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Evaluation of volumetric changes of teeth in a Brazilian population by using cone beam computed tomography

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ABSTRACT

The purpose of this study was to test the usefulness of some morphometric parameters of the teeth in 5 different age groups through images of Cone Beam CT. 118 upper central incisors clinically acquired of 60 women and 58 men aged between 22 and 70 years were selected. The hard tissue volume and the pulp cavity volume of each tooth was obtained and computed by the software DentalSlice® and the measures were assessed (pulp cavity volume, hard tissue volume, tooth volume and pulp cavity/tooth volume ratio). The pulp cavity volume and the pulp cavity/tooth volume ratio showed significant differences between age groups ($p < 0.001$). Linear regression analysis showed a coefficient of determination of 0.21 which suggests that there is a weak correlation between the pulp cavity/tooth volume ratio and age.

1. Introduction

The age estimation of cadavers and living individuals is one of the greatest contributions that Forensic Dentistry provides to the justice system.[1,2] The teeth are the hardest part of the skeleton, the changes experienced by them suffer little influence from external factors and they are also more resistant to burials, carbonizations, immersions and other elements, such as trauma, effects of putrefaction and time.[1–6]

The age estimation in adults is complex. In such cases, the previous methods based on changes from organic evolution can no longer be used and one should resort to the data related to the aging of the individual examined. At this stage, the individual variations are very large and the modifications that occur in individuals are less obvious and less characteristic than in previous stages.[2,4,5,7]

The pulp chamber and root canals, fairly large in young teeth that have just completed their growth, narrow considerably throughout the course of life, often coming to an almost complete obliteration, by deposition of secondary dentin.[7–12]

Since the pioneering work of Gustafson in 1950,[1] numerous studies have questioned the effectiveness of measurements in secondary dentine for age determination. It was found in one of the most extensive investigations made,[13] the formation of secondary dentine continued throughout life and happened in all internal walls of the tooth, it occurred independently of occlusal wear and its formation was faster in young individuals than in adults.

The studies to determine the amount of secondary dentin in adults are based on destructive methods, which use sections of teeth[1,12–15] and non-destructive methods, which use periapical radiography[3,8,9,16–18] and panoramic radiography.[7,10,19]

The destructive methods require that one or more teeth be destroyed and that some of them be prepared in microscopic sections, which is undesirable for cultural reasons and conservative

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needs as well as being unethical and impossible to be done in living subjects.[3,5,8,9,20]

In 1995, Kvaal et al.[17] described a non-destructive method for age estimation by linear measurement of pulp, tooth and root in six types of radiography of teeth in the same dentition and these showed significant influence on age. Since then, length, width and area measurements of the pulp cavity, obtained by X-rays have been widely used as a nondestructive method[3,11] and can be recognized with the indirect deposition of secondary dentin.[7–10,16–19]

Despite the favorable results, the issue of two-dimensional radiographic image of the pulp is discussed because it accumulates only horizontal and parallel aspects of the tooth, not representing, therefore, the complete three-dimensional morphological changes of pulp cavity.[2,11] Such limitation was settled with the clinical use of micro Computed Tomography (micro TC) and Cone Beam Computed Tomography (CBCT) which created new opportunities for obtaining accurate 3D teeth images with a small dose of radiation and in a non-invasive manner. From the initial three-dimensional images, it was possible to create multiplanar reformations through easy manipulation software.[2,20–22]

Vandervoort et al. (2004)[11] first investigate the potential of age estimation methods in various types of single rooted teeth using an X-ray micro CT. Nowadays, similar 3D digital tooth images may be generated by a micro CT or a Cone Beam CT to determine the pulp/tooth volume and correlate it to age.[2,5,20,23–26]

Given the significant changes in dental tissues with the aging process, we performed a three-dimensional study of the tooth at the Faculty of Dentistry of Pernambuco – Brazil, which aimed to calculate the pulp cavity volume, hard tissue volume and tooth volume (pulp cavity + hard tissue volumes) and the percentage of the ratio: pulp cavity/tooth volume in maxillary central incisors to evaluate possible differences related to the chronological age of the subjects through images of CBCT of a data bank.

2. Material and methods

This study was submitted to the University of Pernambuco's Ethics Committee and has been approved under protocol number 043/10. The examiner held a previous training session with 40 Cone Beam CT jaw scans, with at least one intact upper incisor and closed apex, to standardize and systematize the stages of the study and to verify that the methodology and instruments were appropriate. Later, a calibration was carried out by the examiner in order to ensure uniformity of interpretation, understanding and application of assessment criteria. The scans used in this study were included in the main investigation.

2.1. Selection of the sample

One hundred and eighteen maxillary central incisors of 72 Computed Tomography (CT) scans were selected for this study, 60 from female patients and 58 male from male patients, 57 maxillary right central incisors and 61 maxillary left central incisors, patients from 22 to 70 years of age, five age groups (Table 1). The sample was selected by analyzing maxillary CBCT scans present in i-CAT® Next Generation (Cone Beam 3-D Dental Imaging System – Imaging Sciences International, Hatfield, PA/USA) database, in a Radiology Center in Recife – Pernambuco – Brazil. The images were stored on optical media and visualized on i-CAT® software to assess the inclusion and exclusion criteria.

Table 1
Distribution of teeth examined by tooth type, age and gender.

Age	Female		Male		Total
	Tooth 11	Tooth 21	Tooth 11	Tooth 21	
22–30	6	6	7	6	25
31–40	6	7	6	4	23
41–50	5	7	5	8	25
51–60	6	7	5	7	25
61–70	6	4	5	5	20
TOTAL	29	31	28	30	118

2.2. Criteria for inclusion

Maxillary tomographies where the intact upper central incisors had closed apex.

2.3. Criteria for exclusion

Maxillary CBCT scans which had no upper central incisors, and maxillary central incisors that presented: images of periapical lesions, such as thickening apical periodontitis, bone sclerosis, osteolytic periapical image, diffuse periapical lesion; cortical solution of continuity suggesting fistulous processes; decrease in root length suggesting resorption or remodeling; solutions of continuity in any location, consistent with loss of substance or fracture; abfraction lesions, lower density image in the crown suggestive of caries, endodontic treatment, fixed orthodontic treatment, prosthesis, restorative treatment, changes in the shape, impaction and teeth with open apex were excluded from the samples.

2.4. Processing procedure of the tomographic images

The selected CT scans went through a sequence of procedures for the construction of the final three-dimensional image. Initially, they were exported to the Digital Imaging and Communication in Medicine format (DICOM), a unique system of digital archiving, which stores only the axial images. The conversion into DICOM file (extension.dcm) was performed by the software i-CAT®. The time required for this step was approximately 2 min.

2.5. Morphometric analysis

Subsequently, the DICOM data sets were imported into an open source 3D image construction software (i-CAT® Workstation) for the calculation of pulp chamber and tooth volumes. The imported contiguous axial slices were reconstructed with a size of element cubes (voxel-size) of 0.25 mm and were displayed as grayscale images where each value corresponds to pixel intensity. The software performs a mapping in grayscale density, identifying those pixels with values that are within a range of density (tooth tissue density), marking the outer contour of each slice (Fig. 1). For the segmentation of the inner contour, the ideal limit is visually evaluated and selected by the operator for each slice, resulting in the first identification of hard tissues and subsequently the pulp canal. After this step, the software DentalSlice® three-dimensionally resets the separated tissue by density image and automatically shows the volume in mm^3 (Fig. 2). The individualization process for each tooth took approximately 15 min. Only one technician operated the software at all stages of processing and reconstruction of CT images without the knowledge of age or gender of the patients being examined.

2.6. Statistical methods

Descriptive statistics and inferential statistical techniques were used in data analysis. The descriptive statistics techniques correspond to the utilization of absolute distributions, percentages and