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Evaluation of cone-beam computed tomography in the diagnosis of simulated small osseous defects in the mandibular condyle

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Introduction: In this study, we investigated the impact of defect size and scan voxel size on the accuracy of cone-beam computed tomography (CBCT) diagnoses of simulated condylar defects and assessed the value of orthodontic CBCT images typically scanned at lower settings (0.4-mm voxel size and full-size field of view) in diagnosing condylar erosion defects. **Methods:** Cylindrical holes simulating condylar defects with varied diameters (≤2, 2-3, and >3 mm) and depths (≤2 and >2 mm) were created in 22 fresh pig mandibular condyles, with defect number and size per condyle and quadrant randomly determined. With the soft tissues repositioned, 2 CBCT scans (voxel sizes, 0.4 and 0.2 mm) of the pig heads were obtained from an i-CAT unit (Imaging Science International, Hatfield, Pa). Reconstructed CBCT data were analyzed independently by 2 calibrated, blinded raters using Dolphin-3D (Dolphin Imaging and Management Solutions, Chatsworth, Calif) for defect identification and localization and defect diameter and depth measurements, which were compared with physical diagnoses obtained from polyvinyl siloxane impressions. **Results:** Identification and localization of simulated defects demonstrated moderate interrater reliability and excellent specificity and sensitivity, except for extremely small defects (both diameter and depth ≤2 mm) viewed with 0.4-mm scans, which had a significantly lower sensitivity (67.3%). Geometric measurements of simulated defects demonstrated good but not excellent interrater reliability and submillimeter inaccuracy for all defects. Receiver operating characteristic analyses demonstrated that the overall accuracy of diagnosing simulated condylar defects based on CBCT geometric measurements was fair and good for the 0.4-mm and 0.2-mm voxel-size scans, respectively. With the prevalence of condylar erosion defects in the patients considered, the positive predictive values of diagnoses based on 0.5-mm size (diameter or depth) cutoff points were near 15% and 50% for asymptomatic and symptomatic temporomandibular joints, respectively; the negative predictive values were near 95% and 90%, respectively. **Conclusions:** When using orthodontic CBCT images for diagnosing condylar osseous defects, extremely small (<2 mm) defects can be difficult to detect; caution is also needed for the diagnostic accuracy of positive diagnoses, especially those from asymptomatic temporomandibular joints. (Am J Orthod Dentofacial Orthop 2014;145:143-56)

Approximately 6% to 12% of the population in the United States suffers from symptoms of temporomandibular joint (TMJ) disorders, including pain, limited range of motion, joint sounds, or headaches.[1] Although osseous changes of the TMJ have been radiographically observed in 14% to 44% of these patients with 2-dimensional imaging, more accurate diagnosis is critical for understanding the pathophysiology and designing treatment plans for these TMJ disorders.[2] Clinicians typically use panoramic radiographs, cranial projections, and tomograms to radiographically assess the TMJ and its osseous components, but research has shown the limitations of these imaging modalities.[3] TMJ imaging is inherently difficult because of the small nature of its components and the indistinct image that frequently results from superimpositions with the cranial base.[4] Particularly, the commonly used panoramic radiography for orthodontic patients provides a cost-effective gross depiction of the entire TMJ and might be helpful for the identification of significantly altered bony anatomy of the condyle, but it cannot delineate relatively small osseous lesions at the condylar surface.[4-6]

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Cone-beam computed tomography (CBCT) has been used for routine orthodontic diagnosis and treatment planning by some orthodontists. This imaging tool brings practitioners new opportunities and responsibilities for better diagnosis of structures shown in the CBCT images, including the TMJ. Rendering 3-dimensional images with reduced cost and radiation compared with conventional computed tomography, CBCT was suggested in several recent studies to be a promising tool to diagnose osseous conditions of the TMJ.[7-10] More specifically, Honda et al[11] demonstrated that CBCT can be used to assess osseous abnormalities of the mandibular condyle, and Katakami et al[12] confirmed that CBCT images can accurately depict large erosive changes of the cortical bone of the condyle. Based on the analysis of simulated spherical lesions in dry human mandibular condyles, Marques et al[13] concluded that overall, CBCT is an accurate method for evaluating condylar lesions, with greater difficulty associated with smaller simulated lesions. On the other hand, Librizzi et al[14] recently reported that the diagnostic efficacy for small erosive condylar changes deteriorates with increases of the field of view and the voxel size of the CBCT scans.

A sound radiographic tool for the diagnosis of condylar osseous lesions must be reasonably reliable and accurate, first in a qualitative aspect for the identification and localization of defects, and then in a quantitative aspect for the measurements of defect dimensions. No previous study, however, has systematically examined both aspects. For example, Marques et al[13] only evaluated the qualitative aspect using condylar specimens without overlying soft tissues; this differs from the situation of clinical patients and tends to introduce errors in CBCT diagnosis.[15] It remains to be investigated how accurately one can measure the size of defects from CBCT images, and how one can determine that a suspected defect is a true defect based on quantitative CBCT measurements of the suspected defect. Conceivably, answers to these questions are important for clinical selection of imaging tools, such as CBCT, especially when condylar osseous defects are suspected. More importantly, for orthodontists using CBCT images instead of conventional panoramic and cephalometric films for diagnosis and treatment planning, the images were often obtained at a lower setting (typically 0.4-mm voxel size and full-size field of view) than those used for the diagnosis of pathology. Whether orthodontic CBCT images provide adequate accuracy for diagnosing condylar defects is currently unknown.

The purpose of this study was to address these questions. Specifically, by simulating osseous defects of varied sizes on pig condyles, which were subsequently scanned under common clinical settings and analyzed by blinded raters, we investigated the impact of defect sizes and scan voxel sizes on qualitative (defect identification and localization) and quantitative (defect size measurements) diagnoses. We hypothesized that the sensitivity of qualitative diagnoses and the accuracy of quantitative diagnoses would increase with larger defect sizes and higher CBCT scan resolutions. Then, in a clinically relevant manner, we assessed the value of orthodontic CBCT images in the diagnosis of mandibular condylar erosion defects.

MATERIAL AND METHODS

Eleven 3-month-old fresh nonembalmed pig cadaver heads, having a total of 22 condyles (4 quadrants per condyle), were collected from a university animal laboratory immediately after the pigs were killed. Before that, all pigs had received an endoscopic abdominal operation as part of a surgical training program, which was neither a component of nor a disturbance to our study. After making a skin incision around the TMJ area, the subcutaneous soft tissues were dissected to expose the mandibular condyles. The soft-tissue attachments medial to the condyle were then severed; this allowed moving the entire condylar head laterally out of the fossa to be fully exposed. No tissue was removed during these procedures. The articular surface of each mandibular condyle was divided into 4 quadrants (demarcated by grooves with glued gutta percha markers) (Fig 1, *A*). After excluding 8 quadrants with natural defects (cracks or grooves macroscopically visible on the condylar surface), 80 quadrants were used for defect creation and subsequent analysis. Cylindrical holes simulating condylar defects of 3 diameters (≤2, 2-3, and >3 mm) and 2 depths (≤2 and >2 mm) were created using a dental hand piece and carbide burs (Volvere VMax; Brasseler USA, Savannah, Ga). The mean and range of the actual defect size for each level were obtained from physical measurements of polyvinyl siloxane impressions (detailed below) by 2 raters (A.P. and E.J.). After the defects were created, the condyle was returned to the fossa, and the soft tissue overlying the condyle was repositioned for subsequent CBCT scans.

A prestudy power analysis was conducted based on a hypothesis that the sensitivity of CBCT defect detection would improve from 50% for the smallest defects to 100% for the largest defects; therefore, we determined that a minimum of 16 sites for each defect size was required to reach 90% power. With 2 study sites in each condylar quadrant (Fig 1, *A*), the number (0, 1, or 2) and the size of the defects were assigned to each quadrant according to a random number table. A negative control site received no defect assignment.