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DENTAL AGE ESTIMATION BASED ON PULP CHAMBER/CROWN VOLUME RATIO MEASURED ON CBCT IMAGES

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ABSTRACT

Purpose : Evaluation of accuracy of volumetric analysis of pulp chamber / crown volume ratio 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 age by developing regression equation using volumetric measurements on tooth by using 2 different softwares as Mimics and Acteon Imagining Suite programme.

Results : The coefficient of determination of the regression equation derived from the volume ratios calculated by using Mimics software was 0.812 and from the volume ratios calculated by using Acteon Imagining Suite software was 0.764 .

Conclusion : The prediction equations derived from the volume ratios using Mimics software had higher prediction ability than equations derived from the volume ratios using Acteon Imagining Suite software.

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

INTRODUCTION

The precise determination of age serves as a crucial indicator in criminal and civil proceedings related to individuals who are deceased or alive. The determination of the age of living individuals has an important role in various legal contexts, including but not limited to cases involving immigrants, refugees, individuals lacking documents, memory impairment, pension claims, criminal liability, and age verification. Forensic practitioners play an important role in providing expert analysis and assessments that inform legal choices in these instances [1].

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Various anatomical features of the human body can be employed as indicators for estimating an individual's age. Nevertheless, in instances of serious accidents, burns, or cases where remains are buried, numerous human body parts undergo significant deformation, rendering them unsuitable for the purpose of age assessment. Teeth persist postmortem for extended periods and can be utilized for the purpose of estimating age. [2]

One of the primary benefits associated with dental age estimation is the relatively limited susceptibility of teeth to external physical, chemical, or mechanical influences compared to other components of the skeletal system. Due to this rationale, the outcomes of dental age estimation have exhibited minimal fluctuation in relation to chronological age [3]

Dental age estimation in pediatric populations is a reasonably straightforward process that relies on assessing the developmental stage of the teeth. However, estimating the age of adults is a greater challenge [4]

Age-related alterations in the pulp-dentin complex (PDC) have been seen as a result of the deposition of secondary dentin. Hence, it is plausible that the volume of the pulp chamber may undergo alterations as a result of the aging process [5]

The development of secondary dentin can be attributed to various factors, including attrition, abrasion, erosion, caries, and the natural process of aging, which collectively contribute to a reduction in the volume of the tooth pulp chamber. Hence, the alterations in the volume of the pulp chamber within undamaged teeth are regarded as a reliable indicator of dental age [6]

The assessment of morphological alterations necessitates the process of tooth sectioning, a procedure that is unfeasible to perform on individuals who are alive. Therefore, the techniques employed for age assessment primarily rely on non-invasive radiographic imaging [5]

Numerous investigations have demonstrated a strong association between measurements of the pulp cavity and chronological age through the utilization of periapical and panoramic radiography. Nevertheless, the conventional approaches have encountered several limitations that hinder their accuracy, including image distortion, superimposition, and magnification [7]

Nowadays, the utilization of three-dimensional (3D) cone-beam computed tomography (CBCT) scans has proven to be highly advantageous in providing comprehensive 3D data pertaining to teeth. This advanced imaging technique enables more precise assessment of tooth and pulp dimensions in comparison to traditional two-dimensional radiography [8].

The radiation dose associated with cone beam computed tomography (CBCT) is significantly more than that of conventional radiography. However, the potential risks can be mitigated by adhering to particular standards. Moreover, as compared to micro-CT, cone beam computed tomography (CBCT) provides a substantial advantage for its ability to capture a larger scanning area. Additionally, CBCT scans can be conducted without the need for tooth extraction. this characteristic of CBCT distinguishes it from micro-CT [5]

The objective of this study is to assess the accuracy of dental age estimation by utilizing the pulp chamber/crown volume ratio as determined on cone beam computed tomography (CBCT) images.

MATERIALS AND METHODS

This study is a retrospective analysis that utilized archived cone-beam computed tomography (CBCT) radiographs of 1000 teeth (one tooth from each patient). The sample consisted of 544 male and 456 female patients across a wide age range of 15 to 60 years. These radiographs were obtained from the database of the outpatient clinic within the Department of Oral and Maxillofacial Radiology

at the Faculty of Dentistry, Minia University. The CBCT imaging was performed for various purposes, including dental implant surgery and orthodontic treatment.

Inclusion Criteria:

1. Images show the entirety of the maxillary anterior teeth.
2. The CBCT scans that have evident visibility, revealing a fully erupted permanent tooth with a root that displayed entire normalcy.
3. Only teeth that are in a state of optimal health are chosen.
4. Single-rooted teeth are chosen.

Exclusion Criteria:

In our study, any image that possesses any of the following characteristics was excluded:

1. The teeth exhibiting caries, notable wear or attrition, dental restorations, impaction, root resorption, traumatic lesions, cysts or tumors, dental abnormalities, disease, or calcification.
2. Teeth that have undergone either prosthetic crown placement or endodontic treatment.
3. Patients that are younger than 15 years of age
4. Images displaying radiographs of low quality.

Ethical regulation:

The proposal of this thesis was approved by Research Ethics Committee of faculty of dentistry, Minia University No (83) at 1/11/2021.

All cases were coded before interpretation.

Image acquisition

The cases were acquired utilizing the SCANORA® 3Dx CBCT dental machine, with scan times ranging from 18 to 34 seconds, effective exposure times ranging from 2.4 to 6 seconds, a focal spot size of 0.5 mm, and X-ray settings of 60-90 kV and 4-10 mA.

Volumetric analysis:

The images were exported in the Digital Imaging and Communications in Medicine (DICOM) file format to facilitate 3D analysis and calculations. The DICOM images were imported into two 3D software applications: Mimics image analysis program version 21, developed by Materialise in Leuven, Belgium, and Acteon imaging suite (AIS) 3D version 5.0, developed by Acteon group in Roma, Italy. The image processing tool inside the software was utilized to modify the contrast and brightness of the images. This adjustment was made with the intention of achieving an optimal level of visualization, which would facilitate the subsequent construction of 3D models for both the pulp and tooth.

The segmentation of the dental crown extends from the cementoenamel junction (CEJ) to the cusp tip. Subsequently, the volume of the pulp chamber was quantified from the pulp chamber horn to the level of the pulp at the CEJ. Similarly, the volume of the crown was measured from the cusp tip to the CEJ [9]

A-Mimics software

Initially, the DICOM files were imported into the software, followed by the execution of appropriate image orientation adjustments in the axial, coronal, and sagittal planes.

Masks were created to cover the pulp cavity and another mask for calcified tooth structures. Subsequently, the masks underwent cropping in all three plans. In the process of editing masks, a coronal stop was positioned at the incisal border for calcified tooth and pulp chamber, while the apical stop was placed at the reference of cementoenamel junction (Fig 1).

The software's 'region-grow' tool was utilized to expand the regions between the apical and coronal stops. Subsequently, the "calculate part" was employed to create the object in three dimensions. Following this, the volume of the pulp chamber and crown were determined by accessing the "Properties" section.

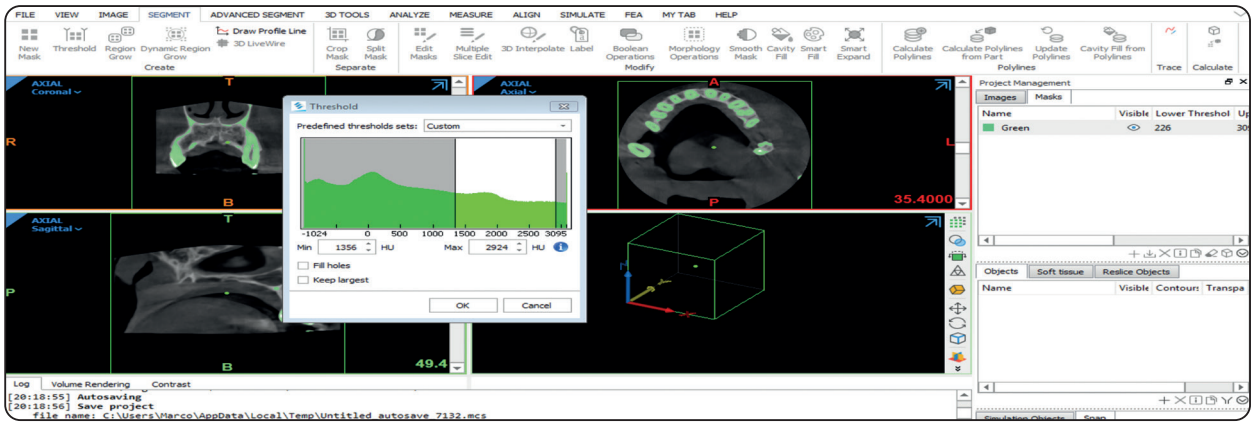

Fig. (1) Showing selection of suitable mask for pulp and crown structures for Mimics software

B-Acteon imaging suite software

Initially, the DICOM images were imported into the software. Subsequently, the segmentation module was chosen, and distinct threshold values were employed to generate masks for the pulp cavity and calcified tooth structures individually (Figure 2).

Subsequently, the area cut tool is employed on the three-dimensional object in order to independently extract the region of interest from the jaw. Subsequently, the crown and root were separated at the cemento enamel junction using the erase tool on a 2D brush.

The crown and coronal pulp chamber were separated using the 'Split mask' technique, followed by manual refinement to eliminate any excess in object. Subsequently, the volume was calculated.

Regression Models

The regression model that provided the best fit was determined based on the measurements that exhibited a statistically significant correlation with chronological age. Following that, the regression equation was evaluated in order to assess the accuracy of the model in predicting age.

The aforementioned procedure was conducted on an additional set of 100 cone-beam computed tomography (CBCT) images, specifically focusing on central and canine teeth. The sample consisted of 50 male and 50 female subjects, all of whom met the predetermined eligibility criteria outlined in the study.

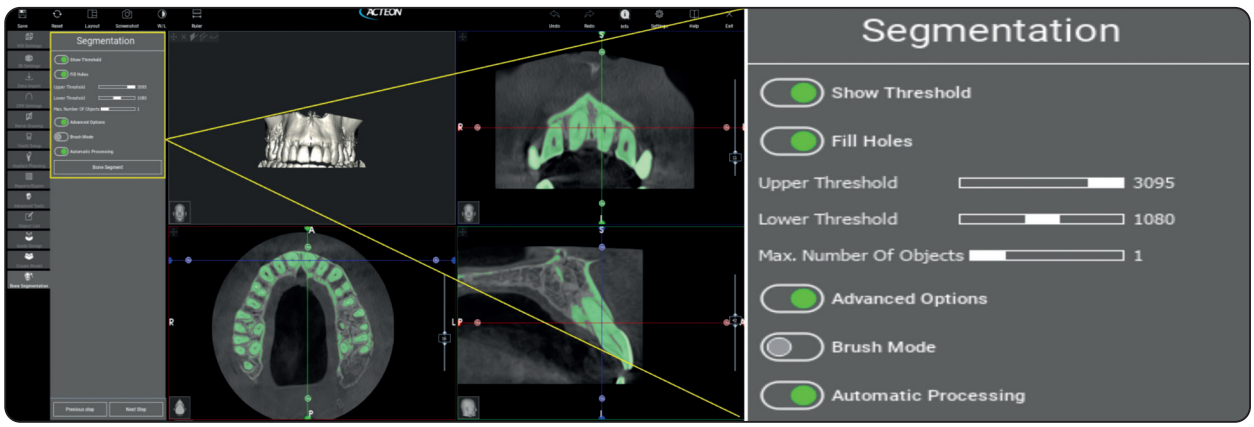

Fig. (2) Showing selection of suitable mask for pulp and crown structures for AIS software

Sample size justification

Setting the power= 0.99 and α=0.05 with using PASS 11th release **(Hintze 2011) ,** a sample size of 70 cases is required to achieve 99% power to detect a change in slope from 0.00 under the null hypothesis to 1.66 under the alternative hypothesis when the standard deviation of the X's is 2.82, the correlation is 0.92, and the two-sided significance level is 0.05000 but we will include 1000 cases for further possible relations[10]

Statistical analysis

The data that was gathered underwent coding, tabulation, and statistical analysis using IBM SPSS statistics software version 28.0, developed by IBM Corp. in Chicago, USA in 2021. The normality of the quantitative data was assessed using the Kolmogorov-Smirnov test. The data was afterwards described using the mean±SD (standard deviation), along with the minimum and maximum values of the range. Qualitative data is typically represented using numerical values and percentages. The study employed a linear regression model to identify the independent variables that influence specific situations. The level of significance was determined to be statistically significant when the p-value was less than 0.05 and non-significant otherwise.

RESULTS

Table (1) showed tooth measures and ratios by volumetric measurements among the studied cases

TABLE (1) Tooth measures and ratios by volumetric measurements among the studied cases

Variables	Mean±SD	Range
Pulp volume (PV Mimics)	4.16±3.32	0.47–13.80
Crown volume (CV Mimics)	278.37±60.43	186.70–399.50
Pulp volume (PV AIS)	4.52±3.59	0.62–15.06
Crown volume (PV AIS)	298.95±63.63	199.21–436.25
Pulp volume / Crown volume (Mimics) (PV/CV Mimics)	0.014±0.009	0.002–0.040
PV/CV Pulp volume / Crown volume (AIS) (PV/CV AIS)	0.014±0.009	0.002–0.039

Total=1000.

TABLE (2) Tooth measures and ratios by volumetric measurements among the studied cases

Variables	Mean±SD	Range
Pulp volume (PV Mimics)	4.16±3.32	0.47–13.80
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Pulp volume / Crown volume (Mimics) (PV/CV Mimics)	0.014±0.009	0.002–0.040
PV/CV Pulp volume / Crown volume (AIS) (PV/CV AIS)	0.014±0.009	0.002–0.039

Total=1000.

Table 2: showed tooth measures and ratios by volumetric 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)
Volume ratio (Mimics)	Age=46.22-3.55(Male) - 751.91(PV/CV)(canine) + 56.74 (PV/CV) (Central)	0.002*	0.812	6.093
Volume ratio (AIS)	Age=45.81-3.18(Male) -762.91(PV/CV)(canine) + 53.44 (PV/CV) (Central)	0.003*	0.764	7.231

Table (3) showed that: The prediction equations derived from the volume ratios using Mimics software had higher prediction ability than equations derived from the volume ratios using AIS software.

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

Methods	R^2
Volume ratio (Mimics)	0.934
Volume ratio (AIS)	0.930

Table (4) showed that: Prediction equations derived from volume ratios using Mimics software and AIS software are highly valid for application to estimate age

DISCUSSION

Estimating the age of adult individuals based on skeletal remains is a significant issue within the fields of forensic and anthropological research. While there are many body parts that can be used for age estimate, the utilization of such parts is generally hindered due to the deteriorated state of the remains. Specifically, incidents such as collisions and fires can render various body parts nonfunctional in the case of recently deceased individuals, while humidity and burial conditions can have a similar effect on elderly patients. Due to this rationale, teeth are commonly employed for identification and age estimation purposes in cases where skeletal remains are in a state of deterioration [9].

Cone beam computed tomography (CBCT) has been widely recognized as a valuable diagnostic imaging technique in the field of dentistry. This is primarily attributed to its advantageous features, including little radiation exposure and the capability to generate precise, life-sized images with a high level of accuracy. Image enhancement software, such as Mimics and Acteon Imaging Suite (AIS), has the capability to exploit data obtained from cone-beam computed tomography (CBCT) scans in order to rebuild the pulp cavity and calcified tooth structures in three dimensions [11]

Nevertheless, the deposition of secondary dentin is not uniform across all surfaces of the pulp chamber. Challenges have been documented in the identification of small structural boundaries at the apex of the tooth root, specifically in distinguishing between pulp tissues and calcified dental structures. The manual approach to this task would be laborious and time-intensive [12]

Canines and centrals in human dentition are less affected by occlusal stress and periodontal diseases. Hence, they typically represent the final set of teeth that persist in the oral cavity and are commonly observed, particularly among elderly adults. In addition, the canines exhibit distinct characteristics that differentiate them from other teeth. Notably, they possess the largest crown and particularly lengthy roots among all dental structures. This anatomical feature grants them a substantial and firmly secured foundation, hence enhancing their stability. Consequently, canines are often well-preserved inside the dental arch [13]

The maxillary anterior teeth exhibit a notable reduction in both crowding and attrition when compared to their mandibular counterparts. Furthermore, it should be noted that the pulp cavity has a significantly larger volume in comparison to other teeth with single roots. This substantial volume facilitates the observation of alterations with greater ease, as opposed to teeth with smaller pulp volumes [13]

The findings of the current study revealed that the coefficient of determination values for volumetric analysis of pulp chamber/crown ratios, as determined through the utilization of Mimics software, exhibited a slightly higher value (0.812) compared to the value reported by **Asif** (0.775).

This disparity in results may be attributed to the larger sample size employed in the present study, which encompassed a total of cases, in contrast to the smaller sample size of only 110 cases utilized in **Asif's** study[11]

Additionally, the coefficient of determination (R2) for the volumetric analysis of pulp chamber/crown ratios using Mimics software (0.812) was found to be higher compared to other studies that utilized pulp/tooth ratios, such as **Abdinian** (0.43), **Kazmi** (0.33), and **Asif** (0.639) respectively. This difference in R2 values may be attributed to the challenges encountered in detecting subtle structural boundaries at the root apex and root canal, in contrast to the more prominent structure of the pulp chamber as they used pulp/tooth volume [11, 14, 15]

The current study observed that the regression models derived from pulp chamber/crown ratios using AIS software exhibited a higher coefficient of determination (0.764) compared to the coefficient of determination obtained from **Merdietio** (0.53). This disparity may be attributed to the utilization of different software programs, as Merdietio employed ITK-snap software, which employs a different segmentation technique [16]

CONCLUSION

From this study we can conclude that the prediction equations derived from the volume ratios using Mimics software had higher prediction ability than equations derived from the volume ratios using AIS software.

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