HUMAN DENTAL AGE ESTIMATION BY CONE BEAM COMPUTED TOMOGRAPHY – AN IN VITRO STUDY

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Franziska Laura Fritsch (Praxis Dr. Höß & Kollegen, Maintal, Germany), Paul-Heyse-Straße 46, 60431 Frankfurt (Main), Germany, +49 152 33 54 30 97, fritsch_f@yahoo.de
Willershausen, Brita (University Medical Center Mainz, Department of Restorative Dentistry),
Gleissner, Christiane (University Medical Center Mainz, Department of Restorative Dentistry)

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Abstract

The formation of secondary dentine leads to an age-related decrease of the pulp cavity volume. Hence, the volume of the pulp cavity relative to the volume of its tooth could be useful for dental age estimation based on three-dimensional cone-beam computed tomography (CBCT) x-ray images. A sample of 69 single-rooted teeth from 26 patients aged 19-89 years was collected for this pilot study. The teeth had no caries or signs of restaurative dental treatment and showed unimpaired root apices. All teeth were scanned by a CBCT (Accuitomo, J. Morita, Kyoto, Japan) using an clearly defined experimental set up ensuring a uniform exposure setting, determined by pretrials. Using threshold segmentation, three methods for segmentation and volume measurement of enamel, dentine and pulp cavity were tested. Tooth and pulp volumes and volume ratios were calculated for the whole tooth, the root region and at four levels. The relationship between the volume ratios and age was determined by Pearson's correlation coefficient (r), the accuracy of age estimation by the determination coefficient R^2. The Wilcoxon sign rank test was employed to measure the intraobserver error of manual segmentation. From the three segmentation methods, the manual non-reconstructable method showed the highest coefficient of determination (R^2 = 0,663). There were no statistically significant intraobserver differences. From the specific volume ratios, the highest correlation was observed for the coronal third of the root (R^2 = 0,621). The results provide support for the use of tooth-pulp volume measurements from clinically acquired CBCT images for age estimation.

Introduction

Dental age estimation is a central topic of forensic science. Verification of the chronological age in living people is necessary mainly for forensic reasons when age is unknown or the accuracy of the given age is not verifiable. Usually, a non-invasive technique is employed. During dental development, an accurate age estimation is based on the comparison of the dental status with reference data. In adults, age can be estimated by using a combination of several criteria. One of them is the dental pulp cavity volume that decreases with age due to the formation of secondary dentine. For this reason, the volume of the pulp cavity in relation to the volume of its tooth could be useful for dental age estimation [Someda et al. 2009, Aboshi et al. 2010]. In vivo, the size of the dental pulp cavity can only be measured on x-rays. This study aimed to evaluate a method for dental age estimation based on three-dimensional cone-beam computed tomography (CBCT) x-ray images of extracted teeth.

Fig. 2 a: segmented enamel cap

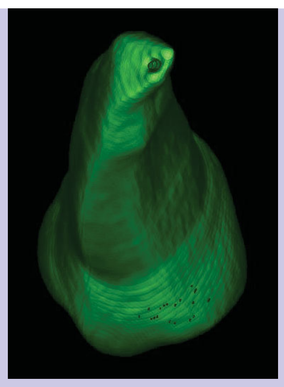


Fig. 2 b: segmented dentine

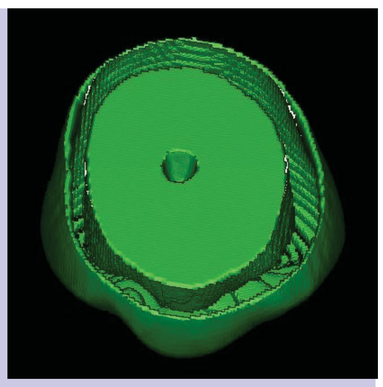


Fig. 2 c: segmented dentine, cross-section

Material and methods

Sample

- 69 extracted teeth of 26 patients, aged 12 to 89 years
- 43 incisives, 13 canines, 13 premolars
- single-rooted; no caries, no signs of restaurative dental treatment, unimpaired root apices (Table 1).

Scan

All teeth were scanned by a cone-beam CT (Accuitomo, J. Morita, Kyoto, Japan) using a clearly defined experimental set up ensuring a uniform exposure setting (64 kV, 8 mA, FOV 40 x 40 mm) that had been determined by pretrials. After alignment according to the tooth axis, the sliced image data was exported as DICOM-file and imported into the diagnosis and therapy planning software VoXim (IVS Technology GmbH, Chemnitz, Germany) which was used for segmentation and volume measurement.

Segmentation

Based on the sliced image data, three-dimensional structures were reconstructed and presented as grey scale images (range: -850 to +2250). Using threshold segmentation, the greyscale range for the segmentation of enamel (+2244 to +2250), the upper threshold for the segmentation of dentine (+2243) and the lower threshold needed to segment the pulp cavity (-850) were determined. Those values derived from the grey level presentation of the dental tissue and could be applied uniformly for all teeth. To separate the pulp cavity from dentine, no uniform grey level unit was available, therefore, three methods for segmentation were tested:

Method 1: segmentation by software default settings; uniform grey scale range (+350 to +2250);reproducible.
Method 2: segmentation by strictly defined manual procedure; reproducible.
Method 3: free manual segmentation; visually assessed for each tooth; non-reproducible.

Volume measurements and volume ratios

Tooth and pulp volumes were measured by voxelcounting and volume ratios were calculated for the whole tooth (W, WE*), the root region (R) and at four levels (PTVR1 - PTVR4) (Fig. 1). When dentine was segmented as described above, a small part of enamel at the outer border was always included (Fig. 2). Thus, the volume ratio WE after Someda et al. had to be modified (WE*).
For comparison of the 3 segmentation methods described above, the volumes of the whole tooth were measured and the ratio W was calculated.
For comparison of the different volume ratios, method 1 was used.
All measurements were made by the same examiner.

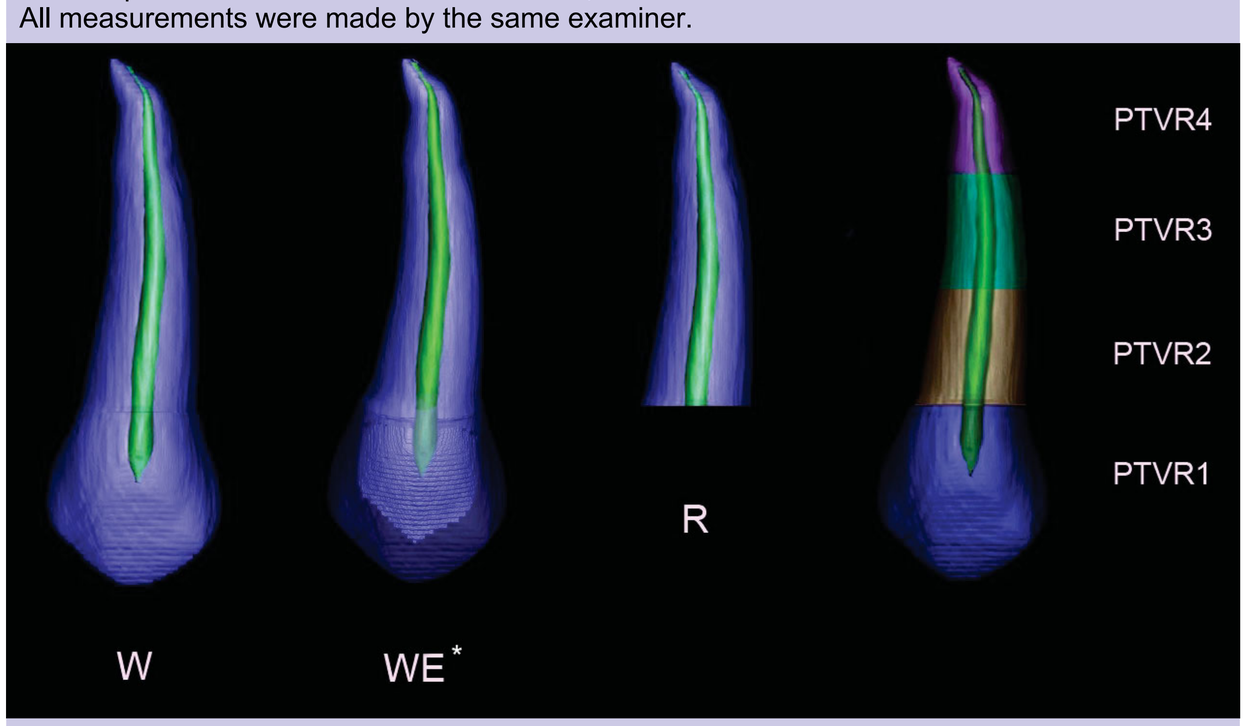


Fig. 1 Tooth and pulp volumes and volume ratios

The results presented in this poster are part of the doctoral thesis of Franziska Laura Fritsch.

Statistical analysis

The volume ratios of the teeth were averaged per patient.
The relationship between the volume ratios and age was determined by Pearson's correlation coefficient (r), the accuracy of age estimation by the determination coefficient R^2. The three methods for segmentation and the different volume ratios were compared by the determination coefficient R^2.
The Wilcoxon sign rank test was employed to measure the intraobserver error of manual segmentation (method 3).

Table 1: age (by 10-year age groups) and sex distribution of samples (patients)

Age (years)	10 - 19	20 - 29	30 - 39	40 - 49	50 - 59	60 - 69	70 - 79	80 - 89	all
male	2 (1)	0	3 (1)	1 (1)	10 (3)	10 (4)	5 (4)	8 (2)	39 (16)
female	2 (1)	0	0	11 (2)	8 (3)	0	6 (2)	3 (2)	30 (10)
all	4 (2)	0	3 (1)	12 (3)	18 (6)	10 (4)	11 (6)	11 (4)	69 (26)

Results

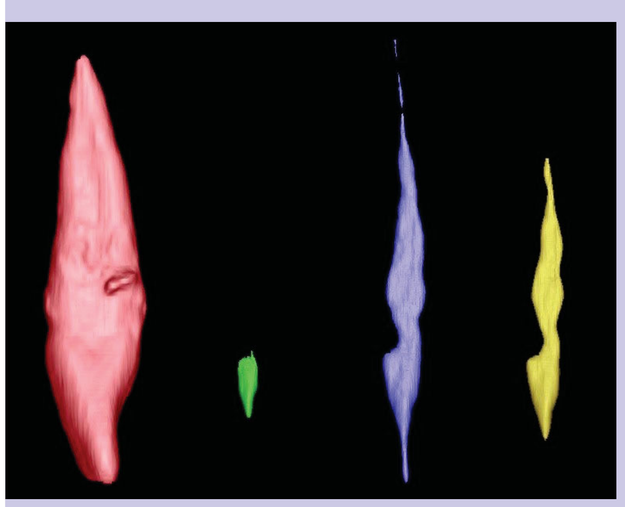
From the three segmentation methods, the manual non reconstructable method showed the highest correlation and coefficient of determination (Table 2).
There were no statistically significant intra-observer differences between the volume rations calculated from repeated measurements.
From the specific volume rations, the pulp/tooth ratio for the whole tooth when enamel was excluded (WE*) showed the highest accuracy for age estimation. From the volume ratios of tooth segments, the highest correlation was observed for the coronal third of the root (Table 3).
The registration of the pulp cavity by the three segmentation methods gave sometimes widely differing results for the same tooth (Fig. 3 and 4).

Table 2: Correlation of volume as calculated by the segmentation methods and age

Method no.	r	R^2
1	-0,756	0,571
2	-0,643	0,414
3	-0,794	0,630

Table 3: Correlation of volume ratios and age

Volume ratio	r	R^2
W	-0,756	0,571
WE*	-0,765	0,585
R	-0,750	0,562
PTVR1	-0,689	0,475
PTVR2	-0,788	0,621
PTVR3	-0,699	0,489
PTVR4	-0,707	0,500



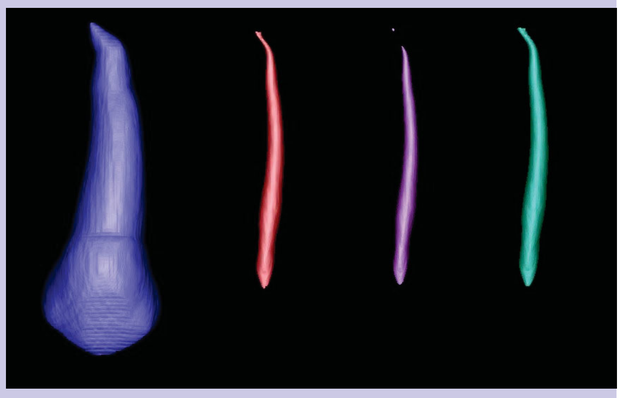


Fig. 3 and 4: 3-D-reconstruction of two teeth and their pulp cavities as registrated by the three segmentation methods

Conclusions

The results of this in vitro study using a clearly defined experimental design confirm those of other authors and provide support for the use of tooth-pulp measurements from clinically acquired CBCT images for age estimation.

References
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