Accuracy of linear measurements of teeth on CBCT images for application on dental age estimation.

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Abstract:

Purpose: Evaluation of accuracy of linear measurements of teeth on CBCT images for application on dental age estimation**. Material and Methods:** CBCT radiographs of 1000 teeth of patients which range from 16 to 58 years were analyzed to estimate the chronological age by developing regression equation using different linear measurements on tooth. **Results:** The coefficient of determination of the regression equation derived from the linear ratios was 0.558 and from the linear measurments was 0.338. **Conclusion:** The prediction equations derived from linear ratios had higher prediction ability than equations derived from linear measurements.

Keywords: Cone-Beam CT, Forensic dentistry, dental age estimation.

Introduction:

Accurate age estimation is an important clue in criminal and civil events for both living and dead persons. Legal decisions in many situations such as immigrants, refugees, , lack of documentation, memory loss, pensions, criminal responsibility, and age falsification depend on the role of forensic practitioners in determining the age of living persons [1]

Different parts of the human body can be used for age estimation. However, in severe accidents, burns or buried bodies, many human parts lose their natural form and cannot be used for age estimation. Teeth remain for years after death and are suitable for human age estimation [2]

The advantage of dental age estimation is that teeth are less affected by extrinsic physical, chemical, or mechanical factors than are other parts of the skeleton. For this reason, dental age estimation results have shown a low variability as a function of chronological age [3]

In children, age estimation using teeth is relatively simple and is done based on the developmental stage of the teeth. But, age estimation in adults is a challenge in forensic medicine [4]

It has been reported that the pulp-dentin complex (PDC) shows age-related changes due to the secondary dentine accumulation .Therefore, the pulp chamber volume could be altered by the aging process [5]

The formation of secondary dentine may be caused by attrition, abrasion, erosion, caries, changes in osmotic pressure throughout the pulp chamber, or aging and decreases the volume of the dental pulp chamber. Therefore, the volume changes of the pulp chamber in intact teeth are considered as a dental age predictor [6]

Assessment of morphological changes requires tooth sectioning, which is impossible in living individuals. Thus, methods used for age estimation are mainly based on radiographic

imaging [5]

Many studies revealed a strong correlation between the pulp cavity measurements and chorological age by using bi-dimensional periapical and panoramic radiographs .However, the accuracy of these conventional methods has been limited by some drawbacks such as image distortion, superimposition and magnification [7]

At present, three-dimensional (3D) cone-beam computed tomography (CBCT) scans provides valuable 3D information about teeth and allow more accurate measurement of tooth and pulp dimensions compared with 2D radiography CBCT is the most ideal and accurate method of measurement of pulp to tooth ratio [8]

CBCT radiation dose is much higher than conventional radiology, but its risk can be minimized by following certain task specific protocols .Also, in comparison with Micro-CT, CBCT offers large scanning area and can be performed without teeth extraction [5]

So, this study aims to evaluate the accuracy of linear measurements of teeth on CBCT images for application on dental age estimation.

Materials and Methods

This is a retrospective study using archived CBCT radiographs of 1000 tooth, 544 males and 456 females patient with varying ages that range between 15-60 years of cases who made CBCT imaging for different purposes (dental implant surgery or orthodontic treatment) that were taken from database of outpatient clinic of oral and maxillofacial radiology department, Faculty of Dentistry, Minia University.

Inclusion Criteria:

1-Images showing complete maxillary anterior teeth

2-Clearly visible CBCT images that showed fully erupted permanent tooth with completely normal root

3- Only healthy teeth are selected

4- Single root teeth are selected

Exclusion Criteria:

We will exclude any image with any of the following:

1- The teeth that showed caries, significant wear or attrition, restoration, impaction, root resorption, traumatic lesions, cysts or tumors, dental anomalies, pathology or calcification

2-Teeth with prosthetic crowns or endodontic treatment

3-Patients under 15 years

4-Images with low quality radiographs

All the cases were obtained using SCANORA® 3Dx CBCT dental unit (Scan time 18 - 34 s, Effective exposure time 2.4 - 6 s , Focal spot 0.5 mm. kV 60-90, mA 4-10)

Linear measurements:

CBCT images were obtained with a slice thickness of 0.2 mm. The measurements were made to the nearest 0.01 mm with a caliper. The scans were evaluated in the coronal view at the slice the showed the tooth completely

The measurements were taken from teeth as following [9]:

- Maximum tooth length (Fig1-A)
- Pulp length (Fig1-B)
- Maximum root length on the mesial side (Fig1-A)
- Pulp width at level a, c, b (a-cementoenamel junction, c-midroot level, b-midpoint of a and c) (Fig1-C)
- Root width at level a, c, b (a-cementoenamel junction, c-midroot level, b-midpoint of a and c) (Fig1-D)

From these 9 measurements a total of 10 ratios were derived in order to compensate for personal variations. The ratios determined were

1. T- Root length/tooth length
2. R- Pulp length/tooth length
3. P- Pulp length/root length
4. A- Pulp width/root width at level a
5. B- Pulp width/root width at level b
6. C- Pulp width/root width at level c
7. M- mean values of all ratios
8. W- Mean value of width ratios from levels b and c

9. L- Mean value of length ratios P and R

10. W-L- Difference between W and L

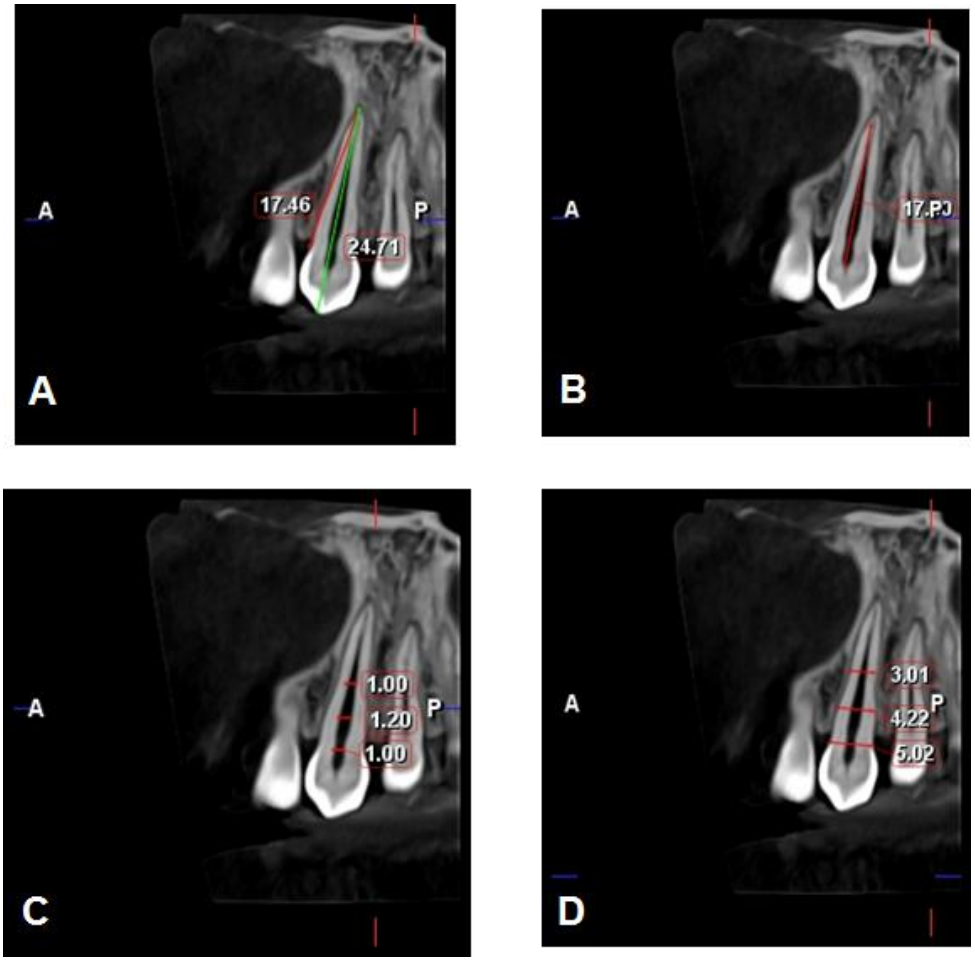

Figure (1): shows the linear measurements of teeth

a- tooth length and root length b-pulp length c-pulp width at different levels d-root width at different levels

The best fit regression model was calculated from the measurements showing significant correlation with chronological age. Subsequently, the regression equation was validated to determine the models accuracy in age prediction.This was done on another sample of 100 CBCT images of centrals and canines (50 males and 50 females) with the same mentioned eligibility study criteria.

Statistical analysis:

The significance limit was chosen as $p < 0.05$ in all statistical analyses and all calculations were done using the SPSS 14.1 package program. The relationship between age and morphological variables was calculated by the Pearson correlation coefficient. Multiple linear regression models were established for each tooth, age as dependent variable, and morphological variables as independent variables. The backward elimination method was used to select the independent variables when constructing multiple regression models.

Results

Table (1): Tooth measures by linear measurement among the studied cases

Variables	Mean±SD	Range
Tooth length (TL)	23.54±2.50	17.62-27.89
Root length (PL)	16.30±2.18	11.16-19.81
Pulp length (PL)	15.02±2.10	10.80-18.97
Pulp width a (PWa)	1.15±0.21	0.65-1.65
Pulp width b (PWb)	1.14±0.27	0.75-1.80
Pulp width c (PWc)	0.85±0.16	0.40-1.25
Root width a (RWa)	5.95±0.69	4.46-7.50
Root width b (RWb)	5.27±0.69	4.01-6.80
Root width c (RWc)	4.56±0.69	3.12-6.42

Total=1000.

Table (1) showed tooth measures by linear measurement among the studied cases

Table (2): Tooth measures ratios by linear measurements among the studied cases

Variables	Mean±SD	Range
Root length/tooth length (T)	0.69±0.03	0.60-0.77
Pulp length/tooth length (R)	0.64±0.04	0.53-0.73
Pulp length/root length (P)	0.92±0.04	0.81-0.99
Pulp width a /root width a (A)	0.19±0.04	0.12-0.28
Pulp width b /root width b (B)	0.22±0.05	0.14-0.40
Pulp width c /root width c (C)	0.19±0.04	0.10-0.28
Mean values of all ratios (M)	0.48±0.03	0.40-0.54
Mean value of width ratios b and c (W)	0.20±0.04	0.14-0.34
Mean value of length ratios P and R (L)	0.78±0.04	0.67-0.85
Difference between W and L (W-L)	0.58±0.05	0.48-0.69

Total=1000.

Table (2) showed tooth measures ratios by linear measurements among the studied cases

Table (3): Linear regression for demographic and teeth ratios to predict age

Methods	Regression equation	p-value	R^2	MSE (years)
Linear measures	**Age=107.51+3.83 (Male)+18.73 (canine)+11.63 (central)-5.46 (TL)+7.66 (RL)-5.94 (PL)-13.42 (RWa)+19.78 (RWb)+33.17 (PWa)-19.56 (PWb)-38.22 (PWc)**	**0.04***	0.338	11.625
Linear ratios	**Age=144.22+ 7.31 (central)+ 5.22 (canine) -96.21 (P)+ 93.19 (A)-226.27 (B)-282.44 (C)+290.76 (W)**	**0.02***	0.558	9.820

Table (3) showed that: Prediction equations derived from linear ratios had higher prediction ability than equations derived from linear measurements.

Table (4): The validty of linear regression equations derived from linear measurements and ratios

Methods	R^2
Linear measures	0.925
Linear ratios	0.961

Table (4) showed that: Prediction equations derived from linear ratios and equations derived from linear measurements are highly valid for application to estimate age

DISCUSSION

The need to estimate age in skeletons of adult people is an important problem in forensic and anthropological sciences. Although several parts of the body can be used for age estimation but the poor condition of the remains often prevent their use. In particular, crashes and fires in the case of the recently dead, and dampness and burial conditions in the case of elderly subjects, make many parts of the body unusable. For this reason, the teeth are that part of the body most frequently used for identification and age estimation when skeletal remains are in poor condition [10]

On the other hand age estimation in the living poses significant challenges because the methods need to be non-invasive, accurate and ethically viable. Non-destructive age estimation methods are also required in forensic cases where the evidence is not available for destructive analysis and/or in cases where for religious reasons the extraction of teeth is prohibited [11]

CBCT is an effective and noninvasive diagnostic imaging modality in clinical dentistry due to its limited radiation exposure and the ability of producing highly accurate life size images. Image enhancing software like Mimics and Acteon imaging suite (AIS) can utilize data from CBCT for the 3-dimensional reconstruction of the pulp cavity and calcified tooth structures [12]

The deposition of secondary dentin is a significant predictor of dental age; thus, alterations in the pulp volume of intact teeth are considered a predictor able to estimate the chronological age of the subjects [13]

However, the apposition of secondary dentine is not homogeneous on all walls of the pulp cavity. Difficulties have been reported in detecting minute structural demarcations at the root apex (pulp tissue and calcified tooth structures), and undertaking this manually for this purpose would be time-consuming [14]

Canines and centrals in human dentition are less affected by occlusal stress and periodontal diseases. They are therefore usually the last teeth that remain in the mouth, and are the most frequently found even in older individuals. Moreover, the canines are distinguished from other teeth by their size: their crown and especially their roots are the longest of all the teeth, giving them a large anchored root and greater stability, so they are frequently preserved on the dental arch [15]

Maxillary anterior teeth show considerably less crowding and attrition as compared to their mandibular counterpart. Also, the volume of the pulp cavity is proportionately large, the greatest volume of the single-root teeth which allows modifications to be observed more easily than for other teeth with smaller pulp volume [15]

In this study, by using the regression equation derived from the linear ratios, the coefficient of determination was 0.616 which is higher than **Akay et al. 2017** [16] and **Moshfeghi et *al*. 2019** [17] (0.296 and 0.567) respectively; this difference may be related to large sample size of this study compared to small sample which was 211 and 180 tooth respectively.

In the other hand, the coefficient of determination of the regression equation derived from the linear ratios is lesser than **Gomathi et**

al. 2020 [9] which was 0.76; this difference may be due to using the upper 6 anterior teeth but in this study we use upper central and canine only.

In this study the the coefficient of determination of the regression equation derived from the linear ratios is higher than linear measurments which was 0.558 and 0.338 respectivly ; this may be due to using ratios eliminate the fault measurements result from variation of teeth size or length from one individual to other **(Gomathi et al. 2020).**

The regression equations had been validated in an independent sample of 100 subjects and revealed high accuracy. Accordingly, the availability maxillary canine tooth and maxillary central tooth could efficiently help in the age estimation of adults.

The use of CBCT offers the advantage of being able to perform objective and precise measurements in the study and to be applied on living individuals as well as on corpses since the method is a radiographic method. CBCT technology is continuously evolving with better contrast resolution, smaller voxel size, and higher grey-scale values. With the use of software programs with appropriate segmentation and separation adaptation, we believe that more accurate measurements of teeth can be achieved in future studies.

Conclusion:

From this syudy we can conclude that the prediction equations derived from linear ratios had higher prediction ability than equations derived from linear measurements

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