Open-Mouth Bone Scintigraphy Is Better than Closed-Mouth Bone Scintigraphy in the Diagnosis of Temporomandibular Osteoarthritis

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Abstract

Purpose Closed-mouth bone scintigraphy (CM scan) and closed-mouth single-photon emission computed tomography (CM SPECT) are used for conventional evaluation of osteoarthritis of the temporomandibular joint (TMJ). However, the adequacy of open-mouth bone scintigraphy (OM scan) has not yet been evaluated. Therefore, the purpose of this study was to compare the diagnostic performance of CM scan, CM SPECT, and OM scan.

Methods Thirty-six patients with suspicion of an abnormality of the TMJ and who underwent a ^{99m}Tc-HDP CM scan, CM SPECT, and an OM scan were enrolled. The scans were assessed visually for the presence of positive focal uptake in the TMJ. Osteoarthritis was defined as arthralgia plus crepitus or radiologic signs of arthrosis.

Results Of 72 TMJs, 21 (29.2 %) were diagnosed with osteoarthritis. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy were 90.5 %, 49.0 %, 42.2 %, 92.6 % and 61.1 % for the CM scan,

81.0 %, 58.8 %, 44.7 %, 88.2 % and 65.3 % for CM SPECT, and 81.0 %, 82.4 %, 65.4 %, 91.3 % and 81.9 % for the OM scan, respectively. The accuracy of the OM scan was higher than that of CM SPECT and the CM scans ($p=0.004$ and $p<0.001$, respectively).

Conclusions The OM scan was more accurate than the conventional CM scan and even CM SPECT for diagnosing TMJ osteoarthritis.

Keywords Open mouth · Temporomandibular joint · Osteoarthritis · Bone scintigraphy · Bone scan

Introduction

The temporomandibular joint (TMJ) is functionally important for chewing, speaking, swallowing and movement of the head [1]. This joint is used many times every day. When it is overloaded by jaw movement, the degenerative disease osteoarthritis occurs [2]. TMJ osteoarthritis occurs more frequently in women than in men, and is strongly correlated with age [3]. TMJ osteoarthritis is associated with secondary inflammation and bony changes including remodeling of the articular surface, narrowing of the joint space, cortical thickening, osteophytes and calcified intraarticular bodies. However, anatomical changes in the surrounding joint structures observed on imaging do not always correlate with symptoms [4, 5]. Bone scintigraphy is a highly sensitive imaging method that requires an increase in osteoblastic activity of only about 10 % to detect early changes in the bone [6–8]. The early diagnosis of osteoarthritis is clinically important, because it allows control of disease progression from an early stage and invasive surgery to be avoided [9, 10].

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Conventional planar bone scintigraphy and single-photon emission computed tomography (SPECT) can be used to acquire TMJ images with the patient in the closed-mouth position [4, 11, 12]. However, the mandibular fossa of the skull and the condylar process of the mandible are very close to each other with the mouth closed, and the TMJ joint space is quite narrow. Therefore, overlap of physiologic uptake of the bones can occur, mimicking pathologically increased focal uptake in the images. On the other hand, when the mouth opens, the condyle moves anteriorly out of the glenoid fossa, and the two bony structures become considerably separated [13] so that the overlap in the physiologic uptake of the bones may be reduced.

Therefore, we evaluated whether the ^{99m}Tc -hydroxymethylene diphosphonate (HDP) planar bone scintigraphy with the patient in the open-mouth position (OM scan) could provide better diagnostic performance than ^{99m}Tc -HDP planar bone scintigraphy with the patient in the closed-mouth position (CM scan) or ^{99m}Tc -HDP SPECT bone scintigraphy with the patient in the closed-mouth position (CM SPECT).

Materials and Methods

Patients

From October 2008 to January 2013, we retrospectively enrolled 36 patients (8 men, 28 women; mean age 28.9 ± 12.5 years; 72 TMJs) who underwent an OM scan) together with a conventional CM scan and CM SPECT. All the patients had symptoms or signs suspicious for TMJ osteoarthritis, including TMJ pain, crepitus and/or bone deformity. Patients who had a history of head trauma, TMJ disorder, metabolic bone disease, metastatic bone disease or rheumatoid disease were excluded. The study was approved by the Institutional Review Board, and the need for written informed consent was waived.

Clinical Diagnosis of TMJ Osteoarthritis

According to the research diagnostic criteria for temporomandibular disorders (RDC/TMD guidelines), TMJ osteoarthritis was clinically defined as fulfilling all the previously suggested diagnostic criteria, based on a review of clinical assessment by dentists: (1) pain on palpation, (2) self-report of pain during jaw movement, and (3) crepitus during any movement or radiologic signs of arthrosis (erosion of normal cortical delineation, sclerosis of all or part of the condyle and joint eminence, flattening of the joint surfaces, and presence of osteophytes) [14]. We divided the TMJs into two groups: those with and those without osteoarthritis.

^{99m}Tc -HDP Bone Scintigraphy

Sequential CM scans, OM scans and CM SPECT were acquired 3 h after intravenous injection of 740 MBq (20 mCi) of ^{99m}Tc -HDP. Lateral view images of the TMJ with the patient in both the closed-mouth and open-mouth positions were obtained with a count of 500,000 using a dual-head gamma camera (e.cam; Siemens Medical Solutions) equipped with a low-energy parallel-hole collimator. For the open-mouth scans, the patients were instructed to hold a 3-cm caliber plastic cylinder between their teeth [15]. No patient complained of discomfort or aggravation of pain as a result of holding the cylinder, and all patients successfully underwent the OM scan without failure or the need to re-try. Skull bone SPECT with the patient in the closed-mouth position was performed using the same machine equipped with a low-energy parallel-hole collimator. The 360° acquisitions comprised 60 projection images with 15 s per projection and 128×128 matrices. Transaxial and coronal tomograms were reconstructed using a Butterworth filter and ramp-filtered back-projection.

Image Analysis

Two experienced nuclear medicine physicians analyzed the right and left TMJs separately on the ^{99m}Tc -HDP scintigraphy images. The TMJs were regarded as positive for osteoarthritis when there was clearly localized focal uptake and increased uptake in the TMJ distinguishable from the surrounding normal bone. The two readers were blinded to each other's findings.

In addition, semiquantitative analysis was performed to demonstrate that the focal uptake was quantitatively reduced on the OM scan. Square regions of interest (ROI) of 13×13 pixels were drawn on both TMJs and parietal bones [4]. The maximal counts per pixel in the ROIs on the TMJs and on the parietal bones as background were measured. The maximal uptake ratio was defined as the maximal count of the TMJ divided by the mean count of the ipsilateral parietal bone.

Statistical Analysis

Sensitivity, specificity and accuracy were calculated for each of the imaging methods. McNemar's test was used to compare the diagnostic performance. The chi-squared test was used to evaluate the association between the diagnostic criteria and focal uptake in the TMJ with the three imaging methods. To evaluate interobserver agreement in the visual analysis, the kappa values were calculated for the three methods. A paired *t* test was used to compare the maximal uptake ratios of the TMJ between the OM scan and CM scan. A value of $p < 0.05$ was considered to be statistically significant, and the analysis was carried out using SPSS Statistics, version 21.0 (IBM Corp, Armonk, NY).

Table 1 Characteristics of the evaluated TMJs

Classification	Symptoms and signs	No. of joints
Osteoarthritis	Palpation pain, pain self-report, crepitus or radiologic signs	21
Non-osteoarthritis	Pain on palpation and pain self-report	4
	Pain self-report, crepitus or radiologic signs	2
	Pain on palpation, crepitus or radiologic signs	0
	Pain on palpation only	5
	Pain self-report only	3
	Crepitus or radiologic signs only	15
	No complaint	22

Results

Clinical Diagnosis of the TMJ Osteoarthritis

Of the 72 TMJs, 21 (29.2 %) were diagnosed with osteoarthritis, and 29 joints showed incomplete fulfillment of the diagnostic criteria. The remaining 22 TMJs were not associated with pain on palpation, pain self-report, crepitus or radiologic signs of arthrosis (Table 1).

Pain self-report was associated with positive TMJ uptake with all three imaging methods, but pain on palpation and crepitus were variably associated with positive TMJ uptake ($p < 0.05$). Pain on palpation and crepitus were associated with positive uptake on the OM scan, pain on palpation was associated with positive uptake on CM SPECT, and crepitus was associated with positive uptake on the CM scan (Supplementary Table 1).

Diagnostic Performance of the Three Methods

The OM scan, CM SPECT and CM scan showed 26, 38 and 45 positive TMJs, respectively (Table 2). The number of positive TMJs diagnosed clinically using the RDC/TMD guidelines was not significantly different from the number diagnosed with the OM scan ($p = 0.267$, McNemar's test). However, the numbers diagnosed with CM SPECT and the CM scan were significantly different from the number diagnosed clinically ($p = 0.001$ and $p < 0.001$), and from the number diagnosed with the OM scan ($p = 0.004$ and $p < 0.001$).

Table 2 Diagnostic performance of the three imaging methods for TMJ osteoarthritis

Method	Positive	Negative	True positive	True negative	False positive	False negative
OM scan	26	46	17	42	9	4
CM SPECT	38	34	17	30	21	4
CM scan	45	27	19	25	26	2

OM scan ^{99m}Tc -HDP planar bone scintigraphy with the patient in the open-mouth position, *CM SPECT* SPECT with the patient in the closed-mouth position, *CM scan* ^{99m}Tc -HDP planar bone scintigraphy with the patient in the closed-mouth position

The sensitivity, specificity, positive predictive value, negative predictive value and accuracy were 81.0 %, 82.4 %, 65.4 %, 91.3 % and 81.9 % with the OM scan, 81.0 %, 58.8 %, 44.7 %, 88.2 % and 65.3 % with CM SPECT, and 90.5 %, 49.0 %, 42.2 %, 92.6 % and 61.1 % with the CM scan, respectively. The accuracy with the OM scan was higher than with the other methods (Fig. 1). The maximal uptake ratio in the same TMJ was significantly lower with the OM scan than with the CM scan (uptake ratios 6.5 ± 1.2 vs. 5.9 ± 1.2 for the CM scan and OM scan, respectively; $p < 0.001$).

Interobserver Agreement for the Three Methods

There was excellent interobserver agreement in the visual analysis of the images from the three methods. The kappa values for positive uptake on the OM scan, CM SPECT and the CM scan were 0.791, 0.831 and 0.785, respectively (Supplementary Table 2).

Discussion

The present study demonstrated the diagnostic utility of the OM scan for diagnosing TMJ osteoarthritis. It was more accurate than CM SPECT and the CM scan. Bone scintigraphy and SPECT are usually used to find and evaluate painful osseous lesions. Similarly in this study, painful TMJs were identified by bone scintigraphy. Both bone scintigraphy and SPECT provide important information in the evaluation of

Fig. 1 Diagnostic performance of the CM scan, CM SPECT and the OM scan for TMJ osteoarthritis. The accuracy, specificity and PPV were highest with the OM scan

joints with suspected osteoarthritis; for example, early detection of bony changes before radiographic signs can be identified [16, 17]. Therefore, TMJ disorders, including osteoarthritis, have been evaluated with conventional bone scintigraphy and SPECT with the patient in the closed-mouth position.

The uptake ratio has also been found to be increased in TMJs diagnosed with osteoarthritis [4]. The sensitivity and specificity of the TMJ uptake ratio for diagnosing osteoarthritis were 72.2 % and 57.7 %, respectively, with an optimal uptake ratio cut-off value of 3.88. However, the presence of arthralgia or bone alterations was not significantly associated with the uptake ratio observed on bone scintigraphy. Ahn et al. [12] evaluated TMJ pain using SPECT. A high TMJ index, defined as the TMJ counts divided by the reference skull

counts on SPECT images, was significantly associated with a positive diagnosis by visual interpretation of bone scintigraphy images. The accuracies of the TMJ index for identifying joints with spontaneous pain, pain on mouth opening, palpatory and any type of pain in this study were 59.5, 60.0, 61.0 and 61.9 %, respectively. Saridin et al. [18] also found that SPECT is a useful method for evaluating unilateral condylar hyperactivity.

However, it is very difficult to differentiate physiologic bone uptake from the mandibular fossa of the skull and the condylar process of the mandible in a closed mouth. Therefore, we performed the OM scan using a simple plastic cylinder that can easily be found in the clinical setting and can be used without inducing any physical or psychologic burden in the patients. The anatomical separation of the condyle of the mandible and the mandibular fossa of the temporal bone improved the performance of ^{99m}Tc -HDP bone scintigraphy in diagnosing TMJ osteoarthritis by decreasing the rate of false-positive findings. In our study, 17 TMJs changed from false-positive focal uptake on the CM scan to true-negative uptake on the OM scan. Also, 12 TMJs changed from false-positive focal uptake on CM SPECT to true-negative uptake on the OM scan (Fig. 2). The OM scan contributed to improvement in the accuracy and specificity in diagnosing TMJ osteoarthritis.

On the other hand, because the condyle of the mandible is very close to the mandibular fossa of the temporal bone in the closed mouth, the uptake in TMJ on the CM scan and CM SPECT is significantly affected by the overlap in physiologic uptake of the bones of the TMJ. The overlap in uptake could

Fig. 2 CM scan, CM SPECT and OM scan images of the right TMJ in a patient with osteoarthritis. The patient did not show disorder in the left TMJ. **a** The CM scan image shows false focal uptake in the left TMJ (closed arrow) and true focal uptake in the right TMJ (open arrow). **b** The CM SPECT image shows false focal uptake in the left TMJ (closed arrow) and true focal uptake in the right TMJ (open arrow) on . **c** The OM scan image does not show the false focal uptake in the left TMJ (closed arrow), but does show the true focal uptake in the right TMJ (open arrow)

make the physiologic uptake of the bones of the TMJ more prominently increased compared with the uptake of the surrounding bones. Although SPECT images are three dimensional and are better for localizing the focus, SPECT could not distinguish the physiologic uptake of the condyle and mandibular fossa in our study. This can partially be attributed to the low spatial resolution of SPECT (about 4.8 mm in our study) in comparison with the short distance between the condyle and the mandibular fossa of <3 mm in the closed mouth [19]. Consequently, SPECT images show merged uptake of the condyle and mandibular fossa that has the appearance of high and prominently focal uptake. However, the distance between the condyle and the mandibular fossa is increased to more than 10 mm in the open mouth [20], reducing the overlap of physiologic uptake of the bones. Finally, prominently focal uptake that consists of merged physiologic uptake disappears, as shown by the decreased maximal uptake ratio after opening the mouth in our study.

The method used in the previous study by Kim et al. [4] was not appropriate for our study. Because the square ROI on the both TMJs was so large that the condyle could not be excluded from the ROI, the total counts could not be significantly changed. ^{18}F positron emission tomography/CT (PET/CT) was used in a previous study [11], and showed high diagnostic accuracy. PET/CT has better spatial resolution, and thus may show less overlap of physiologic uptake from surrounding bones even in the closed mouth. However, there are cost-effectiveness and reimbursement problems in performing PET/CT in patients with suspicion of TMJ osteoarthritis. The OM scan may be a simpler and cheaper way to evaluate TMJ osteoarthritis.

Several previous studies have shown the value of imaging patients with TMJ disorders other than osteoarthritis in the open-mouth position. Hayashi et al. [21] found that the sensitivity of CT for evaluating articular disc displacement was higher with the patient in the open-mouth position than in the closed-mouth position. The articular disc is located in the narrow TMJ space in the closed mouth, preventing its identification on CT images due to the partial volume effect, but is located in the wider TMJ space in the open mouth increasing its detectability. Drace and Enzmann [15] used open-mouth MR imaging to distinguish the anterior displacement of the articular disc without reduction from that with reduction. The same underlying mechanism was used to successfully evaluate TMJ osteoarthritis in our study.

Our study had some limitations. Because we enrolled a small number of patients, we analyzed the uptake of the right and left TMJ separately in the same patients. The positions of the two TMJs could have overlapped on the two-dimensional lateral bone scintigraphy images. Therefore, visual analysis of uptake in a TMJ might have been affected by the uptake in the contralateral TMJ. Nevertheless, this is the first study to evaluate the diagnostic performance of $^{99\text{m}}\text{Tc}$ -HDP bone

scintigraphy in the open mouth, and showed better diagnostic performance. We compared the diagnostic performance of only the OM scan, CM scan and CM SPECT. Data for OM SPECT are lacking due to the prolonged acquisition time needed and the reimbursement problem. However, OM SPECT may add more diagnostic value, and this needs to be clarified in future studies.

Conclusion

The OM scan showed a higher performance than the conventional CM scan and CM SPECT in diagnosing TMJ osteoarthritis. The diagnostic performance of planar bone scintigraphy can be simply and safely enhanced by scanning the patient in the open-mouth position.

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Compliance with Ethical Standards

Conflicts of interest Ki Seong Park, Ho-Chun Song, Sang-Geon Cho, Sae-Ryung Kang, Jahae Kim, Haeng Man Jun, Minchul Song, Geum-Cheol Jeong, Hee Jeong Park, Seong Young Kwon, Jung-Joon Min and Henry Hee-Seung Bom declare that they have no conflicts of interest.

Ethical statement The study was approved by an institutional review board and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. The institutional review board waived the need for informed consent.

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