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Original Article

Age estimation from root diameter and root canal diameter of maxillary central incisors in Chinese Han population using cone-beam computed tomography

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Abstract: Age estimation from dental radiographs is a non-destructive method to obtain information. The purpose of this investigation was to evaluate the possibility of age estimation from root diameter and root canal diameter of maxillary central incisors radiographs. 420 cone-beam computed tomography images of maxillary central incisors (210 males and 210 females) aged 15 to 84 years were chosen and classified into 7 age groups each sex: group I (15-24 years), group II (25-34 years), group III (35-44 years), group IV (45-54 years), group V (55-64 years), group VI (65-74 years) and group VII (75-84 years). Root diameter, root canal diameter and root canal diameter/root diameter ratios were obtained by dedicated software together with cone-beam computed tomography. Gender difference was significant ($P<0.05$). Data of root canal diameter and root canal diameter/root diameter ratios showed statistically significant correlation ($r=0.849$ & $P<0.05$ for male, $r=0.692$ & $P<0.05$ for female from root canal diameter; $r=0.862$ & $P<0.05$ for male, $r=0.735$ & $P<0.05$ for female from root canal diameter/root diameter ratios) with age through correlation and regression analysis while root diameter had no significant correlation with age. Linear regression equations were performed separately for both sexes along with the corresponding Standard Error of Estimate that ranged from 2.28 to 3.05 years. In conclusion, dental age estimation is possible using cone-beam computed tomography from root diameter and root canal diameter of maxillary central incisors in Chinese Han population.

Keywords: Cone-beam computed tomography, maxillary central incisors, aging changes, forensic odontology, age estimation

Introduction

Dental age estimation has received a considerable attention along with the development of 3D digital images, which is a non-destructive and simple method to get information. It can be used not only in the deceased individuals but also in living individuals [1].

Tooth is the hardest tissue in the body and it can be preserved for long time even after people dead. Kvaal *et al* [2-4], proposed a number of length and width measurements of tooth and pulp on radiographs to estimate age depend on secondary dentin deposition. Age estimation based on different radiographic technologies has been reported in earlier studies [5-7]. As a novel technology, cone-beam computed tomography not only widely used in clinical of stomatology to help diagnosis, but also used in forensic odontology with better contrast resolution and lower dose.

Yang et al estimated age through volume matching of teeth imaged by cone-beam CT; they evaluated the pulp/tooth radio of twenty-eight single rooted teeth in 19 individuals [8]. Recent reports promoted to enhance age prediction taking population-specific data into account [9]. Therefore, the present study sought to evaluate the possibility of age estimation from root diameter and root canal diameter of maxillary central incisors radiographs in Chinese Han population using cone-beam CT.

Materials and methods

Materials

A total of 420 cone-beam computed tomography images were taken from the CT room of the Department of Radiology, Stomatological Center of Chinese PLA, consisting of 210 males and 210 females aged between 15 and 84 years with individuals' chronological age. The

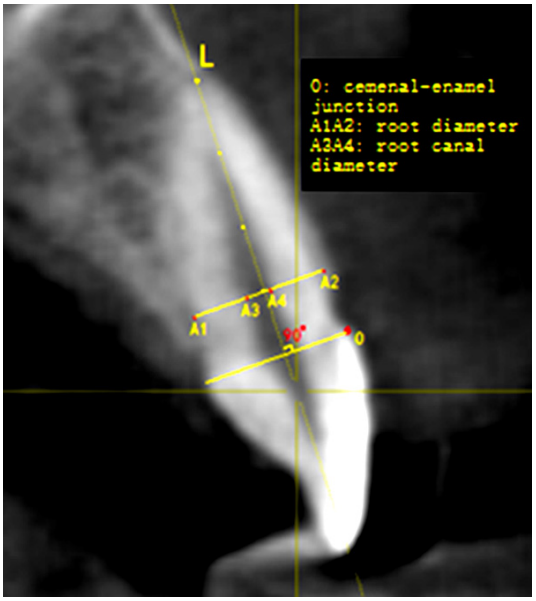

Figure 1. The point O is the cemenal-enamel junction, draw a line O through point O which is perpendicular to line L. L is a line at the 3/4 level from line O to root apex, A1A2 is root diameter, and A3A4 is root canal diameter.

Table 1. Distribution for age and gender of cone-beam computed tomography images among the studied samples

Age category (years)	No. of males	No. of females	Total
Group I (15-24)	30	30	60
Group II (25-34)	30	30	60
Group III (35-44)	30	30	60
Group IV (45-54)	30	30	60
Group V (55-64)	30	30	60
Group VI (65-74)	30	30	60
Group VII (75-84)	30	30	60
Total	210	210	420

exclusion criteria were: the right maxillary central incisor is missing; Torsion of the right maxillary central incisor; the right maxillary central incisor with root canal treatment, with large areas of enamel overlap between neighboring teeth, patients with severe periodontitis, with wedge-shaped defect, with root curvature, with vestibular radio-opaque dental restorative materials or pathological process visible on the CBCT images. Protocol of the study was approved by the Ethical Committee of the 306 Hospital of PLA.

Cone-beam computed tomography images

Images taken by Galileo cone-beam computed tomography (Kv85, mAs28, s14, Sirona, Germany) were classified into 7 age groups each sex: group I (15-24 years), group II (25-34 years), group III (35-44 years), group IV (45-54 years), group V (55-64 years), group VI (65-74 years) and group VII (75-84 years).

Kvaal *et al* found permanent teeth from the left and right side of the jaw have no significant differences. In the present study, teeth were chosen from the right side [2].

The points used to mark root canal diameter and root diameter in maxillary central incisors were determined (**Figure 1**). The picture was adjusted to a specified position in the longitudinal section of the radiographs. A1A2 was defined as root diameter, A3A4 was defined as root canal diameter, root diameter and root canal diameter were measured by dedicated software together with cone-beam computed tomography, the ratios of root canal diameter and root diameter was calculated. All measurements were carried out three times by one examiner. A random sample of 36 root canal diameter and root diameter were re-examined after an interval of one month to test intra-examiner reproducibility by paired t-test according to Aboshi et al [10].

Statistical analysis

Statistical Program for Social Sciences (SPSS), Version 21 (IBM Company, Chicago, IL) was used to perform statistical analysis. Gender difference was evaluated through analysis of covariance (ANCOVA). Correlation coefficient was calculated to determine the association between age and root canal diameter as well as the association between age and root canal diameter/root diameter ratios. A linear regression model for age estimation for Chinese Han population was developed, linear regression equations were performed separately for both sex along with the corresponding SEE (Standard Error of Estimate).

Results

Paired t-test showed no statistical significant differences between the paired data of measurements (r=0.98 & P=0.491).

Table 2. Descriptive statistics for the chronological age of the Chinese Han population sample

Age (years)	Gender	No	Min.	Max.	Mean.	SD
Group I (15-24)	M	30	15	24	19.70	7.528
	F	30	15	24	20.23	8.806
Group II (25-34)	M	30	25	34	29.50	8.535
	F	30	25	34	29.47	8.809
Group III (35-44)	M	30	35	44	39.33	8.713
	F	30	35	44	39.40	8.731
Group IV (45-54)	M	30	45	54	49.47	9.016
	F	30	45	54	49.00	7.724
Group V (55-64)	M	30	55	64	59.60	7.145
	F	30	55	64	58.67	7.954
Group VI (65-74)	M	30	65	74	68.77	7.564
	F	30	65	74	69.47	7.154
Group VII (75-84)	M	30	75	83	77.90	7.679
	F	30	75	84	78.37	8.447

Min: Minimum, Max: Maximum, SD: Standard deviation, No: Number, M: Male, F: Female.

Age and sex distribution of individuals are presented in **Tables 1** and **2**. The descriptive statistics for different age groups, for root diameter, for root canal diameter and ratios of root canal diameter/root diameter of maxillary central incisors were shown in **Table 3**, respectively.

ANCOVA analysis showed that gender difference was significant in root diameter, root canal diameter and ratios of root canal diameter/root diameter of maxillary central incisors ($P<0.05$). Data of root diameter revealed no significant difference in age through ANCOVA analysis ($P=0.338$).

Figure 2 was a scatter diagram which shows the correlation between age and ratios of root canal diameter/root diameter obviously. Linear regression analysis, where age was the dependent variable and root canal diameter/root diameter ratios was the independent variables, showed a coefficient of determination ($R^2=0.576$ for total sample, $R^2=0.743$ for male and $R^2=0.541$ for female). **Figure 2** also revealed that root canal diameter/root diameter ratios decreased faster in female than that in male.

Correlation and regression analysis of root canal diameter and root canal diameter/root diameter ratios showed statistically significant correlation with age ($r=0.849$ & $P<0.05$ for male, $r=0.692$ & $P<0.05$ for female from root canal diameter; $r=0.862$ & $P<0.05$ for male, $r=0.735$ & $P<0.05$ for female from root canal diameter/root diameter ratios).

Root canal diameter/root diameter ratios showed higher correlation with age than root diameter, which was used to estimate age for both sex in different age groups from 15 to 84 years. Linear regression equations for age estimation from root canal diameter/root diameter ratios were presented in **Table 4**.

Regression equations along with standard error of estimate (SEE) have been computed separately for each age group both sexes in **Table 5**. The SEE ranged from 2.28 to 3.05 years for age estimation from total sample.

Discussion

A number of methods were applied to estimate age through analysis of morphological parameters and biological indicators of the teeth, such as dental translucency, cementum annulations, amino acid racemization and dental nuclear tests. Some of them need a large amount of time, money and energy. Some are destructive with tooth extracted, which is unethical and would be limited for other reasons like religious and cultural. With the rapid development of imaging techniques, it has been widely used in age estimation studies as a non-destructive method and considered to be more reliable [11]. Nowadays, the clinical introduction of cone-beam CT creates a new approach to be used in dental age estimation.

Maxillary teeth were chosen as the teeth in the upper jaw because that shows a stronger correlation than mandibular teeth for the dental age estimation, as previously described by Brkic *et al* [12]. Additionally, the root canal systems, morphological and anatomical characters of central incisors are not much complicated as compared with other types of teeth in the same jaw, and easier to measure and subsequent statistical analysis.

Method to adjust cone-beam computed tomography images to a specified position in longitudinal section (**Figure 1**) past consistency test was used with interclass correlation coefficient

Table 3. Descriptive statistics of Chinese Han population

Groups	No	Root diameter (mm)				Root canal diameter (mm)				Ratio			
		M (210)		F (210)		M (210)		F (210)		M (210)		F (210)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Group II (25-34)	60	5.62	0.421	5.44	0.581	1.58	0.208	1.12	0.218	0.28	0.032	0.21	0.035
Group IV (45-54)	60	6.01	0.438	5.49	0.4	1.2	0.208	0.9	0.144	0.2	0.033	0.16	0.027
Group V (55-64)	60	5.78	0.392	5.61	0.334	1.02	0.195	0.86	0.132	0.18	0.029	0.15	0.024
Group VI (65-74)	60	5.84	0.457	5.54	0.411	0.84	0.207	0.84	0.167	0.14	0.039	0.15	0.031
Group VII (75-84)	60	5.92	0.456	5.62	0.47	0.69	0.219	0.71	0.156	0.12	0.035	0.13	0.026
Total	420	5.81	0.445	5.53	0.489	1.2	0.396	0.96	0.236	0.21	0.072	0.17	0.043

No: Number, SD: Standard deviation, M: male, F: female, ratio: root canal diameter/root diameter.

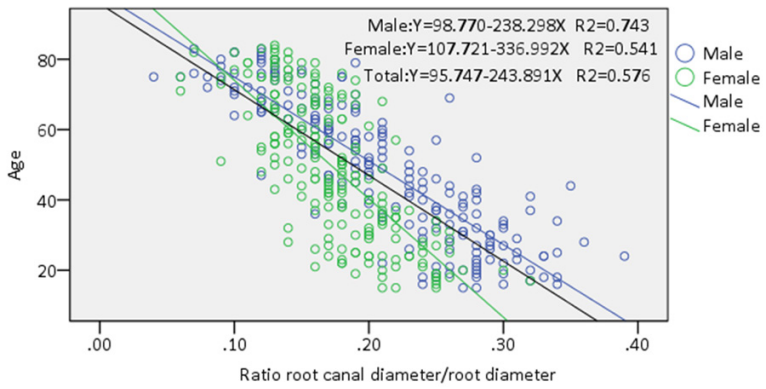

Figure 2. Regression equations together with coefficient of determination of each sex as well as total were showed, in which age was dependent variable and root canal diameter/root diameter ratio was independent variable.

Table 4. Linear regression equations for both sexes and total in Chinese Han population

	No	Linear regression equation	R^2	SE
Male	210	Y=98.770-238.298X	0.743	2.139
Female	210	Y=107.721-336.992X	0.541	3.851
Total	420	Y=95.747-243.891X	0.576	2.052

No: Number, R^2: coefficient of determination, SE: Standard error.

before we start the present research with *ICC* >0.9. Landis and Koch suggest the value of *ICC* should be above 0.80 [13]. Root diameter and root canal diameter at the 3/4 level from line O to root apex are considered more stable and reliable as this area was encased by alveolar bone which could help avoid impact of environmental factors, such as abrasion, saliva and food.

Earlier research has indicated that secondary dentin is correlated with chronological age [14-16] and can be measured indirectly by radiographs [2, 4]. Root canal diameter is an indirect quantification of secondary dentin deposition [10]. Root canal diameter/root diameter ratios was calculated and used in this study, in order to reduce the effects of the variation in tooth sizes and eliminate the magnification and angulations of the radiographs [2]. Results of correlation and regression analysis of root canal diameter and root canal diameter/root diameter ratios demonstrated it, root canal diameter/root diameter ratios showed higher correlation with age than root diameter.

The present study showed statistically significant gender difference on dental age estimation in Chinese Han population by ANCOVA analysis. This was meeting with Babshet M *et al* [17]. On the contrary, Zaher JF *et al* who stated that there was no significant effect of gender in age estimation on central and lateral incisors [18]. In addition, Cameriere *et al* reported that there is no gender difference on the regression models in study of age estimation [19]. The opposite result can be explained by racial difference [17].

Together with linear regression equations, standard error of estimate (SEE) have been computed to predict the deviation of estimated age from actual age and lower value indicates greater reliability. According to Solheim T *et al* stated that SEE < ±10 years is considered acceptable in forensic age estimation [20]. In present research, SEE ranged from 2.28 to

Table 5. Linear regression equations for each age group both sex for Chinese Han population

Groups	Gender	Linear regression equation	SEE	R^2
Group I (15-24)	M	Y=15.496+14.564X	2.735	0.018
	F	Y=28.397-36.383X	2.695	0.049
Group II (25-34)	M	Y=33.526-14.312X	2.937	0.089
	F	Y=30.127-3.195X	3.018	0.011
Group III (35-44)	M	Y=34.948+17.520X	2.913	0.005
	F	Y=53.719-76.845X	2.277	0.091
Group IV (45-54)	M	Y=50.343-4.398X	3.052	0.040
	F	Y=54.830-32.573X	2.920	0.091
Group V (55-64)	M	Y=68.047-47.993X	2.331	0.238
	F	Y=58.498+7.169X	2.714	0.052
Group VI (65-74)	M	Y=72.512-26.011X	2.604	0.031
	F	Y=70.957-9.826X	2.704	0.017
Group VII (75-84)	M	Y=78.528-5.365X	2.814	0.023
	F	Y=79.576-9.526X	2.947	0.034

SEE: Standard error of estimate, M: male, F: Female.

3.05 years for age estimation from total sample which was smaller and more stable than Zaher JF *et al* reported SEE ranged from 1.2 to 5.08 years for age estimation on central and lateral incisors [18]. And the result is similar to Cameriere *et al* determined SEE is about 2.5 years from canine pulp/tooth area ratio for age estimation [19].

This study showed a statistically significant correlation between age and root canal diameter/root diameter ratios in Chinese Han population aged 15 to 84 years by using cone-beam CT. The result was parallel to Ubelaker & Parra, who reported that correlation coefficients vary from 0.69 to 0.86 for single-rooted teeth from Peru [9]. Additionally, the result showed a greater correlation compared to Yang et al who showed a coefficient of determination: R^2=0.29 & SE=5.82 years from pulp/tooth volume ratio of incisors and biological age [8]. The correlation coefficient in present research revealed more reliable than Zaher JF *et al*, who calculated that r=0.23 for maxillary central incisors and r=0.2 for maxillary lateral incisors by correlation and regression analysis [18].

In conclusion, this research showed promising results for dental age estimation by using cone-beam computed tomography from maxillary incisor teeth in Chinese Han population. It may be stated that, dental age estimation using cone-beam computed tomography is reliable from root diameter and root canal diameter of maxillary central incisors in Chinese Han population. Additionally, there is an obvious correlation between the root canal diameter/root diameter ratio and age from maxillary incisor teeth in Chinese Han population, which shows that the root canal diameter/root diameter ratio in maxillary central incisors is an age-dependent variable which can be used to estimate age with reasonable accuracy. It is also recommended that ethnic difference and gender difference should be taking into account in studies of age estimation. However, further research is needed to collect larger samples with different types of teeth together and multiple regression analysis must be used to improve age estimation with maximum accuracy.

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Disclosure of conflict of interest

None.

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