Abstract: We compared the diagnostic reliability of 3.0-T magnetic resonance imaging (MRI) for detection of osseous abnormalities of the temporomandibular joint (TMJ) with that of the gold standard, cone-beam computed tomography (CBCT). Fifty-six TMJs were imaged with CBCT and MRI, and images of condyles and fossae were independently assessed for the presence of osseous abnormalities. The accuracy, sensitivity, and specificity of 3.0-T MRI were 0.88, 1.0, and 0.73, respectively, in condyle evaluation and 0.91, 0.75, and 0.95 in fossa evaluation. The McNemar test showed no significant difference ($P > 0.05$) between MRI and CBCT in the evaluation of osseous abnormalities in condyles and fossae. The present results indicate that 3.0-T MRI is equal to CBCT in the diagnostic evaluation of osseous abnormalities of the mandibular condyle.

Keywords: cone-beam computed tomography; magnetic resonance imaging; temporomandibular joint (TMJ).

Introduction

Imaging methods such as plain radiography, arthrography, magnetic resonance imaging (MRI), computed tomography (CT), cone-beam CT (CBCT), and arthroscopy are used for diagnostic evaluation of the temporomandibular joint (TMJ). After screening examinations, CT and CBCT are used in clinical practice for assessing the structure of small bones in the oral and maxillofacial region. Limited-field-of-view (FOV) CBCT is frequently used to evaluate small structures such as teeth, and clinical and experimental studies have shown the benefits of CT and CBCT for oral maxillofacial diagnosis (1-5). These two modalities differ in visualization of soft tissue, FOV, resolution, radiation dose, and cost (1). In an analysis of CBCT benefits, Matsumoto et al. (6,7) concluded that limited-FOV CBCT benefits patients by reducing the radiation dose and that it is one of the most reliable modalities for assessing TMJ bone morphology.

MRI has been used to evaluate the disk, joint cavity, and bone in the TMJ. The details of hard and soft tissues in the TMJ are clearly visualized on MRI. Several studies have described the importance of MRI in TMJ management (8-11). In Japan, 3.0-T MRI has been used clinically since 2003; however, few hospitals have used 3.0-T MRI for TMJ diagnosis, and 0.5-1.5-T MRI devices are still widely used in routine clinical practice. Although the
advantages of 3.0-T MRI are well-known (e.g., high signal-to-noise ratio), the practical benefits of 3.0-T MRI for evaluating TMJ structures have not been comprehensively studied. Schmid-Schwap et al. (12) reported that perceptibility of the TMJ disk was better with a 3.0-T system than with a 1.5-T system when determining disk shape and position. However, no studies have compared the performance of 3.0-T MRI for evaluation of TMJ bone morphology. In this study, we compared the diagnostic reliability of 3.0-T MRI and CBCT—the gold standard—in detecting osseous abnormalities of the TMJ.

**Materials and Methods**

**Participants**
The subjects were 28 patients (56 joints; 10 men, 18 women; mean age 39.3 years) who underwent both MRI and CBCT examinations of the TMJ for clinical purposes (Table 1). The exclusion criteria were history of facial trauma, luxation, fracture, ankylosis, neoplasm, growth abnormality, TMJ surgery, systemic arthritides (rheumatoid arthritis, psoriatic arthritis, or gout), and contraindications for MRI. This study was approved by the Ethical Committee of Nihon University School of Dentistry (EP2008-24, EP16D009) and was performed in accordance with the Helsinki Declaration. Written informed consent was obtained from all participants.

**CBCT apparatus**
CBCT images were obtained by using a 3D Accu-I-tomo FPD 8 device (Morita Co., Kyoto, Japan). The imaging parameters were a tube voltage of 70 kV, a tube current of 9 mA, and an FOV diameter and height of 4 cm each. Modified sagittal images (slice thickness, 1 mm; sliced with the short axis parallel to the condyle) were obtained by multiplanar reconstruction and sent to an image archiving and communication system.

**3.0-T MRI apparatus**
MR images were obtained by using a Magnetom Verio 3.0-T device (Siemens AG, Munich, Germany) with a head coil. The imaging conditions were a matrix size of 256 × 256 and an FOV of 13 × 13 cm. Proton density-weighted images in both closed and open mouth positions were obtained as modified sagittal slices (parallel to the short axis of the condyle). All images were constructed with a slice thickness of 2.5 mm.

**Study protocol**
Oblique sagittal 3.0-T MRI proton density-weighted images of the 56 TMJs were independently assessed for abnormalities of the condyles and fossae, including erosion, osteophyte formation, sclerosis, and flattening, by two oral and maxillofacial radiologists (K.H. and T.A.). The observers examined the MR images in closed and open mouth positions for osseous abnormalities. Evaluation of oblique sagittal CBCT images was performed on another day by the same observers. Images obtained by one modality were interpreted without knowledge of the findings for images obtained with the other modality. The findings from the two imaging techniques were tabulated to show points of agreement and disagreement between them. Finally, the presence of osseous abnormalities in the condyles and fossae on each modality were noted and analyzed statistically.

**Statistical analysis**
For each modality, sensitivity, specificity, and accuracy for detection and assessment of osseous abnormalities of the TMJ were calculated for the condyles and fossae. The 3.0-T MRI and CBCT assessments of condyles and fossae were compared by using the McNemar test. A P value of less than 0.05 was considered to indicate statistical significance.

**Results**
MRI showed a normal mandibular condyle in 19 TMJs and osseous abnormalities in 37 TMJs, whereas CBCT showed a normal mandibular condyle in 30 TMJs and osseous abnormalities in 26 TMJs. MRI indicated normal mandibular fossae in 46 joints and osseous abnormalities in 10 joints, while CBCT showed normal mandibular fossae in 44 joints and osseous abnormalities in 12 joints. Table 2 shows the presence of osseous abnormalities in condyles and fossae on MRI and CBCT.

In the detection of osseous abnormalities, the accu-
The accuracy, sensitivity, and specificity of 3.0-T MRI were 0.88, 1.0, and 0.73, respectively, for mandibular condyle evaluation and 0.91, 0.75, and 0.95 for mandibular fossa evaluation (Table 3). Representative CBCT and MR images of patients are shown in Figs. 1-4. The McNemar test showed no significant difference (P > 0.05) between MRI and CBCT in the evaluation of osseous abnormalities in condyles and fossae.

**Table 3** Diagnostic reliability of 3.0-T MRI

<table>
<thead>
<tr>
<th>Examination</th>
<th>True-positive</th>
<th>True-negative</th>
<th>False-positive</th>
<th>False-negative</th>
<th>Accuracy</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandibular condyle</td>
<td>30</td>
<td>19</td>
<td>7</td>
<td>0</td>
<td>0.88</td>
<td>1</td>
<td>0.73</td>
</tr>
<tr>
<td>Mandibular fossa</td>
<td>9</td>
<td>42</td>
<td>2</td>
<td>3</td>
<td>0.91</td>
<td>0.75</td>
<td>0.95</td>
</tr>
</tbody>
</table>

**Fig. 1** Modified sagittal CBCT (a) and 3.0-T MR (b) images from a 34-year-old woman who presented with a chief complaint of moderate pain in the left TMJ. Normal bone structure is indicated by the absence of cortical erosion, osteophyte, sclerosis, and flattening. Both CBCT and 3.0-T MRI show normal mandibular condyles and fossae. The observers determined that 3.0-T MRI yielded true-negative results for the mandibular condyle and fossa.

**Fig. 2** Modified sagittal CBCT (a) and 3.0-T MR (b) images from a 64-year-old woman who presented with chief complaints of severe pain in the left TMJ and trismus. CBCT and 3.0-T MR images show osseous abnormalities in the mandibular condyle and fossae. This was classified as a true-positive 3.0-T MR image of the mandibular condyle and fossa.

**Fig. 3** Modified sagittal CBCT (a) and 3.0-T MR (b) images from a 46-year-old woman who presented with a chief complaint of trismus. CBCT and 3.0-T MR images show osseous abnormalities in the mandibular condyle; 3.0-T MRI yielded true-positive results for the mandibular condyle. CBCT shows a normal mandibular fossa, while 3.0-T MRI shows osseous abnormalities of the mandibular fossa. This was considered a false-positive result for the mandibular fossa.

**Fig. 4** Modified sagittal CBCT (a) and 3.0-T MR (b) images from a 36-year-old woman who presented with a chief complaint of moderate pain in the right TMJ. CBCT shows a normal mandibular condyle, while 3.0-T MRI shows osseous abnormalities of the mandibular condyle. This demonstrates that 3.0-T MRI can produce false-positive results for the mandibular condyle. Both CBCT and 3.0-T MRI show that the mandibular fossa was normal; 3.0-T MRI yielded true-negative results for the mandibular fossa.

**Discussion**

After toothache, temporomandibular disorders (TMD) are the most common cause of orofacial pain (13). Symptoms of TMD are pain, joint noise, and disturbance of jaw movement, and TMD are often accompanied by cervical and neck muscle pain and headache (13). Internal derangement of the TMJ is defined as abnormal positioning of the articular disk relative to TMJ components and is the most common TMD pathology. MRI can noninvasively identify the position of the articular disk.
and has been the standard modality for detailed imaging diagnosis in patients with internal derangement of the TMJ. Chronic internal derangements frequently result in osteoarthritis or degenerative changes (1). Imaging diagnosis of TMD patients contributes to disease staging, and monitoring changes in the components over time is important in TMD management.

After the development of CBCT, in 2000, numerous clinical studies investigated the TMJ (1-7). Honda et al. (14) compared the accuracy of CBCT and helical CT in diagnosing osseous changes of the condyles and reported sensitivities of 0.80 and 0.70, respectively, for condylar bone abnormalities. The specificity for condyle evaluation was 1.0 for both, and the accuracy was therefore 0.90 and 0.86, respectively. CBCT and helical CT did not significantly differ in the evaluation of bone abnormalities of the mandibular condyle ($P = 0.286$). Thus, CBCT was used in the present study as the gold standard for evaluation of bone abnormalities.

MRI accurately determines disk position, disk form, bone marrow status, and joint effusion and is currently considered the optimal imaging modality for patients with internal derangement of the TMJ, although it is generally inferior to CBCT and CT for evaluating small hard-tissue structures (19). Westesson (20) showed that 0.3-T MRI diagnosed osseous abnormalities of the TMJ with an accuracy of 0.6, sensitivity of 0.5, and specificity of 0.71. However, Katzberg et al. (21) reported that 0.3-T MRI had an accuracy of 0.94, sensitivity of 0.83, and specificity of 1 for diagnosis of TMJ osseous abnormalities. In general, MRI devices with a higher field strength have numerous potential benefits (22). The stronger magnetic field of 3.0-T devices improves signal-to-noise and contrast-to-noise ratios. This enables acquisition of thinner images with improved spatial resolution, while maintaining adequate signals. Thus, we originally expected that diagnostic accuracy in the detection of osseous abnormalities in the TMJ would be much higher for 3.0-T MRI than for lower field-strength MR units. However, the present results were similar to those reported in the two studies described above. Several factors may explain this similarity.

Schmid-Schwap et al. (12) reported that, as compared with 1.5-T MRI, 3.0-T MR images were of better quality with respect to perceptibility of disk position and shape of the TMJ. However, they did not evaluate perceptibility of bone morphology of the condyles or fossae. Stehling et al. (23) showed that imaging of normal TMJ anatomy, such as the disk and bone components, was significantly better with 3.0-T MRI. They hypothesized that this advantage of 3.0-T MRI would permit more-detailed analysis of capsular and disk pathology. In addition, they showed that the anatomical structure of the TMJ was shown in greater detail by 3.0-T than by 1.5-T MRI. These two studies focused mainly on comparing the visibility of TMJ anatomical structures on 1.5-T and 3.0-T MRI. However, no previous report compared the performance of 3.0-T MRI and CBCT for evaluation of TMJ bone morphology. The present results indicate that the reliability of 3.0-T MRI for TMJ bony components is equal to that of CBCT. In addition, statistical analysis showed no significant differences between the two modalities in identifying osseous abnormalities of the condyles and fossae. Consequently, 3.0-T MRI has acceptable reliability for evaluating bony changes in TMJ, and for soft-tissue evaluation.

In conclusion, 3.0-T MRI and CBCT are equally reliable for diagnostic evaluation of osseous abnormalities of the mandibular condyle. We believe that the present findings, and the absence of radiation exposure, for MRI make it the preferred method of imaging diagnosis, including the evaluation of bone morphology, for TMD patients.

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Conflict of interest
None declared.

References