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The effect of computed tomographic scanner parameters and 3-dimensional volume rendering techniques on the accuracy of linear, angular, and volumetric measurements of the mandible

Brian J. Whyms, BS,[a] Houri K. Vorperian, PhD,[b] Lindell R. Gentry, MD,[c] Eugene M. Schimek, MS,[a] Edward T. Bersu, PhD,[d] and Moo K. Chung, PhD[e]
University of Wisconsin-Madison, USA; University of Wisconsin Hospital and Clinics, University of Wisconsin-Madison, USA

Objectives. This study investigates the effect of scanning parameters on the accuracy of measurements from three-dimensional (3D), multi-detector computed tomography (MDCT) mandible renderings. A broader range of acceptable parameters can increase the availability of computed tomographic (CT) studies for retrospective analysis.
Study Design. Three human mandibles and a phantom object were scanned using 18 combinations of slice thickness, field of view (FOV), and reconstruction algorithm and 3 different threshold-based segmentations. Measurements of 3D computed tomography (3DCT) models and specimens were compared.
Results. Linear and angular measurements were accurate, irrespective of scanner parameters or rendering technique. Volume measurements were accurate with a slice thickness of 1.25 mm, but not 2.5 mm. Surface area measurements were consistently inflated.
Conclusions. Linear, angular, and volumetric measurements of mandible 3D MDCT models can be confidently obtained from a range of parameters and rendering techniques. Slice thickness is the primary factor affecting volume measurements. These findings should also apply to 3D rendering using cone-beam CT (CBCT). (Oral Surg Oral Med Oral Pathol Oral Radiol 2013;115:682-691)

Three-dimensional computed tomography (3DCT) is increasingly utilized in clinical and research settings to qualitatively and quantitatively characterize normal and abnormal anatomic structures. There has been an ever-growing need to perform 3DCT imaging of the mandible or maxilla with conventional multi-detector (MDCT) and cone-beam CT (CBCT) systems. The development of CBCT has significantly increased the clinical applications of 3D imaging because CBCT can be acquired outside the environment of a conventional MDCT imaging suite while offering lower patient radiation exposure. For example, 3D CBCT has been used to assess the changes in the mandible after orthognathic surgery for mandibular advancement or setback procedures,[1] to evaluate screw placement and fracture alignment during fracture reduction or orthognatic surgery,[2,3] and to develop clinical applications for dental[4,5] and craniofacial imaging.[6,7] Conventional MDCT continues to be routinely used in many institutions to evaluate patients with mandibulomaxillary trauma, sinonasal inflammatory disease, developmental conditions (e.g., midface and mandibular hypoplasia), and neoplastic conditions of the oral cavity, maxilla, and mandible.

Despite these documented 3D applications of conventional MDCT and CBCT, there has been no systematic assessment of the specific CT image-acquisition parameters[8] as well as the 3D reconstruction techniques[9] that provide the most accurate linear, angular, volumetric, and surface area measurements. Assessments of 3DCT renderings (MDCT and CBCT) using human body parts, bony remains, phantom objects, and anatomical models have consistently found linear measurements to be statistically accurate, irrespective of CT acquisition parameters.[10-20] A limited number of studies comparing CBCT and MDCT have focused on linear measurements, using

Statement of Clinical Relevance

Typically, 3DCT is retrospectively requested from scans performed for other purposes. This study details acceptable CT acquisition parameters for modeling of the mandible. Clinical relevance lies in confident treatment planning and monitoring while minimizing the need for patient rescanning.

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[a]Research Specialist, Waisman Center, University of Wisconsin-Madison.
[b]Senior Scientist, Waisman Center, University of Wisconsin-Madison.
[c]Professor, Department of Radiology, University of Wisconsin-Madison.
[d]Professor, Department of Neuroscience, University of Wisconsin-Madison.
[e]Associate Professor, Department of Biostatistics and Medical Informatics, University of Wisconsin-Madison.
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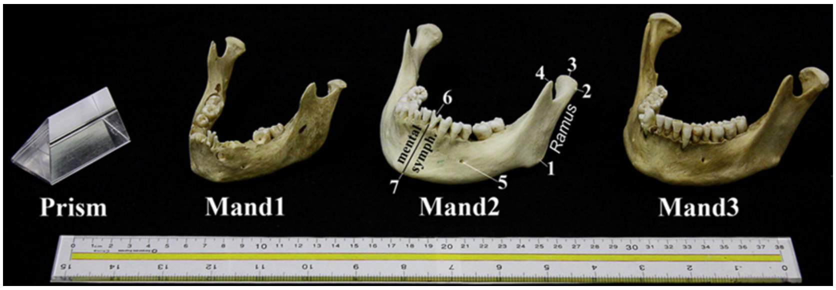

Fig. 1. Specimens scanned: glass prism, Mand1-child, Mand2-adult, and Mand3-adult. Mand2 is labeled to reflect anatomic landmarks listed in Table I: (1) gonion, (2) condyle lateral, (3) condyle superior, (4) coronoid process, (5) mental foramen, (6) dental border posterior-on lingual aspect, and (7) gnathion. The mental symphysis and ramus are also labeled.

mostly CT series with manufacturers' recommended scanning parameters.[9,18,21] Studies examining volumetric measurements are even rarer,[22] thus, there is a need to systematically extend assessment of scanner parameters and 3D rendering techniques to include angular, volumetric, and surface area measurements from 3D rendered models.

It is important to determine the scanner parameters and the 3D rendering techniques that yield a comprehensive set of accurate anatomic measurements to ensure optimal patient management. Such information will aid research efforts to collect and establish normative data of structures such as the mandible by tapping into rich databases of extant imaging studies acquired for different medical reasons. At present, such use of existing imaging studies in medical records is of questionable validity because the images were acquired using scanner parameters that may not be optimal for visualizing specific structures.

With the overall goal of broadening the application of CT studies to render 3DCT models for diagnostic and research purposes using extant imaging studies,[23-25] the purpose of this study is to assess the effect of varying MDCT scanner parameters to determine those acceptable for quantitative 3D modeling for preoperative and postoperative[16] planning, constructing accurate prosthetic material, recognizing treatment change with greater accuracy,[8,19,26,27] monitoring normal growth and development, and establishing normative data. More specifically, this study examines a range of CT scanner parameters typically used for oral treatment to determine the optimal MDCT, image-acquisition parameters and 3DCT rendering techniques for securing accurate linear, angular, volumetric, and surface area measurements of the mandible and are representative of anatomic truth (reference standard measurements).

MATERIALS AND METHODS

Materials

Figure 1 displays the 3 mandible specimens and the phantom object scanned in this study. The mandibles (1 child and 2 adults) were obtained from the Anatomy Department at the University of Wisconsin-Madison, where they had been dried and prepared. The phantom object [an acrylic prism made of a synthetic polymer (polymethyl 2-methylpropenoate)] had easily defined edges and was used to confirm methodology of landmarking and measuring the mandibles as described below.

Landmarks

Landmarks needed to define the various measurements were determined for both the mandibles (Figure 2) and the prism. The mandibular landmarks placed on the 3DCT rendered models are depicted as circular nodes (Figure 2, Table I). All linear and angular measurements, using the predetermined landmarks, are listed in Table II. The prism's landmarks were its clearly defined edges, corners, and planes. An experienced researcher placed all landmarks.

Reference standard measurements

Measurements representative of the anatomic reference standard (linear, angular, volume, and regional surface area) were obtained directly from the dry mandible specimens and the prism and compared with measurements from their respective 3DCT models (Table II). Using an electronic digital caliper with an LED display (KURT Precision Instruments, Minneapolis, MN, USA; resolution ± .01 mm) and a digital angle rule (GemRed, Guilin, Guangxi, China; ±.3° accuracy), the same researcher measured the dry mandibles and the prism on 3 different dates, each 1 week apart. The mean of the 3 measurements was used as the reference standard, against which all software-generated measurements from the 3D rendered models were compared (Table III).

Volumes of the mandibles and prism were established by 3 separate water displacement trials, in which each mandible was covered with a thin layer of an adhesive plastic sheet (to prevent water seepage into the alveolar bone and foramina and hence minimize the potential of underestimating water volume displaced on