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EFFECT OF CONE BEAM COMPUTED TOMOGRAPHY VOXEL SIZE IN VOLUME MEASUREMENT OF UPPER CANINE PREPARED PULP SPACE

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ABSTRACT

Objectives: the purpose of this research was to determine how various voxel sizes affected volume segmentation of the upper canine's pulp area.

Study design: in vitro study.

Materials and methods: Following endodontic preparation, CBCT images were taken for 20 maxillary canines. The gold standard was the actual physical volume of pulp spaces that had been produced. Three different voxel sizes of the CBCT were used to scan the teeth: (1) Endodontic mode (75 µm) (2) High- dose mode (150 µm), (3) Low- dose mode (400 µm). The prepared pulp area was evaluated using a semi-automated segmentation technique by the Materialise Mimics program.

Results: with the actual physical volume "gold standard," the endodontic mode (75 µm) had excellent agreement (95%), high dose mode (150 m) had admissible agreement (74%) whereas the mode of low dose (400 m) had unsatisfactory agreement (33%). These discrepancies were statistically significant.

Conclusions: The accuracy of the segmented volume decreased when the voxel size was increased during scanning.

INTRODUCTION

Depending on how the operator engages with the system, segmentation may either be carried out manually or with the help of a computer. In in-vivo research, manual segmentation is the gold standard since it is thought to be just as precise as direct measurements. The operator does it slice by slice, and the program then merges the split

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slices to produce a 3D volume. However, it was discovered that this process takes a lot of time and is not practical for clinical application. Therefore, the methodology of interest today is computer-aided approach involving both semi-automatic and fully automatic segmentation. [1]

One of the crucial factors affecting the volumetric assessment of 3D objects is voxel size. It was shown that when voxel sizes increased during scanning, the volume measurements of structures tended to be large than actual size. This might be attributable to dispersion and the partial-volume effect. [2]

Accuracy describes how close segmentation matches the ground truth. Since absolute true segmentations are generally not available in real scenarios, manual segmentations performed by experts are often used as a replacement for ground truth. [3]

The total volume may be estimated by adding the voxels together in a known volume. An approximation of the volume may also be calculated from the size and quantity of pixels as well as the section interval if many sections of the 3D region of interest are utilized at regular intervals. Fortunately, the most popular soft wares in the maxillofacial field include image segmentation. This is being used to the creation of 3D virtual objects which used for the planning of operations, the diagnosis and treatment, as well as other biomechanical tasks. [4, 5]

The discrepancy in volumetric measurement is often caused by parameter selection and CBCT scanning artifacts. The reconstructed visual picture and the real physical image will ultimately differ due to artifacts such beam-hardening artifacts, partial volume effects, "aliasing" artifacts, ring artifacts, and motion artifacts, as well as noise and scatter. [2]

Although the CBCT systems on the market vary in a number of technical aspects that impact spatial resolution, such as voxel size and field of view (FOV), CBCT pictures may also be utilized to create realistic teeth models for 3D printing. Anatomical detail may be obtained from CBCT acquisitions with voxels smaller than 0.1 mm, and narrower FOVs are related to better resolution. Therefore, the current study's objective is to assess how changing in voxel sizes affect the volume measurement of segmented prepared pulp space of upper canine.

MATERIALS AND METHODS

20 maxillary canines were chosen from the surgical clinic and the orthodontic clinic (faculty of dentistry, Minia University).Standard periapical radiographs were used for examination. Teeth were selected according to the following criteria: single straight root with no root caries, restorations, fracture, resorption or pulp calcification.

Then all teeth were disinfected for a week by soaking in a solution containing 0.1% thymol. Teeth were removed from the thymol solution 24 hours before the experiment, rinsed, and stored in distilled water.

Preparing teeth for endodontic

Each tooth had an access cavity created in it. The pulp chamber will be fully accessible after the roof has been entirely removed, and the canal is clearly visible. A size 10 K-file was used to measure the working length. When the file has passed through the apical foramen and is no longer visible, it is wound backwards, and the length is measured from a known landmark. The teeth will next be filed with hand tools up to size 20 to the working length, irrigating with sodium hypochlorite between each file. The root canals will next be prepared using ProTaper rotary equipment (Maillefer Dentsply, Baillagues, Switzerland)..

Volume measurement:

The imprint material was injected into each tooth using an injectable gun until the gap was completely filled. After that, extra imprint material was eliminated. After setting for at least five minutes, the imprint material was taken out.

Rapid Soft addition Silicone Impression Material (BMS Dental S.r.l. throygh M. Buonarroti, 21-23-25 z.lind. le 56033 Capannoli (Pisa) Italy) was used to quickly construct a copy. The replica's volume served as a representation of the prepared pulp space's physical volume (VP).

Water was poured into a 10-ml measuring cylinder with an accuracy of 0.1 ml and filled to the 5 ml mark at room temperature (23.51C). The measuring cylinder was fully submerged with the replica imprint. The new water level was recorded after the water displacement process. After obtaining the volume after submerging the replica in the water in the cylinder, the water`s volume that was displaced was estimated by subtraction of the volume [8].

Three readings were taken by three separate observers for each copy to ensure the smallest possible amount of inaccuracy.[9] The resulting average volume was used as the actual volume.

Phantom setup: Individual installations of five blocks of hefty silicon imprint putty, each with four teeth. To depict soft tissue (the head phantasm), the blocks were set in a 150 mm by 200 mm thin plastic cylinder filled with water. Planmeca Oy, Helsinki, Finland, installed the cylinder in the Promax 3D unit's chin rest. [10] Each tooth was imaged after endodontic preparation. The four teeth on the block were scanned with three different voxel sizes [11]: endodontic mode (75 m), high-dose mode (150 m), and low-dose mode (400 m), with the block being centered in the smallest field-of-view (FOV) (50mm x 50 mm).

The pulp space was subjected to volumetric analysis. To this end, each image formed of the (CBCT) was exported in the Digital Imaging and Communication on Medicine (DICOM) format. The DICOM data were imported into Mimics Research 21.0, a software developed by Materialise N.V. in June 2018 (Manufactured by: Materialise N.V., Technologielaan 15- 3001 Leuven, Belgium, L-10780-02 1992-2018), for further 3D calculations and analysis.

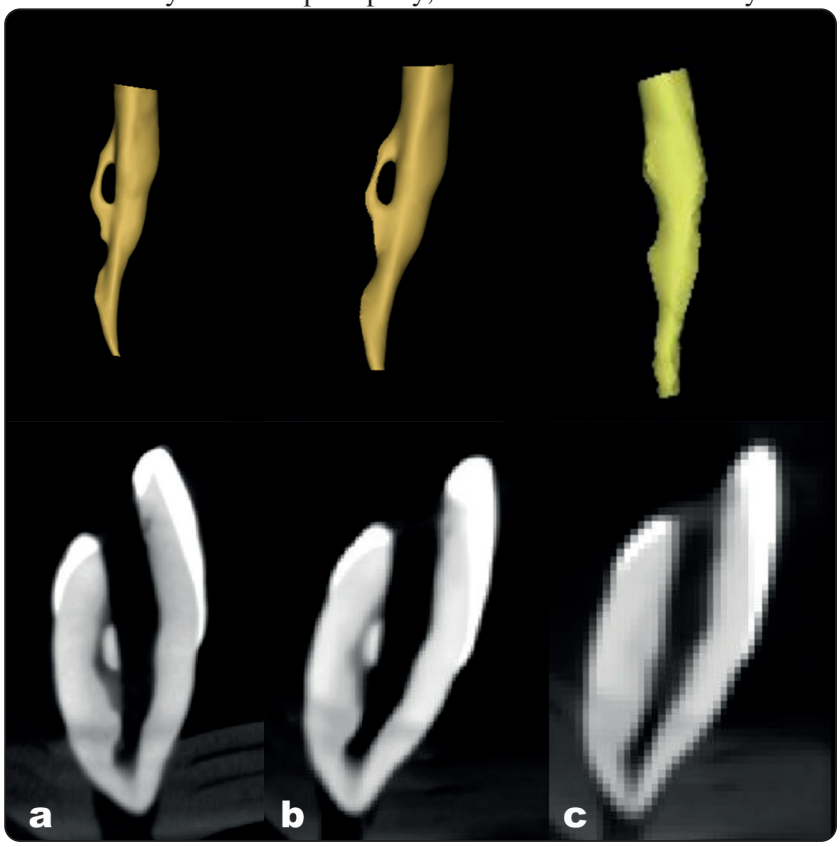

Fig. (1) Illustrates segmented prepared pulp space at 75, 150, and 400 microns, respectively.

By defining a gray scale threshold that took into account the diverse tooth structures' varying shades of gray, the endodontic prepared pulp spaces were separated and segmented semi-automatically. The pulp space's volumes (mm^3) were then automatically determined by the program. [12]

Statistical analysis

For the current experiment, 20 maxillary canines were acquired from an orthodontic and surgical clinic. The statistical analysis of the data was conducted using IBM SPSS Statistics, version 25. The statistical measures of mean and standard deviation were utilized to represent the numerical data. The reliability and agreement between classes were assessed using Cronbach's alpha, while the validity was confirmed through the utilization of the correlation coefficient test. The cocron R package was also used to test the equivalence of independent alpha coefficients at a 95% level of confidence. P-values of 0.05 or less were considered significant. Apply the statistical methods just to the table.

RESULT

The aforementioned table demonstrates that for assessing the actual volume "gold standard," the endodontic mode has strong positive "linear" correlation, the high dosage mode has moderate positive "linear" correlation, and the low dose mode has weak positive correlation. These variations are statistically noteworthy.

DISCUSSION

Assessment of the correctness of the virtual 3-D model created following segmentation when considering the potential of 3-D printed medical equipment as well as replicas as an upholding for clinical diagnosis, planning, and treatment. Simulated external resorption of dental roots scanned using voxel sizes of 0.40, 0.30, and 0.20 mm. Despite the fact which states that simpler at a lower voxel size of 0.30 or 0.20 mm, it has been found that the outcomes from the various voxel sizes were identical. [14] When completing a CBCT scan, the FOV is crucial. This decision affects the spatial and contrast resolution and has a direct correlation with voxel size [15]. Therefore, the Planmeca ProMax® 3D with the smallest field of view was used in the present experiment.

According to the findings, the endodontic mode has excellent agreement, the mode of high-dose has fair agreement, and the mode of low-dose have poor agreement. These differences are statistically significant, allowing one to compute the physical volume of space of the prepared pulp in the upper canines.

Our findings are in line with those of Hassan et al. (2010), who looked at the effect of voxel size on the quality of the 3D surface models of the dental arches created from CBCT and discovered that growing voxel size decreased the visibility of the occlusal surfaces and bone in the anterior region in both the upper and lower jaws [16]. However, our

TABLE (1): Accuracy between CBCT imaging at three different voxel sizes for the maxillary canines

Voxel size	Agreement	95 % CI	Sample size	Number of items	R	P - value
Endodontic mode (75 µm)	0.957	0.8914- 0.9830	20	2	0.92	0.006*
High-dose mode (150 µm)	0.740	0.3220- 0.8960	20	2	0.6	
Low-dose mode (400µm)	0.330	-0.6927- 0.7348	20	2	0.22	

N=20 *significant

findings differ from those of Sang et al. (2016), who found that voxel size had no impact on volume accuracy [17].

In addition, Ye et al. (2012) found that when voxel sizes increased during scanning, the volume measurements of teeth tended to be large than actual size. [12]

Additionally, Liang et al. (2010) discovered artifacts near the scan volume's edge that could significantly alter the image and affect the model's accuracy. These so-called "halation defects" resemble rings or streaks. In this investigation, we discovered that the laser scans' assessments of tooth volume were less than those obtained using CBCT scans. This outcome might be a consequence of the partial-volume effect's surface artifacts, which can disperse and function as a halation around the teeth [18].

We suggested that it would be possible to reduce voxel size as a result to diminish the surface surrounding artifact that affects segmentation accuracy.

CONCLUSION

The prepared pulp space of the upper canines was measured less precisely after a change in the voxel sizes used in cone beam computed tomography.

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