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Original communication

A new age estimation procedure based on the 3D CBCT study of the pulp cavity and hard tissues of the teeth for forensic purposes: A pilot study

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ABSTRACT

Background: Dental age of adults can be estimated by the analysis of the progressive physiological and degenerative phenomena which affect dental tissues. The pulp-dentinal complex is one of the dental structures that show modifications related to age, mainly resulting in the reduction of the pulp chamber volume due to the continual deposition of secondary dentin. The study aims to evaluate the accuracy of a simple and conservative method for estimating the age of adults based on CBCT (Cone Beam Computed Tomography) analysis of the narrowing of the pulp chamber caused by secondary dentin deposition.

Materials and methods: Two operators have randomly analyzed 148 CBCT (Scanora 3D – Soredex) and considered the upper left central incisor. The sample consists of 57 male individuals and 91 females aged between 10 and 80 years. This research was designed to simplify dental volume measurement through geometric approximation of the different parts of the tooth. The root and the pulp were assimilated to elliptical based cones and the crown to an elliptical based truncated cone and these volumes were calculated through measurements using Osirix® software (OnDemand 3D software CyberMed Inc.). The ratio between the pulp volume and the hard tissues volume (PHr) was assumed as a variable according to the following formula: PHr = V pulp/V ht. The proposed method based on geometric approximation of dental volumes was validated comparing volumes calculated using CBCT with physical measurements of real volumes of 3 teeth.

Results: The physical measurements revealed that the measurement procedures using CBCT produce a regular underestimation of real volumes, that ranges from 53% to 70%. Since the error occurs quite regularly both for pulp and for hard tissue volume, it tends to be eliminated when their ratio is considered. The PHr was statistically significant (p-value < 0.001) as a predictor for age estimation. The gender variable was not significantly correlated with age (p = 0.7694) and it was, therefore, excluded from the linear regression formula for age estimation: Age = −64.14 − 32.00*Ln PHr. The age cohorts between 30 to 59 years showed the highest accuracy in age prediction (residual errors 0.71, 2.88, and −5.86 years), whilst for other age cohorts the estimation error is similarly reported by applying other dental methods.

Conclusion: The outcomes of this pilot study show that the narrowing of the pulp chamber is a reliable parameter for estimating the age of adults, and that CBCT is an easy and conservative approach that allows accurate calculation of tooth volumes. The proposed approach based on geometric approximation of upper central incisor volumes measured by CBCT remarkably reduced the operating time in comparison to other more complex and expensive techniques. The validation procedure in which real volumes are compared with those calculated using CBCT supports the accuracy of the experimented approach and the good inter-examiner agreement (ICC 0.99) demonstrates that the method is highly reproducible.

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1. Introduction and aim of the research

Age estimation is adopted in forensic human identification and also in criminal and civil proceedings.[1] Dental data are considered a primary identifier in particularly for the victims of mass disasters or unidentified human remains. The methods for age assessment that rely on the development and modification of tooth structures are renowned for their validity and accuracy and many methods based on the analysis of regressive phenomena of dentition due to ageing have been previously described.[2,3]

The pulp-dentinal complex is one of the dental structures that show modifications related to age, mainly resulting in the reduction of the pulp chamber volume due to the continual deposition of secondary dentin by odontoblasts along the pulp chamber walls.[4] It is a lifelong process that begins at the end of dental calcification[5,6] and causes a progressive narrowing of the pulp chamber volume of all teeth, although the rate of such narrowing varies according to the different tooth positions and types. Secondary dentin deposition should thus be considered an uneven biological process.[4,7]

Quantification of the morphological changes in the pulp chamber walls and pulpal volumes typically requires destructive procedures such as the extraction and sectioning of the tooth, that are unemployable in living subjects and sometimes even in human remains or corpses for specific religious, cultural, or scientific reasons. Therefore, many conservative techniques for age estimation in living individuals have been introduced and most of them, such as 2D studies (e.g. common periapical X-rays, orthopantomogram [OPG]) and 3D studies (computed tomography [CT], micro-CT and cone beam CT), rely on radiological imaging of teeth.[8–14]

The goal of this pilot study was to evaluate the accuracy of a simple and conservative method for estimating the age of adults based on CBCT (Cone Beam Computed Tomography) analysis of the narrowing of the pulp chamber caused by secondary dentin deposition. The additional purposes of this study were: 1) to validate the proposed method through physical measurements of real volumes of teeth; 2) to determine if there is a correlation between dentinal deposition and progressive narrowing of the pulp chamber volume according to gender and age; 3) to develop a statistical model for easily estimating age in daily forensic practice; and 4) to compare the proposed approach to other similar radiographic methods used to estimate the age of adults.

2. Material and methods

2.1. Study sample

A total of 148 CBCTs were independently examined by two experienced forensic odontologists. The personal details of the patients were masked during the assessments. All 148 subjects were healthy and the CBCT scans had been previously taken by the same radiological technician using a Scanora 3D dental cone beam unit (Soredex, Tuusula, Finland) from a private radiology office located in northern Italy. The exposures were taken at 90 kV and 5–8 mA, field of view selection between 60 × 60 or 75 × 100, scanning time of 11–13 s.

The sample was composed of 57 males and 91 females of Caucasian origin who were divided into eight age cohorts ranging from 10 to 80 years old. The chronological age of the examined individuals was recorded in days (date of CBCT − date of birth) and years for study purposes.

2.2. Description of the method

In accordance with some previous studies,[8,15–20] the healthy upper left central incisor was chosen to evaluate pulp/tooth volume. Teeth with treatments, restorations, cavities, evident wear, or attrition were excluded from the study.

Since previously described methods for pulp volume calculation have been based on complex and time-consuming procedures[9,16,21] this research was designed to simplify dental volume measurement through geometric approximation of the different parts of the tooth. The root and the pulp were assimilated to elliptical based cones and the crown to an elliptical based truncated cone (Fig. 1). The volume of such solids was calculated by taking nine measurements (3 linear and 6 areas) on DICOM images using Osirix® software (OnDemand 3D software − CyberMed Inc, Seoul, South Korea):

The following measurements were taken for calculating the pulp and tooth volume (Figs. 2–4):

a) The maximum height of the pulp (hP) taken from the sagittal view of CBCT and measured from the root apex up to the roof of the pulp chamber
b) The height of the root (hR) taken from the root apex to the cementum–enamel junction (CEJ) on the sagittal view of CBCT. The height of the considered portion of the crown (hC) is then calculated as hP − hR
c) The elliptical area of the pulp measured at the level of its maximum extension into the crown (coronal view of CBCT). As base of the cone we considered the maximum extension of the pulp that can be simply found by running the coronal sections of CBCT. The roof of the pulp chamber and the maximum extension of the pulp are retrievable at different levels (crown, CEJ or root) during life so that it is impossible to establish the level at which such measurement has to be taken. Hence the operator is simply required to measure the maximum coronal area of the pulp detectable in the CBCT sections. Moreover two measurements of this area were calculated: the maximum and the minimum that were then averaged to reduce errors. The maximum area corresponds to the elliptical area that includes the points of maximum extension of the pulp, whilst the minimum area corresponds to the elliptical area that passes through the points of minimum extension of the pulp (Fig. 2).
d) The area (maximum and minimum) of the root section measured at CEJ level on coronal section of CBCT. The maximum area was the elliptical area that passes through the points of maximum extension of the root and the minimum was the elliptical area that includes the points of minimum extension of the root (Fig. 3).
e) The maximum and the minimum area of crown measured in the first CBCT coronal section (from apex to incisal edge) that displays no more pulp image (Fig. 4).

Every area (maximum and minimum) was measured twice and the average was then calculated in order to reduce errors. The radiological measurements (heights and areas) allow calculation of the volume of the different solids (two cones and one truncated cone with elliptical bases) provided in the adopted geometric approximation (Fig. 1). The volume of the dental crown above the pulp is not included in the calculation (Fig. 1).

The ratio between the pulp volume and the hard tissues volume (PHr) was assumed as a variable according to the following formula: $PHr = V\ pulp/V\ ht$.where $Vht = Vtot - V\ pulp$, V pulp is the volume of the pulp, Vht is the volume of dental hard tissues, and Vtot the total volume of the tooth. The PHr is the ratio between the aforementioned volumes.

According to previous researches which have compared the results from radiological images with the real volumes of natural teeth[10,19] direct measurements of the dental volumes were made in