Accuracy of linear measurements from cone-beam computed tomography-derived surface models of different voxel sizes

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Introduction: The aims of this study were to determine the linear accuracy of 3-dimensional surface models derived from a commercially available cone-beam computed tomography (CBCT) dental imaging system and volumetric rendering software and to investigate the influence of voxel resolution on the linear accuracy of CBCT surface models.

Methods: Glass sphere markers were fixed on 10 dry mandibles. The mandibles were scanned with 0.40 and 0.25 voxel size resolutions in 3 sessions. Anatomic truth was established with 6 direct digital caliper measurements. The surface models were rendered by a volumetric rendering program, and the CBCT measurements were established as the mean of the 3 measurements.

Results: The intraclass correlation coefficients between the physical measurements and the measurements of the CBCT images of 0.40 and 0.25 voxels were all more than 0.99. All CBCT measurements were accurate. There was no difference between the accuracy of the measurements between the 0.40 and 0.25 voxel size groups. The smallest detectable differences of the CBCT measurements were minimal, confirming the accuracy of the CBCT measurement procedure.

Conclusions: The measurements on 3-dimensional surface models of 0.25 and 0.40 voxel size data sets made with the 3D eXam CBCT scanner (KaVo Dental GmbH, Bismarckring, Germany) and SimPlant Ortho Pro software (version 2.00, Materialise Dental, Leuven, Belgium) are accurate compared with direct caliper measurements. An increased voxel resolution did not result in greater accuracy of the surface model measurements.

Read the full text online at: www.ajodo.org, pages 16.e1-16.e6

EDITOR’S SUMMARY
We are receiving more submissions that use cone-beam computed tomography (CBCT). Many of them aim to assess the accuracy and reliability of CBCT with measurements on the axial, coronal, and sagittal slices, or on 3-dimensional (3D) iso-surface renderings. The results generally show that CBCT accurately represents the anatomy of our orthodontic patients to a clinically acceptable degree. However, another use of CBCT is to plan surgical treatment by simulating osteotomies and performing virtual bone movements. These applications require the construction of a surface model from the CBCT data. The surface model usually consists of a dense triangular mesh that approximates the bone’s surface and is automatically constructed from the voxel data, requiring only the input of a threshold value that specifies what is bone and what is not. Once constructed, the surface model can be used independently of the CBCT data. Because they require significantly less memory storage and can take advantage of today’s graphic processors’ capability to render triangles quickly, surface models are well suited for surgical simulations on personal computers.

These researchers aimed to assess the accuracy of surface models constructed from CBCT images. It is expected that a surface model would be more faithful to the original object when imaged with a small voxel size (high resolution), but this increases the radiation dosage. These authors tested 2 voxel sizes to determine whether the radiation dosage can be kept low without sacrificing accuracy.

The authors found that the larger voxel size resulted in equally accurate models. They used dry mandibles and glass markers, which allowed establishment of the “ground truth” by direct measurements. However, this methodology does not accurately reflect clinical application, because no soft tissues are in contact with bone, thus making bone surface easier to identify.
Turpin: You discussed the limitations of your study regarding the absence of soft tissues around the dry mandibles. Is this a major issue that might affect accuracy in the clinical setting, and are you planning future studies to address this problem?

Damstra: As we mentioned, the lack of soft tissues resulted in increased contrast of the landmarks; this influenced the threshold and segmentation process. In a recent commentary to a related article, Halazonetis explained how the midvalue between the densities of 2 materials is used as the threshold for segmentation. This is known as the “full width at half maximum” method. In our study, this method would indicate a threshold value equal to half the difference between the mandibles and air. However, in the clinical setting, mandibular hard tissues are in contact with the soft tissues. The threshold should be set higher at these levels because soft tissues are much denser than air. To overcome this problem, the threshold must be adjusted at a local level. Therefore, in the clinical setting, the segmentation process becomes critical and time-consuming when producing an accurate surface model. We are currently investigating the influence of soft tissues and segmentation on the accuracy of surface models. Further research will also focus on improving the consistency of tissue densities of CBCT scanners to improve accuracy during segmentation.

Turpin: The largest voxel size you tested was 0.4 mm. Could we accept even larger voxel sizes and further reduce the radiation dosage to patients?

Damstra: We tested the maximum preset voxel size of our CBCT scanner. Although a larger voxel size might reduce the radiation, it will also reduce the quality of the images and might influence the segmentation process. The risk of misdiagnosis of possible pathology must be weighed. Therefore, the largest voxel size we use now is 0.4 mm.

Turpin: Do you have any data on the related performance of other CBCT machines?

Damstra: A recent systematic review reported the radiation dose values and settings of various CBCT scanners used in imaging the oral and maxillofacial region. Future research will no doubt examine the difference in accuracy between various CBCT scanners and rendering software.

REFERENCES