RESEARCH

Diagnostic performance of magnetic resonance imaging for detecting osseous abnormalities of the temporomandibular joint and its correlation with cone beam computed tomography

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Objective: With cone beam CT (CBCT) as the reference standard, the objective of this study was to determine the diagnostic accuracy of MRI for assessing osseous abnormalities of the temporomandibular joint (TMJ).

Methods: 106 TMJs from 55 patients with temporomandibular disorder were examined by CBCT and MRI. CBCT images were evaluated by two experienced oral radiologists with regard to the presence or absence of each of the following eight types of osseous abnormalities: Type 1, destructive and erosive osseous changes of the condyle; Type 2, flattening of the articular surface of the condyle; Type 3, deformity of the condyle; Type 4, sclerosis of the condyle; Type 5, osteophyte formation; Type 6, ankylosis; Type 7, erosion of the articular fossa and/or eminence; and Type 8, sclerosis of the articular fossa and/or eminence. For detection of these osseous abnormalities by MRI, proton density-weighted images and T_2 weighted images were evaluated independently by three observers. Using CBCT findings as the reference standard, the diagnostic performance of MRI for detecting various types of osseous abnormalities was evaluated by calculating its sensitivity and specificity.

Results: Out of 106 joints, CBCT revealed Types 1, 2, 3, 4, 5, 6, 7 and 8 abnormalities in 25, 19, 26, 20, 14, 5, 19 and 22 joints, respectively. The mean sensitivities of MRI among the three observers for detecting Types 1, 2, 3, 4, 5, 6, 7 and 8 abnormalities were 61%, 30%, 82%, 40%, 48%, 34%, 61% and 41%, respectively, whereas the mean specificities were 86%, 92%, 91%, 95%, 84%, 98%, 89% and 91%, respectively.

Conclusions: Although high specificity (84–98%) was obtained with MRI, this modality showed relatively low sensitivity (30–82%) for detecting osseous abnormalities of the TMJ. The value of MRI for the detection of TMJ osseous abnormalities is considered to be limited. *Dentomaxillofacial Radiology* (2010) 39, 270–276. doi: 10.1259/dmfr/25151578

Keywords: temporomandibular joint osseous abnormalities; magnetic resonance imaging; cone beam computed tomography

Introduction

It is important to correctly identify osseous abnormalities of the temporomandibular joint (TMJ), because they are associated with clinical signs or symptoms of temporomandibular disorder (TMD), including TMJ pain and changes in occlusion or condylar position.^{1–5}

A recent study by Scrivani et al⁶ focused on the most common forms of TMD, myofascial pain, intra-articular disc derangement and osteoarthritis, and proposed different treatment options for each form. Thus, the presence or absence of osseous abnormalities also affects the treatment planning for TMD.

Several imaging techniques have been used for the evaluation of the TMJ. Among them, MRI has great advantages over other techniques in its ability to depict soft tissue changes of the TMJ.^{7–10} However, its diagnostic value for the detection of TMJ osseous

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abnormalities is still controversial,^{7,11} and this issue has not been fully addressed in the literature.

Recently, cone beam CT (CBCT) has become widely used for the diagnosis of abnormalities of the dental region, and its reliability for detecting osseous abnormalities of the TMJ has been reported by several authors.^{12–17} Thus, the aim of this study was to investigate the diagnostic performance of MRI for the assessment of osseous abnormalities of the TMJ using CBCT as the reference standard.

Materials and methods

Patients

55 patients (110 TMJs) with clinical manifestations of TMD who consulted our hospital between December 2002 and April 2008 and who underwent both CBCT and MRI examinations were included in this study. Four joints were excluded from the study because of motion artifacts in one or both of the modalities. Thus, the remaining 106 TMJs were used for the study. The patients comprised 24 males and 31 females with a mean age of 41 years (range 13–69 years).

The study was approved by our Institutional Review Board, and informed consent was obtained from all patients.

CBCT examination

The 3DX multi-image micro-CT (Morita, Kyoto, Japan) developed by Arai *et al*¹⁸ was used as our CBCT apparatus. Its imaging area is a cylinder with a height of 30 mm (240 voxels) and a diameter of 40 mm (320 voxels), providing isotropic cubic voxels with sides of approximately 0.125 mm. TMJs were examined bilaterally and imaged at a tube voltage of 80 kV, a tube current of 4.5 mA and an exposure time of 17 s. Examinations were performed through 360 degrees of rotation with the patient in an occlusal position. After scanning, contiguous sectional images in three orientations, *i.e.* parasagittal sections (vertical to the long axis of the condylar head), coronal sections (parallel to the long axis of the condylar head) and horizontal sections, were reconstructed from the data with a slice width of 1 mm using dedicated CBCT software (Morita). The parasagittal images were not reformatted parallel to the ramus of the mandible.

MRI examination

All MR images were obtained using a 1.5 T scanner (Magnetom Vision; Siemens Medical Systems, Erlangen, Germany) with a 3-inch-diameter bilateral TMJ surface coil and a field volume size of 120×120 mm. In the sagittal plane, both the proton density-weighted images (PDWI) and fat-suppressed T_2 weighted images (T2WI) were obtained: repetition time/echo time (TR/TE), 1000/20 ms (PDWI) or 2931/96 ms (T2WI); slice thickness, 3 mm; interslice gap, 0.3–0.6 mm; number of images, 7.

In the coronal plane, only PDWIs were obtained: TR/TE, 960–980/15 ms; slice thickness, 3 mm, interslice gap, 0.3–0.6 mm, number of images, 7. Although the sagittal PDWIs were obtained in both the open- and closed-mouth positions, only those of the closed-mouth position were used for the evaluation of osseous abnormalities.

The imaging time was approximately 4 min for the sagittal PDWIs, 2 min for the coronal PDWIs and 3 min for the sagittal T2WIs.

Evaluation of images

Following the example of Uemura *et al*,¹⁹ the osseous abnormalities observed in TMJs were classified into Types 1–8 (Table 1). Two board-certified oral radiologists (NO, SN) with 17–24 years of experience interpreting images of the maxillofacial region, including the TMJ, independently evaluated the CBCT images for the presence or absence of each osseous abnormality. The images were evaluated on a CRT monitor using the CBCT viewer (i-VIEW, Morita). When necessary, the window setting was adjusted to optimize the images for evaluation. When the two radiologists disagreed about image assessment, they evaluated the images again and a consensus was then reached by discussion. The interobserver agreement was evaluated with kappa statistics.

MR images were evaluated on a CRT monitor using the installed DICOM (Digital Imaging and Communications in Medicine) image viewer. The presence or absence of each osseous abnormality was evaluated independently by three observers (AT, KO and MA) who had no previous knowledge of the CBCT findings. When necessary, the window setting was adjusted to optimize the images for evaluation. The three observers, two of whom were board-certified oral radiologists, had engaged in MRI evaluations of TMJs in our hospital for 5–12 years before this study. Interobserver agreement was also evaluated with kappa statistics.

Statistical analysis

The sensitivity and specificity of MRI for detecting each osseous abnormality were calculated using the CBCT findings as the reference standard.

Using Cohen's kappa (SPSS version 16; Chicago, IL), the interobserver agreement was determined based on the following criteria: a kappa value of < 0.40 was

Table 1 Classification of temporomandibular joint osseous abnormalities

Type 1	Destructive and erosive osseous changes of the condyle
Type 2	Flattening of the articular surface of the condyle
Type 3	Deformity of the condyle
Type 4	Sclerosis of the condyle
Type 5	Osteophyte formation
Type 6	Ankylosis
Type 7	Erosion of the articular fossa and/or eminence
Type 8	Sclerosis of the articular fossa and/or eminence

considered to indicate poor agreement, 0.40–0.59 fair agreement, 0.60–0.74 good agreement and 0.75–1.00 excellent agreement.

Results

CBCT clearly depicted the morphology of the condyle and the surrounding bone structure in all of the cases. The interobserver agreement for CBCT was good or excellent for all types of osseous abnormality: kappa values for Types 1, 2, 3, 4, 5, 6, 7 and 8 were 0.82, 0.81, 0.69, 0.70, 0.78, 1.00, 0.68 and 0.72, respectively.

Based on the CBCT images, the frequency of each osseous abnormality ranged from 5% (Type 6: ankylosis) to 25% (Type 3: deformity of the condyle), as shown in Table 2.

All the osseous abnormalities could be detected by MRI. As shown in Table 3, the mean sensitivity of MRI among the three observers was 30–82%, and the mean specificity was 84–98%. MRI was most sensitive for detecting Type 3 (deformity) abnormalities, and least sensitive for detecting Type 2 (flattening). Representative CBCT and MR images are shown in Figures 1–6. The interobserver agreement for MRI was determined to be fair for all types of osseous abnormalities except for Type 8, which showed poor agreement.

Discussion

Among the imaging modalities for the examination of the TMJ, MRI is the most useful technique because it has great advantages in the assessment of the soft tissue components of the joint.^{7–10} In contrast, CT has been considered the best modality for imaging the osseous components of the TMJ.^{7–9} Multidetector-row CT (MDCT) is now widespread, providing much higher resolution and better image quality than conventional CT. Thus, in several recent studies, MDCT has been used as a reference standard to evaluate the accuracy of other modalities in diagnosing TMJ osteoarthritis²⁰ or other osseous abnormalities.^{21–23}

Recently, CBCT for dental use has become widely available. The major advantages of CBCT include low radiation dose and high spatial resolution due to its

Table 3 Diagnostic performance of MRI for detecting temporomandibular joint osseous abnormalities

Type of abnormality	Mean sensitivity (%)	Mean specificity (%)
Type 1	61	86
Type 2	30	92
Type 3	82	91
Type 4	40	95
Type 5	48	84
Type 6	34	98
Type 7	61	89
Type 8	41	91

minute voxels. Several researchers^{12–17} have reported the excellent ability of CBCT to evaluate osseous abnormalities of the TMJ. According to a study by Honey *et al*¹² using dry mandibles, the mean diagnostic accuracy of CBCT for detecting cortical erosive defects in the TMJ was 95%. Honda *et al*¹³ compared the diagnostic accuracy of CBCT with that of MDCT in detecting osseous abnormalities of the TMJ and concluded that CBCT was similar to MDCT and that both modalities were highly reliable. Katakami *et al*¹⁶ performed a similar comparison and showed that CBCT was superior to the other in detecting osseous changes in the TMJ. Other studies^{24,25} compared image quality after using both modalities to assess alveolar bone and tooth structure and concluded that CBCT was superior or at least similar to MDCT. Owing to the high reliability of CBCT demonstrated by these studies, we considered that CBCT, like MDCT, could be used as a reference standard in evaluating osseous changes and decided to perform this study. This enabled us to evaluate a larger number of subjects (106 TMJs) than studies using cadavers.

There have been other studies that evaluated the diagnostic ability of MRI to detect osseous abnormalities of the TMJ using cadaver specimens. Westesson *et al*⁷ evaluated sagittal T_1 weighted images of 15 joints and reported that the sensitivity and specificity of MRI were 50% and 71%, respectively. Similarly, Katzberg *et al*²⁶ evaluated coronal T_1 weighted images of 18 joints and reported that the sensitivity and specificity were 83% and 100%, respectively. Tasaki *et al*¹¹ evaluated coronal and sagittal images of proton density and T_2 weighted sequences of a relatively large number of subjects (55 joints) and reported that the sensitivity and specificity were 87% and 100%, respectively. Thus, except for the first study, the sensitivity of MRI has been reported to be high, which is inconsistent with our results. We believe that this discrepancy is mostly due to differences between study evaluation methods. Specifically, the previous studies evaluated all osseous changes together and did not consider sclerosis or ankylosis, whereas we evaluated the sensitivity of MRI for each TMJ osseous change. Differences between the reference standard are also considered to be attributed to the discrepancy because the CBCT findings may not be completely consistent with direct observations of cadaver specimens. In addition, as indicated in the previous studies,^{7,11} MR

Table 2 Frequency of osseous abnormalities in 106 temporomandibular joints as determined by cone beam CT

Type of abnormality	Frequency % (no. of joints)
Type 1	24 (25)
Type 2	18 (19)
Type 3	25 (26)
Type 4	19 (20)
Type 5	13 (14)
Type 6	5 (5)
Type 7	18 (19)
Type 8	21 (22)

Figure 1 A 59-year-old woman with chief complaints of temporomandibular joint pain and limited mouth opening. (a) The cone beam CT image revealed ankylosis of the right condylar head (arrow); (b) ankylosis was not clear on the coronal proton density-weighted MR image (arrow)

Figure 2 A 64-year-old woman with chief complaints of bilateral temporomandibular joint clicking and limited mouth opening. (a) The cone beam CT image revealed sclerosis of the right condylar head (arrow); (b) sclerosis was not clear on the sagittal proton density-weighted (arrow) or (c) the T_2 weighted MR image (arrow)

Figure 3 A 55-year-old woman with chief complaints of bilateral temporomandibular joint clicking, crepitus, pain and limited mouth opening. (a) A deformity of the right condylar head was detected on both the cone beam CT (arrow) and (b) sagittal proton density-weighted MR images (arrow)

Figure 4 A 22-year-old woman with the chief complaint of intermittent clicking. (a) The cone beam revealed flattening of the left condylar head (arrow); (b) the flattening was not clear on the sagittal proton density-weighted MR image (arrow)

images obtained using cadavers may not be equivalent to those obtained in clinical settings, as the latter are affected by artifacts caused by jaw motion and the pulsation of arteries.

Our results showed that MRI was better at detecting changes in the size of the TMJ, such as deformities, than it was at detecting changes in shape, for example flattening, osteophyte formation or erosion. This fact could be due primarily to the limited spatial resolution of MRI; the slice thickness of MRI is 3 mm or more for clinical use, which may be too thick to detect subtle osseous changes. Other problems include the presence of fibrous tissues inside the TMJ and the attachment of

the lateral pterygoid muscle in close proximity to the articular surface of the condyle, which can be interpreted as either an osseous abnormality or as a disc, and may result in false-positive or false-negative results.^{27–29} In addition, when detecting osseous abnormalities in the articular fossa and eminence, difficulties sometimes arise due to magnetic susceptibility artifacts. Namely, the presence of air spaces in the temporal bone may have led to the poor agreement among the observers for the Type 8 abnormality.

The MRI technique that we used was similar to the standard imaging protocol for the TMJ.³⁰ The use of the dual surface coil technique for simultaneous imaging of

Figure 5 A 42-year-old woman with chief complaints of crepitus, pain and limited mouth opening. (a) Cone beam CT revealed no abnormality of the left condylar head (arrow), whereas (b) erosion was suspected on the corresponding sagittal proton density-weighted MR image (arrow)

Figure 6 A 30-year-old woman with a history of rheumatoid arthritis and steroid treatment for 7 years and a chief complaint of clicking of the left temporomandibular joint, (a) the cone beam CT image revealed no abnormality of the left condylar head (arrow), whereas (b) an osteophyte was suspected on the corresponding sagittal proton density-weighted MR image (arrow).

the right and left TMJs has been of great value because the examination time can be significantly shortened for bilateral TMJ imaging. For better MRI evaluation of normal and pathological conditions affecting the TMJ, a recent study³¹ recommended the use of a 3 T MRI scanner because of its high signal-to-noise ratio at half the slice thickness, which results in better spatial resolution.

Further studies evaluating TMJ osseous changes using the latest 3 T scanner are therefore imminent.

In conclusion, although high specificity (84–98%) was obtained with MRI, it showed a relatively low sensitivity (30–82%) for detecting osseous abnormalities of the TMJ. Thus, the value of MRI for the detection of TMJ osseous abnormalities is considered to be limited.

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