Cone beam computed tomography voxel sizes effect on volumetric analysis of prepared pulp space of maxillary centrals (in vitro study)

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Abstract:

Purpose: the aim of this study was to evaluate the effect of different voxel sizes in volumetric analysis of prepared pulp space segmentation. **Material and Methods:** 20 teeth were imaged after endodontic preparation. Physical volume of prepared pulp spaces were used as a golden standard. The teeth were imaged by using CBCT at two different voxel sizes: (1) High definition mode (150µm) and (2) low dose mode (400µm). Materialise Mimics software and a semi-automated segmentation method were used to segment prepared pulp space. **Results:** the high definition mode (150µm) has acceptable agreement (73%) while the low dose mode (400µm) has unacceptable agreement (21%) for assessing the physical volume "gold standard", and these differences are statistically significant. **Conclusions:** With increasing voxel sizes during scanning, there was decreasing in the accuracy of segmented volume measurements of maxillary centrals prepared pulp space.

Keywords: Cone beam computed tomography, volumetric analysis, maxillary centrals.

Introduction:

More recently, the use of CBCT in endodontic research has enabled 3D assessment of treatments performed within the root canal system. Recent guidelines published AAE/AAOMR Joint Position Statement 2015/2016 Update recommended that limited FOV CBCT should be the imaging modality of choice when evaluating the no healing of previous endodontic treatment to help determine the need for further treatment, such as nonsurgical, surgical or extraction. Moreover, limited FOV CBCT was suggested for nonsurgical retreatment to assess endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, and localization of perforations.(1)

CBCT units offer multiple fields of views (FOVs) and voxels that can better address a variety of specific tasks. Voxel size is of paramount importance in terms of image quality and scanning and reconstruction times of CBCT images. A "voxel" describes the smallest distinguishable box-shaped part of a 3-dimensional (3D) image. In CBCT imaging, voxels are usually isotropic and range from 0.4 mm to as small as 0.075 mm. (2)

Successful management of endodontic cases stems from a detailed understanding of the morphology of the root canal system. Adequate chemo- mechanical preparation and effective filling of the root canal system are based on knowledge of normal root canal morphology and variations from the norm obtained from studies of root and canal morphology. It is well established that the failure to treat all the canals effectively leads to poor endodontic outcomes (3).

Tooth segmentation is more challenging than bone structure segmentation for several reasons, such as the number of teeth per jaw, the proximity of adjacent tooth structures, the difference in density within a tooth (enamel, dentin, cementum, and pulp chamber), and tooth developmentIt is even more challenging to perform segmentation in CBCT images than in CT images.(4)

The segmentation accuracy of CT has already been studied extensively. In CT imaging, segmentation of objects or tissues is performed using thresholding based on prior knowledge of the density of the anatomic structure (Hounsfield units). Unfortunately, gray values cannot be used directly in a quantitative way in CBCT imaging. In addition, low-contrast segmentation in CBCT is hampered by higher image noise compared with CT. (5)

The assessment of segmentation should include all steps, starting from the accuracy of scanning to the segmentation procedure, the latter being a major step in creating accurate digital teeth to allow production of 3-D tooth models. However, to validate the accuracy of the resulting 3-D models, all steps must be taken into account. They include scanning, segmentation, and model fabrication, as previously validated and described by Shahbazian et al. (6)

Consequently, the current study aims to evaluate the effect of different voxel sizes in volumetric analysis of prepared pulp space segmentation.

Materials and methods:

Teeth selection:

Twenty maxillary centrals were collected from surgery clinic and orthodontic clinic. All specimens were being checked for number and curvature of root canals by conventional per-apical radiographs. Teeth with single straight canals will be chosen.

Exclusion criteria:

Teeth with caries extending to the root, restorations, pulp calcifications, root resorption or root fracture will be excluded.

Teeth preparation:

Debris and soft tissue remnants will be cleaned and teeth will be kept in 0.1% thymol solution for a week for disinfection. 24 hours before the experiment, teeth will retrieve from thymol solution, rinse, and store in distilled water.

Endodontic Preparation:

An access cavity was made in each tooth. Access will be completed when the roof of the pulp chamber will be completely removed and a DG16endodontic probe (DG-

16 Endodontic Explorer, Ash UK) could be placed in the pulp chamber and the canal was visible to the naked eye. (7)

The working length was measured by using a size 10 K-file. The file will pass through the apical foramen and then wound backwards when it will be no longer visible, the length will be recorded from a noted landmark. The teeth will be then prepared up to a size 20 file with hand instruments to the working length and will be irrigated with sodium hypochlorite after each file.. ProTaper rotary instruments (Maillefer Dentsply, Baillagues, Switzerland) will be then used to prepare the root canals. The Shaper 1 and Shaper 2 files will be used to the working length and the Finisher 1, Finisher 2, Finisher 3, Finisher 4 and Finisher 5 files will be used 1 mm short of the working length according to root canal size (7)

<u>Prepared pulp space Physical Volume Measurements:</u>

Impression material was mixed according to the manufacturer's instructions and injected into each tooth with a syringe until the space was completely filled. Excess impression material was then removed. The impression material was allowed to set for at least 5 min. and then removed from the space.

A replica was created using rapid soft silicone impression material (vinylight polysiloxane addition curing silicone (BMS dental s.r,l via M. Buonarroti,21-23-25 z .lind. le 56033 capannoli (pisa) Italy). The volume of the replica represented the physical volume (Vp) of the prepared pulp space.

A 10-ml measuring cylinder with an accuracy of 0.1ml was filled with water at room temperature (23.51C) to a 5 ml mark. The replica impression was completely immersed in the measuring cylinder. Following the water displacement technique, the new water level was recorded. The volume of the displaced water was then obtained by subtracting the initial water volume from the final volume obtained after immersing replica in the water in the cylinder (8)

To reduce error to an absolute minimum, three reading were made for each replica.

The volume of each replica was measured three times as described above by three independent observers (9) then; the average volume thus obtained was considered as the gold standard.

<u>Phantom preparation:</u>

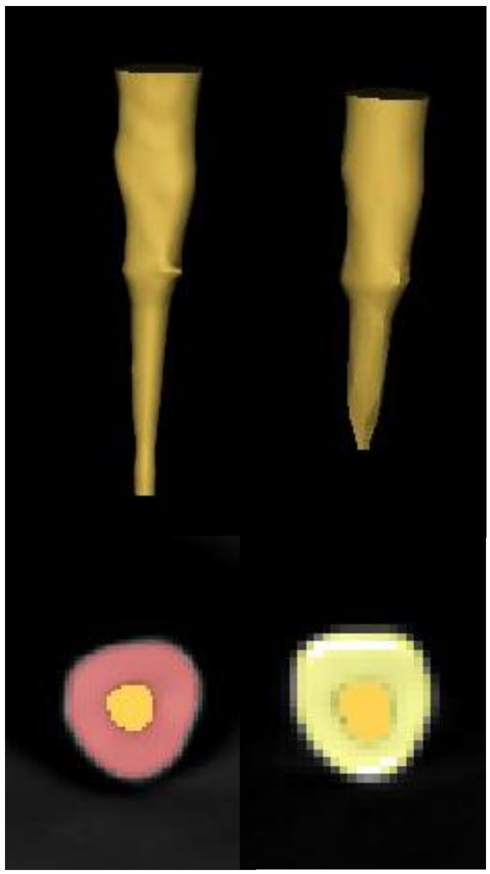
Each 4 teeth were mounted separately in a blocks that were made from silicon impression putty (five blocks). The blocks were placed in a fine plastic cylinder containing water (A 150-mm diameter x 200-mm tall water-filled plastic cylinder was used as the head phantom) to simulate soft tissue. The cylinder was placed on the chin rest of CBCT unit (Promax 3D unit (Planmeca Oy, Helsinki, Finland). (10**)**

<u>Image scanning:</u>

All teeth were imaged after endodontic preparation. The teeth were imaged by centering the block which contains four teeth in a smallest field-of-view (FOV). FOV (H × D) 50 × 50 mm Images will be obtained by using CBCT at two different voxel sizes (11): {1} High definition mode (150 µm) and {2} low dose mode (400µm).

Volumetric analysis of pulp space:

All the collected CBCT images were be exported in Digital Imaging and Communication on Medicine (DICOM) format. The DICOM files were imported to (Mimics Research 21.0,_Materialise N.V. Manufactured in June 2018 by: Materialise N.V. Technologielaan 15- 3001 Leuven, Belgium L - 10780-02 © 1992-2018), for further 3D analysis and calculations. Separation and segmentation of the involved prepared pulp spaces were semi - automatically performed by setting a grayscale threshold referring to the grayscale of the different tooth structure .The software then automatically calculated the volumes (mm3) of the pulp space. Three dimensional model of the prepared pulp space will be created in the form of STL file. (12)



(a) (b)

Figure (1): showing segmented prepared pulp space at (a) 150 µm (b) 400 µm

Statistical analysis

The present study was conducted on 20 upper centrals collected from surgery clinic and orthodontic clinic. Data was analyzed using IBM SPSS statistics version 25. Numerical data were expressed as mean and standard deviation. Correlation coefficient test was used to test the validity while "cronbach's alpha" was used to test the inter-class reliability and agreement. And for Testing the Equality of Independent Alpha Coefficients cocron R package was used, also used at 95% confidence level. P-value < 0.05 was considered significant.

Results:

Table (1): Accuracy between CBCT imaging at two different voxel sizes for the upper central teeth :

Voxel size	agreement	95 % CI	Sample size	Number of items	P-value
High definition mode (150 µm)	0.736	0.3330- 0.8955	20	2	0.012*
low dose mode (400µm)	0.218	0.9757- 0.6905	20	2	

*Significant

The above table shows that the high definition mode has acceptable agreement (73%) while the low dose mode has unacceptable agreement (21%) for assessing the physical volume "gold standard", and these differences are statistically significant.

Discussion

When looking at the future of 3-D printed medical tools and replicas as a support for clinical diagnosis, planning, and treatment, it is of utmost importance to assess the accuracy of the virtual 3-D model obtained after segmentation. Since the CBCT data sets can be obtained from different scanners or scanning protocols, the present study assessed the accuracy and robustness of the obtained virtual 3-D models (13)

The diagnostic ability of CBCT images appears to be influenced by voxel size. *Liedke et al 2008* investigated simulated external root resorption of tooth roots imaged with voxel sizes of 0.40, 0.30, and 0.20 mm. They concluded that the results from the different voxel sizes were the same even if diagnosis was easier at a smaller voxel size of 0.30 or 0.20 mm. (14)

The influence of FOV during CBCT scan is important. This selection is directly related to the voxel size and influences spatial and contrast resolution (15). So, in the present study, we used the Planmeca ProMax® 3D with smallest field-of-view (FOV).

Regarding to the agreement; the result showed that the high definition mode has acceptable agreement while the low dose mode has unacceptable agreement for assessing the physical volume of prepared pulp space of the upper centrals, and these differences are statistically significant.

Our result agrees with *Hassan et al 2010* who investigated the influence of voxel size on the quality of the 3D surface models of the dental arches from CBCT and found that large voxel size reduced the visibility of the occlusal surfaces and bone in the anterior region in both the maxilla and mandible (16)

But our result disagrees with *Sang et al 2016*.who Found that increasing voxel resolution from .30 to .15 mm did not result in increased accuracy of 3D tooth reconstruction (17)

In addition to *Ye et al 2012* discovered that the volume measurements of teeth tended to be larger with increasing voxel sizes during scanning. (12)

And, *Liang et al* 2010 found artifacts located near the periphery of the scan volume that might cause considerable image distortion and influence model accuracy. These “halation defects” have a streak-like or ring-like appearance. In this study, we found that the tooth volume measurements from the CBCT scans were larger than those from the laser scans. This result might be due to the surface surrounding artifacts that can be induced by the partial-volume effect and scatter, and act as a halation around the teeth (18)

That is why; we recommended that it is possible to decrease the voxel size to reduce the probabilities of surface surrounding artifact effect that losing segmentation accuracy.

Conclusion

With changing in voxel sizes of cone beam computed tomography, the volumetric analysis of prepared pulp space of maxillary centrals were affected as it will decrease the accuracy.

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