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Comparison of Diagnostic Performance Between Visual and Quantitative Assessment of Bone Scintigraphy Results in Patients With Painful Temporomandibular Disorder

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Abstract: This retrospective clinical study was performed to evaluate whether a visual or quantitative method is more valuable for assessing painful temporomandibular disorder (TMD) using bone scintigraphy results.

In total, 230 patients (172 women and 58 men) with TMD were enrolled. All patients were questioned about their temporomandibular joint (TMJ) pain. Bone scintigraphic data were acquired in all patients, and images were analyzed by visual and quantitative methods using the TMJ-to-skull uptake ratio. The diagnostic performances of both bone scintigraphic assessment methods for painful TMD were compared.

In total, 241 of 460 TMJs (52.4%) were finally diagnosed with painful TMD. The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of the visual analysis for diagnosing painful TMD were 62.8%, 59.6%, 58.6%, 63.8%, and 61.1%, respectively. The quantitative assessment showed the ability to diagnose painful TMD with a sensitivity of 58.8% and specificity of 69.3%. The diagnostic ability of the visual analysis for diagnosing painful TMD was not significantly different from that of the quantitative analysis.

Visual bone scintigraphic analysis showed a diagnostic utility similar to that of quantitative assessment for the diagnosis of painful TMD.

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Abbreviations: AUC = area under the ROC curve, MRI = magnetic resonance imaging, ROC = receiver operating characteristics, ROI = regions of interest, SPECT = single photon emission computed tomography, TMD = temporomandibular disorder, TMJ = temporomandibular joint.

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INTRODUCTION

Temporomandibular disorder (TMD) is a multifactorial process caused by muscle hyperfunction, traumatic injury, hormones, and articular changes within the temporomandibular joint (TMJ), and >5% of the population suffers from TMD.[1] The most common symptoms of TMD are restricted range of mandibular motion, TMJ pain, joint sounds, and functionally limited jaw opening.[2] Among these, pain in the TMJ is the most important symptom to diagnose TMD. An accurate diagnosis and appropriate treatment are required in patients with painful TMD because sustained pain from TMD can significantly affect a patient's quality of life due to physical, psychological, and social problems.[3]

Various historical, physical, radiographic, and nuclear medicine examinations are used to diagnose TMD. In particular, bone scintigraphy has been widely used and is valuable and helpful for diagnosing TMD.[3–5] Uptake of Tc-99m-labeled bone-seeking radiopharmaceuticals is influenced by the amount of calcium contained on bone phosphate-binding sites and blood flow. Lesions with high osteoblast activity or reactive/inflammatory lesions with abundant blood flow are revealed as high uptake lesions on bone scintigraphy.[3,4,6] Therefore, inflammatory changes or active TMJ remodeling can be detected earlier and more sensitively by bone scintigraphy than by conventional radiographic techniques.[3,7–10]

Visual and quantitative assessments are widely used to interpret TMJ bone scintigraphy data. In general, the quantitative analytical method may provide more exact and valuable information than visual assessment. However, no study has reported which assessment method is most useful for diagnosing painful TMD. The aim of this study was to evaluate whether a qualitative or quantitative scintigraphic method is more valuable for assessing painful TMD.

MATERIALS AND METHODS

Patients

In total, 230 patients (172 women and 58 men; mean age ± standard deviation, 35.0 ± 17.2 years; range, 16–77 years) with clinically diagnosed TMD with or without TMJ pain from June 2012 to June 2013 at our hospital were included. Patients were questioned regarding the history of their pain symptoms and were clinically examined by an expert clinician. A painful joint was defined as orofacial pain caused by TMD together with pain on TMJ palpation, function, jaw movement, and/or parafunctions.[11] Patients with myalgia, trauma, previous treatment history, or metabolic or metastatic bone disease were excluded from this study. The clinical design of this retrospective study was approved by the institutional review board of Ajou University (MED-MDB-15-226).

Bone Scintigraphy

Patients were injected with 740 MBq of Tc-99m dicarboxypropane diphosphonate, and static bone scan images of the TMJ (anterior, right lateral, and left lateral views) were acquired after 4 h using a dual-head gamma camera (GE Healthcare, Waukesha, WI) equipped with a low-energy, high-resolution collimator. Images were analyzed on a Xeleris Workstation (GE Healthcare).

Image Analysis

Bone scintigraphy data were assessed visually by consensus of 2 experienced nuclear medicine physicians who were blinded to other clinical information. The TMJ uptake level was considered abnormal when uptake higher than that of the parietal bone was detected on lateral views. The image of anterior view was not used for analyzing, because of superimposing effect on the adjacent structures in the TMJ area.

The TMJ uptake ratio was assessed quantitatively. Circular regions of interest (ROIs) were drawn manually on the right and left lateral TMJ views. Additionally, a circular ROI was drawn on a uniform reference region in the parietal skull area (Figure 1). The uptake ratio was calculated by dividing the TMJ ROI counts by those of the reference ROI, as described previously.[12]

Statistical Analysis

Student's t test and the chi-square test were used to examine the association between pain symptoms and scintigraphic findings. The diagnostic performance of bone scintigraphy for diagnosing painful TMJ in the visual analysis was assessed by calculating the sensitivity, specificity, positive predictive value, negative predictive value, and accuracy. The diagnostic efficacy of the quantitative bone scintigraphic values (TMJ uptake ratio) was assessed using a receiver operating characteristics (ROC) curve analysis. The area under the ROC curve (AUC) was compared with 0.5, and the best cut-off value was determined as that with the highest Youden index. Agreement between the visual and quantitative analytic findings in each TMJ was evaluated using McNemar's test. The ROC curves were compared to evaluate differences in the diagnostic utility of the visual and quantitative analyses. MedCalc ver. 10.4.8 software (MedCalc Software, Mariakerke, Belgium) was used for all statistical analyses. All P values of <0.05 were considered significant.

RESULTS

In total, 241 TMJs (241/460, 52.4%) were diagnosed as painful TMJs associated with TMD. The other TMJs without pain were classified as the nonpainful TMJ group (219/460, 47.6%). Regarding patients, 200 (200/230, 87.0%) demonstrated unilateral ($n = 159$) or bilateral ($n = 41$) TMJ pain. The mean duration of TMJ pain was 4.4 months. Thirty patients (30/230, 13.0%) did not have pain in TMJs.

Diagnostic Performance of the Visual Analysis

About 49% of TMJs (224/460) showed visually abnormal uptake on bone scintigraphy. The remaining 236 TMJs had normal bone scintigraphic findings (236/460, 51.3%). Significant differences were detected in the visual TMJ results between the painful and nonpainful groups ($P < 0.001$) (Table 1). The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of the visual analysis for diagnosing

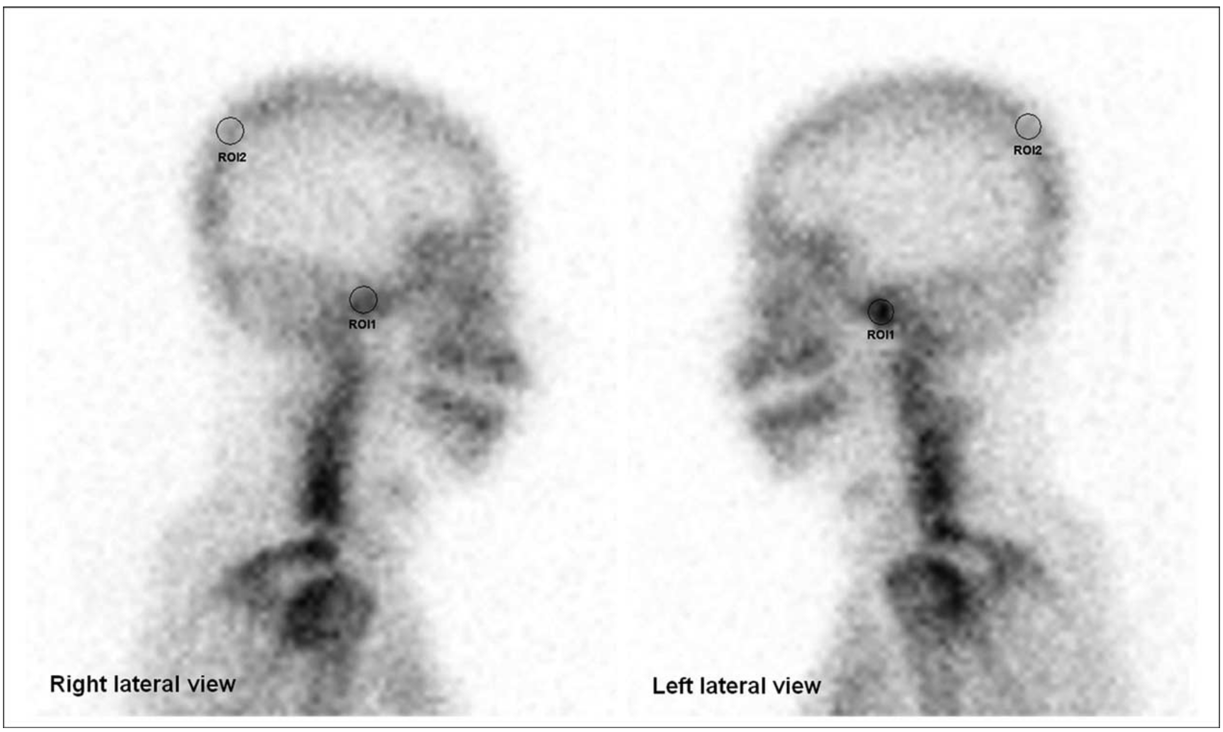

FIGURE 1. Regions of interest (ROIs) used for quantitative analyses. ROI 1 was positioned over the temporomandibular joint in each lateral view. ROI 2 was located over the parietal bone region and was used as a reference for correction. ROI = regions of interest.

TABLE 1. Association Between Pain and Bone Scintigraphic Findings

	All TMJs (n = 460)		Painful TMJs (n = 241)	Nonpainful TMJs (n = 219)	*P* Value
Visual analysis	Normal/abnormal	236/224	98/143	138/81	<0.001*
Quantitative analysis	Uptake ratio (mean ± SD)	1.78 ± 0.49	1.86 ± 0.51	1.69 ± 0.44	<0.001

SD = standard deviation, TMJ = temporomandibular joint.
* Degrees of freedom = 1; chi = 22.11.

painful TMJs were 62.8%, 59.6%, 58.6%, 63.8%, and 61.1%, respectively.

Diagnostic Value of the Quantitative Analysis

The TMJ uptake ratio was significantly higher in the painful TMJ group than in the nonpainful TMJ group (1.86 ± 0.51 vs 1.69 ± 0.44, respectively; $P < 0.001$) (Table 1). The ROC curve analysis results showed that the uptake ratio had a significant ability to help diagnose painful TMJs with an AUC of 0.594 ($P = 0.004$). The sensitivity was 58.8% and specificity was 69.3% for diagnosing painful TMJs when an uptake ratio of 1.86 was used as the cutoff value for abnormal uptake.

Agreement Between the Visual and Quantitative Analyses

McNemar's test results revealed that the quantitative analysis findings using the cutoff value were significantly different from the visual findings ($P < 0.001$) (Table 2).

Comparison of Diagnostic Utility Between the Visual and Quantitative Analyses

Figure 2 shows the comparisons of the diagnostic abilities of the visual and quantitative TMJ analyses using bone scintigraphic data. The AUC values for the visual analysis were not different from quantitative analysis (0.612 ± 0.023 vs 0.594 ± 0.026, respectively; $P = 0.562$).

DISCUSSION

TMD is a generic term describing any clinical problem in the TMJ associated with orofacial pain and/or mandibular dysfunction.[13,14] Deterioration of articular cartilage, bone remodeling, and inflammatory changes in the TMJ occur in patients with TMD.[15–17] Although clinical symptoms and signs are mainly used to diagnose TMD, a number of imaging techniques, such as skeletal radiography, computed tomography, magnetic resonance imaging (MRI), and bone scintigraphy, provide valuable information for a TMD diagnosis in clinical practice.[4,10,18–20]

A bone scan can detect alterations in bone metabolic activity before structural or anatomical bony alterations occur; thus, it can be used to detect TMD early and has high sensitivity for detecting TMD.[4,19,20] Conventional radiographic images mainly reflect structural changes in the TMJs of patients with TMD.[4,21,22] However, radiography is limited for evaluating TMD because the structural changes shown on traditional radiographic images may not be correlated with TMJ pain, as developmental or previous structural changes are no longer active.[6] Plain radiography can detect destruction of bone mineral content in at least 30% to 50% of bone lesions. In contrast, nuclear medical imaging with bone scintigraphy can reveal positive results after only a 10% alteration in bone metabolic activity, even if structural changes cannot be detected on conventional radiography. Therefore, bone scintigraphy has been effectively used for early detection of TMD.[4,18–20]

Bone scintigraphy is usually interpreted subjectively by visual assessment, but it is observer-dependent and has limited capacity to discriminate between borderline results. Some studies have suggested that quantitative methods provide useful information for evaluating TMD.[4,10] However, this is the first study to compare the diagnostic utility between visual and quantitative methods. Thus, we determined whether qualitative or quantitative bone scintigraphy is more valuable to assess painful TMD.

Clinical symptoms of subjective or palpatory pain in TMJs are a determining factor for diagnosing TMD.[15] We evaluated the association between a diagnosis based on clinical pain in TMJs and bone scintigraphic results. About 60% of painful TMJs (143/241) showed abnormally high uptake after visually analyzing the bone scintigraphic results, whereas only 37% of TMJs (81/219) revealed hot uptake lesions visually in patients with nonpainful TMJs. The painful TMD group also showed a significantly higher uptake ratio than did the nonpainful group. These findings suggest that both visual and quantitative assessments of bone scintigraphic results are significantly associated with painful symptoms in patients with TMD. The high correlation between clinically painful symptoms and image changes has been reported previously using MRI.[11]

We found that visually assessing the bone scintigraphic results had a sensitivity of 62.8% and specificity of 59.6% for

TABLE 2. Agreement Between Visual and Quantitative Analyses for the Presence of an Abnormality Detected by Bone Scintigraphy

Visual Analysis		Quantitative Analysis Using a Cutoff Value	McNemar's Test (*P* Value)
Normal	236	282	<0.001
Abnormal	224	178	

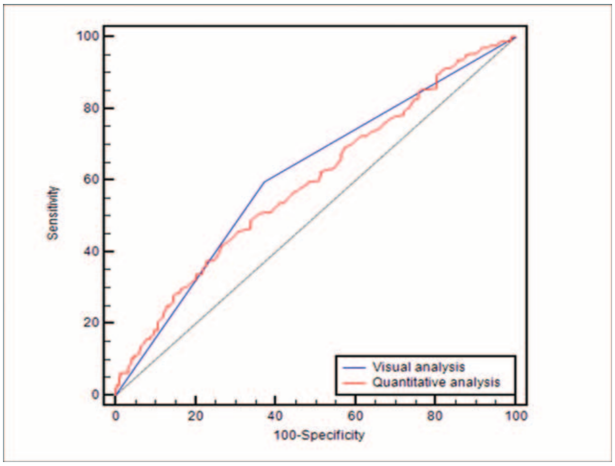

FIGURE 2. Receiver operating characteristic curves used for bone scintigraphy analyses of patients with painful temporomandibular joints. The diagnostic ability was not significantly different between the analytic methods ($P = 0.562$).

diagnosing TMD with pain. According to the quantitative results, the sensitivity was 58.8% and specificity was 69.3% for diagnosing painful TMD when the uptake ratio was >1.86. Kim et al[4] reported that the sensitivity of bone scintigraphy was 72.2% and specificity was 57.7% for diagnosing TMJ osteoarthritis. Notably, our results using a quantitative assessment showed relatively lower sensitivity and higher specificity than the results of that previous study. It was difficult to directly compare our results with those of Kim et al[4] because of differences in study design and patient characteristics. We had a larger number of patients ($n = 230$) than Kim et al ($n = 22$). One possible explanation for low sensitivity of bone scitigraphy in our study might be that current study enrolled patients with very early phase of painful TMD. Indeed, duration of TMJ pain in patients without abnormality in bone scintigraphy (false-negative) showed significantly shorter than that in true-positive patients with abnormal uptake in bone scintigraphy (1.3 ± 0.2 months vs 5.2 ± 2.1 months, respectively; $P < 0.001$). Even if the bone scintigraphy was a well-known sensitive tool for detection of TMJ lesions, painful symptom could be developed earlier than appearing abnormality on bone scitingraphy. A weakness of using bone scintigraphy to evaluate TMJs is the relatively low specificity because growth, healing bone, infection, arthritic changes, or bone tumors may be positive on bone scintigraphic images.[6] Although our results showed lower sensitivity than did the previous study, we cautiously suggest that our relatively higher specificity from the quantitative assessment may compensate for the weakness of bone scintigraphy.

We initially hypothesized that the quantitative method would be more valuable than a visual analysis to evaluate painful TMD, but the results were not consistent with this hypothesis. Indeed, we showed that the quantitative method did not provide more information than visually interpreting the bone scintigraphic results in terms of diagnosing painful TMD. Although the mechanism is unclear, bone scintigraphic results should be visually evaluated carefully, and not only in terms of quantitative values.

Another unexpected finding was the lack of agreement between the visual and quantitative analysis results. We identified significant differences between the 2 methods. Thus, the visual findings did not always agree with the quantitative values, which should be considered when interpreting bone scintigraphic results.

The limitations of this study include the lack of a normal control group to compare with the patients with TMD. Thus, we did not obtain normal quantitative TMJ uptake ratio values and only obtained a cutoff uptake ratio for patients with TMD. Further studies including normal volunteers may be necessary to formulate more accurate conclusions. Another limitation is that single photon emission computed tomography (SPECT) data of TMJ could not be acquired in our patients. Indeed, previous studies reported the superiority of bone SPECT for detecting TMD than planar image.[10,19,23,24] An additional comparison study between visual and quantitative analyses including both SPECT and planar data will provide more precise results.

In conclusion, visual analysis of bone scintigraphy results showed diagnostic utility similar to that of quantitative assessment for diagnosing painful TMD. Qualitative and quantitative assessments of the bone scintigraphic results were complementary in patients with painful TMD.

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