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Comparison of cone-beam computed tomography with multislice computed tomography in detection of small osseous condylar defects

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Introduction: Previous studies have indicated that orthodontic-grade cone-beam computed tomography (CBCT) images are limited when displaying small defects at the mandibular condyles for diagnosis. In this study, we investigated whether this limitation was inherent to CBCT by comparing CBCT with multislice computed tomography (CT), and whether image segmentation and color mapping could overcome this limitation. **Methods:** Nine fresh pig heads (18 condyles, 36 medial and lateral condylar regions) were used. Small osseous defects (diameter and depth, 1.5 mm) were created at the medial and lateral regions of the condyles shown by gutta percha markers. After the overlying soft tissues were restored, the pig heads underwent orthodontic-grade CBCT scans (0.4-mm voxel size; i-CAT; Imaging Sciences International, Hatfield, Pa) and medical-grade CT scans (0.625-mm voxel size; LightSpeed; GE, Little Chalfont, Buckinghamshire, United Kingdom). Subsequently, 2 calibrated and blinded raters diagnosed the defect numbers in each condylar region from CBCT and CT images using Dolphin 3D software (Patterson Supply, St Paul, Minn) without image segmentation, and then 1 week later with the proprietary image segmentation and color mapping tools of Dolphin 3D. Condylar polyvinyl siloxane impressions were collected and evaluated by the same raters to obtain physical diagnoses. Rediagnoses were made on randomly selected subsamples to assess reliability. Using the physical diagnoses as references, the accuracy of imaging diagnosis was assessed and statistically compared among the varied imaging and analysis methods. **Results:** Image diagnoses of all imaging and analysis methods showed good or excellent intrarater and interrater reliability values, except for those of the segmented CBCT images, which were substantially lower. The numbers of overdiagnoses and underdiagnoses per condylar region were not significantly different among the varied imaging and analysis methods (Wilcoxon tests, $P > 0.05$), but classification functions demonstrated substantially lower sensitivity and accuracy with CBCT than with CT. Logistic regression also showed that CT had a significantly higher probability (odds ratio, 2.4) than CBCT in reaching the correct diagnosis, whereas use of the image segmentation and color mapping tool proprietary to Dolphin 3D did not improve the diagnostic accuracy from CBCT images. **Conclusions:** Even at a lower voxel size than medical CT images, orthodontic-grade CBCT images of mandibular condyles may be inherently less reliable and less accurate for the diagnosis of small condylar defects. (Am J Orthod Dentofacial Orthop 2016;150:130-9)

Evaluation of temporomandibular joint (TMJ) structure and function is an important component of orthodontic diagnosis and treatment planning. Overall, the prevalence of temporomandibular dysfunction in orthodontic patients does not differ significantly from that in the general population,[1] which has been reported by several studies to be in a range of 30% to 70%.[2-5] For decades, mainly 2-dimensional (2D) imaging tools such as panoramic radiographs, cranial projections, and tomograms have been used to assess osseous structures of the TMJ; they showed that osseous changes can occur in 14% to 44% of patients with temporomandibular disorder symptoms or signs.[6] These

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tools, however, are inherently limited in displaying the contours of the condyle and articular fossa, thus making diagnoses of pathologies such as osteophytes and erosions difficult and unreliable.[7] Compared with 2D imaging tools, multislice computed tomography (CT) of the TMJ has significantly improved image quality to accurately display osseous changes of the TMJ affected by pathologies.[7] Although representing a significant advance in TMJ imaging, CT is not suitable for common use in orthodontics because of the high radiation dose and financial burden associated with it.[8] As an alternative 3-dimensional (3D) imaging tool, cone-beam CT (CBCT) has become increasingly popular in orthodontics in recent years.[9] In addition to displaying the structures needed for routine orthodontic diagnosis and treatment planning, full field-of-view (FOV) CBCT images, which often also include the TMJ, make it possible to evaluate TMJ skeletal components without additional radiographs. The accuracy and reliability of CBCT for diagnosing osseous pathologies of the TMJ, however, greatly depends on the size of the pathology, the settings of the scan, and even the machine used.[10] More specifically, whereas large osseous abnormalities can be accurately displayed and diagnosed by CBCT,[11,12] small erosive defects, which may indicate early-stage osseous changes,[13,14] are significantly more difficult to diagnose.[15,16] This is especially the case when large FOV or large voxel-size CBCT scans are used.[16,17] Patel et al[18] further demonstrated that for CBCT images of common scan settings (0.4-mm voxel size, full-size FOV), a third of defects smaller than 2 mm can be overlooked.

These findings raise 2 questions. One was whether the difficulty involved in diagnosing small condylar osseous defects was a problem inherent to a relatively large voxel size or to the CBCT visual diagnostic technique. If it were the former, multislice CT images scanned with similar voxel sizes would show the same level of inaccuracy as orthodontic-grade CBCT images in detecting small condylar defects (<2 mm). A number of recent studies have compared CBCT with CT and found that these imaging tools had a similar ability in diagnosing condylar defects.[8,9,11,19-21] However, these previous studies have either omitted the soft tissue factor or focused on relatively large defects (5-10 mm). Thus, whether small defects can be detected with the same reliability and accuracy between CBCT and CT has yet to be investigated. The other question is whether the inaccuracy involved in diagnosing small condylar defects from CBCT images can be improved by changing the analysis methods, such as using image segmentation based on gray levels and visual enhancement through color mapping. These tools are often provided by image-analysis software programs, and image segmentation has also been used before by others to assess condylar morphologic changes and resorption.[22,23] Answers to these questions are important for making clinical decisions regarding the choices of radiographic tools for certain orthodontic patients. An example scenario is when a new patient comes for orthodontic treatment and reports frequent pain in the TMJ area. Should the practitioner prescribe a single large-FOV, large-voxel-size CBCT for both orthodontic treatment planning and diagnosis of the TMJ? Or should conventional 2D radiographs be prescribed for orthodontic treatment planning, and should small-FOV, small-voxel-size CBCT, or even CT be prescribed for diagnosis of the TMJ?

Therefore, the purpose of this study was to address these 2 main questions. Based on findings from previous studies on large condylar defects,[14-16] we hypothesized that (1) the diagnostic ability of detecting condylar osseous defects would not be statistically different between orthodontic-grade CBCT images and medical-grade CT images scanned with clinically large FOVs and voxel sizes,[11,21] and (2) the diagnostic ability of condylar osseous defects from CBCT images would be improved by using global segmentation and color mapping.

MATERIAL AND METHODS

Nine cadaver heads from 4- to 6-month-old pigs were used in this study; they were collected from the Ohio State University Laboratory Animal Resources immediately after the animals were killed. Each condyle was dissected to expose the condylar head with care to preserve the soft tissue attachment. Then the condyles were demarcated into medial and lateral regions by small gutta percha pieces that were glued to the medial, lateral, and posterior sections of the condyle. Overall, 36 medial and lateral condylar regions were created. Before defect creation, the mandibular condyles were examined for existing defects. If any defects were found, the condyle was discarded and a replacement condyle was used. After confirming the intactness of the condyle, an operator (Z.S.) created small osseous defects in each medial or lateral region using a dental handpiece (NSK, Volvere Vmax; Brasseler USA, Savannah, Ga) with an end-cutting, 1.5-mm round bur. The drilling was stopped immediately after the bur was completely submerged into the bone, creating round defects of approximately 1.5 mm in diameter and depth. The number of defects in each region of each animal was predetermined using a random table and printed on a chart for defect creation.