The standard error of prediction (SEP) was 5.70 years. In conclusion, the sPTR on the maxillary central incisor we firstly proposed in this study can be useful for age estimation in Thais.

Keywords: Age estimation, Maxillary central incisor, Periapical radiograph, Pulp/tooth area ratio

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Introduction

Forensic odontology is one of the branches of both dentistry and forensic sciences that provides necessary scientific support in many situations, for instance, accidents, criminal investigations, mass fatalities, disasters and genetic examination in forensic sciences. An individual's age is significant for the component of forensic odontology which is generally applicable to use in archaeological and anthropological research.[1]

Various parts of the skeleton, such as the skull, long bones and clavicle have been widely used to estimate the age of an individual in previous studies.[2-4] However, in a severe disaster, bones are usually destroyed from severe burning, excessive humidity or burial effects on the corpse, while teeth usually survive, since the tooth is the strongest mineralized tissue in the body.[5] Thus, teeth seem the best choice for age prediction among various mineralized tissues. Using teeth as an age predictor, quantification of secondary dentine deposition is an effective method to determine increasing age.[6,7] Pulp to tooth area ratio (PTR) indirectly reflects secondary dentine deposition. This ratio can be measured from dental radiographs, as first described by Cameriere *et al.* in 2004.[8] Cameriere *et al.* predicted sample age using an age estimation equation derived from the correlation between chronological age and PTR. Afterward, several studies in specific races used and tested Cameriere's method for age estimation in their populations.[8-13] Some studies found that age estimation should be derived using equations which are generated for the specific populations.[10,11,13]

In Thai population, there are several studies using dental radiographs for age estimation.[14-16] However, to our knowledge, there is no published study using PTR to estimate individuals' age. The aim of this study was to develop an age estimation equation for Thai population using the segmented PTR (sPTR) method modified from the Cameriere's on the right maxillary central incisor. In addition, the reliability of the age estimation equation was tested.

Materials and Methods

This study was approved by the Human Experimentation Committee of the Faculty of Dentistry, Chiang Mai University, Thailand (Clearance #24/2016).

Sample selection

In order to generate a regression equation, four hundred periapical radiographs, size 2 (31×41 mm), of the right maxillary central incisors from the samples aged more than 10 years old, recorded during 2010-2016, were randomly selected from the Oral and Maxillofacial Radiology Clinic, Dental Hospital, Faculty of Dentistry, Chiang Mai University, Thailand. The samples consisted of 163 men and 237 women aged ranging 10.03-81.61 years (mean=32.38±17.61 years). All images were taken by periapical paralleling technique and had optimal diagnostic quality. The right maxillary central incisors were fully erupted with complete root formation. The teeth showed no pathologies and/or abnormalities, such as dental caries, dental anomalies, crown and root fracture, root dilaceration, root resorption or tooth attrition. The teeth had no restorative materials in either crown or root.

Each radiograph was digitized using a digital camera (Nikon D90, 12.3 effective megapixels, Nikon corp., Shinagawa, Tokyo, Japan) with resolution of 4288×2848. Fixed source-film distance of 15 cm between the camera and all radiographs was performed for standardization. The digitized images were saved as JPEG files in gray scale format in a laptop computer (Lenovo V470, Lenovo™, Beijing, China) for further analysis. The monitor's resolution was 1366×768 pixel.

Measurement

The digitized image was imported into the

Microsoft paint program (Nasdaq "MSFT" @Microsoft, Redmond, Washington, USA) in order to measure the distance between the cemento-enamel junction (CEJ) and the root apex. The original digitized image was used without any enhancement. The tooth's long axis was used as the reference, then the root length was divided by 3. Four horizontal lines were drawn to equally segment the root into 3 parts: the coronal, middle and apical thirds. Then, the segmented image was saved and imported to the Image J program (version 1.50i, National Institutes of Health, Bethesda, Maryland, USA). Only the middle third of the pulp/tooth area was used for the measurements. Using the polygon selection tool, the outline of the tooth and the pulp were drawn with multiple points. The areas of pulp and tooth were then measured and recorded (Fig. 1). The ratio between the pulp and tooth areas, resulting in sPTR value, was calculated for each sample. All measurements were performed by one examiner.

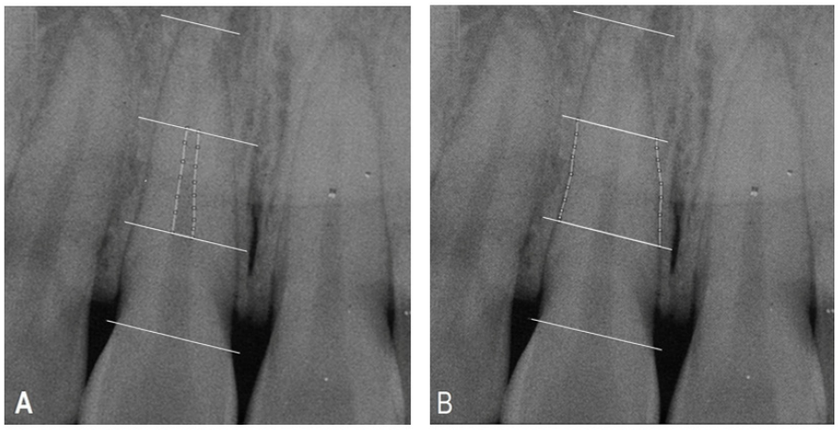

Figure 1 *Pulpal area measurement (a); tooth area measurement (b)*

Before the measurement session, a part of the calibration was done between the examiner and a 15-year experienced oral and maxillofacial radiologist. To test intra-examiner reproducibility, a random sample of 30 digital images were re-examined after an interval of two weeks using ICC statistical analysis.

Statistical analysis

Statistical analysis was processed using Statistical Program for Social Sciences (SPSS), Version 23 (IBM Company, Chicago, IL, USA). The normality of the data was tested. The differences between sPTR in male and female were analyzed using independent sample *t*-test. The relationship between the measured sPTR and the chronological age of the samples were analyzed using Pearson's correlation. The significant level was set at $p<0.05$. A correlation coefficient was drawn and a simple regression model was constructed to generate a regression equation.

In order to test the validity of the regression equation, the equation was tested on another 103 samples in order to estimate the age. The predicted age was compared to the chronological age using Paired *T*-test. The mean difference value between the estimated and the chronological ages, the mean absolute error (MAE) and the standard error of prediction (SEP) were calculated. The mean difference value between the estimated and the chronological ages in 3 different age groups were also analysed for their differences using one-way ANOVA. The significant level was set at $p<0.05$

Results

Distribution of the selected samples, aged ranging from 10.03-81.61 years, was grouped as shown in Table 1. The mean and standard deviation of the sPTR in male and female were 0.182±0.042 and 0.181±0.042 respectively. There was no significant differences between the sPTR value in male and female (p=0.81). Figure 2 shows a scattered plot of the age and the sPTR. The correlation coefficient was statistically significant, with r=-0.86 (p=0.00). The power regression model for the Thai sample yielded the following equation: $Age=0.790\times sPTR^{(-2.059)}$. The coefficient of determination (R^2) was 0.82.

The ICC for intra examiner reproducibility was 0.97. Table 2 showed sample distribution in the tested group. For the tested group (N=103), the estimated ages calculated from the equation were not significantly different from the chronological age (p=0.16). The mean difference value between the estimated and the chronological ages was -0.80. The mean absolute error (MAE) was 4.26 years. The standard error of prediction (SEP) was 5.70 years. Regarding to age distribution, mean error and standard deviation were shown in Table 3. The mean difference values between the estimated and the chronological ages of the middle to old adult age (≥36 years) was significantly different from those of the younger age groups (p=0.00). Age estimation calculated from the generated equation seemed to well predicted in the samples of age 10 to less than 36 years old. Whereas more errors were observed in the samples of age equal to or more than 36 years old.

Table 1 *Sample distribution to formulate the equation*

Age-group (years)	Males	Females	Total
Child & adolescent (10-20.99)	56	91	147 (36.75 %)
Young adult (21-35.99)	49	69	118 (29.50 %)
Middle to old adult (≥36)	58	77	135 (33.75 %)
Total	163	237	400 (100 %)

Table 2 *Sample distribution of the tested group*

Age-group (years)	Males	Females	Total
Child & adolescent (10-20.99)	10	29	39 (37.86 %)
Young adult (21-35.99)	9	23	32 (31.07 %)
Middle to old adult (≥36)	12	20	32 (31.07 %)
Total	31	72	103 (100 %)

Table 3 *The different value between the estimated and the chronological ages of the tested group*

Age-group (years)	N	Mean (years)	Standard deviation (SD)
Child & adolescent (10-20.99)	39	1.44	2.01
Young adult (21-35.99)	32	1.76	4.01
Middle to old adult (≥36)	32	-6.09	6.54

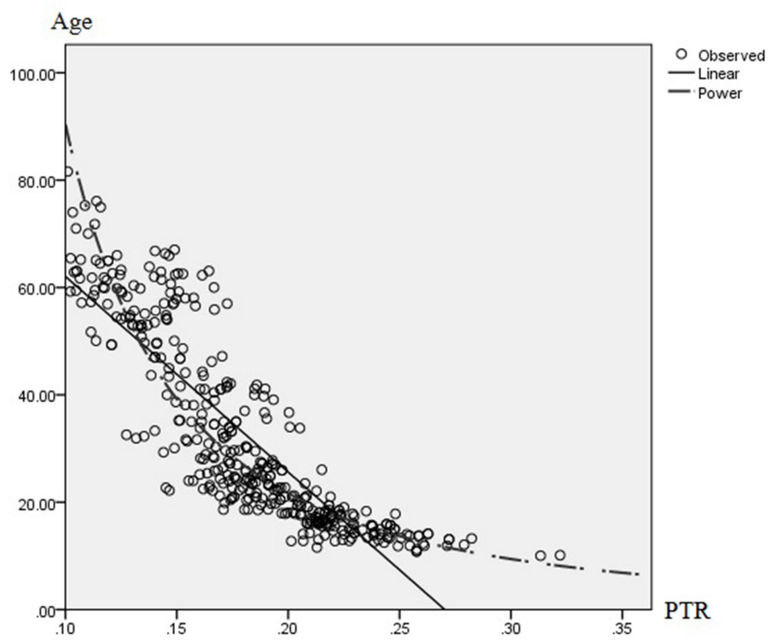

Figure 2 *A scattered plot of the age and the pulp/tooth area ratio*

Discussion

Our study proposed a measurement method for age estimation modified from the Cameriere study.[8] Whereas the Cameriere study measured the PTR from the entire tooth from the incisal edge to the root apex, our study selected only the middle third of the root to be analyzed. The reason we analyzed the middle third of the root because the Cameriere method has some limitations. For example, in many cases of disaster, abuse, murder or accident, the crown of the tooth is usually fractured or destroyed.[17] In these cases, the Cameriere method cannot be applied. Moreover, the visualization of the pulp chamber and the apical third of the root canal boundaries are difficult to clarify. Our method used only the middle third of the root, which was clearly seen in both pulp and tooth. As a result, the correlation coefficient (r) in our study was high (r=-0.86). Previous studies in the populations of Egyptians and Indians using PTR to estimate the age from maxillary

central incisors showed lower correlation coefficients than the results from our study.[9,18,19] However, the original study of Cameriere *et al.,*[8] using right maxillary canines, showed a higher correlation coefficient (r=-0.92) than ours. These discordant findings may result from the differences in tooth types and ethnicity of each study.

We selected the upper right central incisor in our study instead of the canine for two reasons. First, complete root formation of the maxillary central incisor occurs earlier than that of the canine. The maxillary central incisor has complete root formation at approximately 9-10 years, whereas the maxillary canine has complete root formation at approximately 12-15 years of age.[20] Therefore, using the maxillary central incisor could estimate the sample's age in younger group. Second, the maxillary canine is located at the curvature of the dental arch, so the periapical radiograph in this area usually presents with overlapping. With this error, the measurement of PTR in the maxillary canine might not be accurate. Since previous studies on PTR for age estimation used only either left or right tooth for measurement have shown no significant differences between teeth of the left and the right side of the jaw,[6,19] therefore we selected the right central incisor as a representative. Moreover, our equation can be used in both sexes since there was no significant difference between the sPTR measurements in male and female.

Age estimation in Thais using dental radiographs has been reported in a small number of studies.[14-16] Those studies used crown and root development of a variety of tooth types for age prediction, particularly in children and adolescents. To our knowledge, this is the first study using the PTR for age estimation in Thai samples. The Cameriere method is widely used for age estimation in various races.[8-13] The study by Babshet et al. reported MAE of 11.58 years using Cameriere's formula in Indians. They suggested that racial differences might be the cause of that large error.[10] To resolve the problem, they generated their own equation to predict the age and found slight better results (MAE=10.76). Azevedo *et al.* also showed that the equation generated from their study was more accurate than the Cameriere equation for age estimation when used with a group of Brazilian adults.[11] These findings support the need for a specific equation for each population.[10,11,13] In our study the Thai equation using sPTR method showed MAE of 4.26 years. Overall, the mean difference value between the estimated and the chronological ages in the tested group was -0.80. However, the generated equation age prediction appeared to be more accurate in the younger age group (10 to less than 36 years old) than the older age group (more than 36 years old). In the younger group, the estimated age was less than 2 years overestimation. A study by Solheim in 1992 stated that there was a tendency of reduced speed of secondary dentin formation in the elderly group.[21] This might be reasonable explanation why the age estimation using the sPTR, that reflects the secondary dentine deposition, in our older sample groups demonstrated poorer prediction.

Measurement of PTR in multiple teeth showed greater accuracy for age prediction than by using only one tooth type. Kavaal *et al.* found that the coefficient of determination for age estimation was strongest, when using the combination of the PTR of six teeth compared with the use of the PTR in only the mandibular canine.[6] Babshet *et al.* found that using the PTR among the tooth combination of lateral incisor, first premolar and canine, gave higher correlation coefficient than using a single tooth type.[22] In our study, we used only one tooth, the right maxillary incisor. In further studies, the use of multiple teeth is obviously needed to increase the prediction accuracy.

For clinical application, the sPTR we firstly proposed is another choice for age estimation in Thais using periapical dental radiographs. It uses only one central incisor and it could predict age in the population with broader age groups from children to old adults compared to other studies in Thai population. Recently, previous studies in Thais using third molars have

demonstrated accurate prediction the age in the population of 8 to 23 years old.[15,16] Similarly, a study by Duangto *et al.* presented good result of age estimation in 6 to 15 years old samples using a Demirjian *et al.* seven teeth method.[14] However, in real situation forensic odontologist tried to use many methods as much as possible in one case to minimize the error. This new method developed in this study can be one of the several methods available for forensic odontologists.

In conclusion, the sPTR on the maxillary central incisor we proposed in this study can be useful for age estimation in Thais, particularly in child and adolescent and young adult groups.

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