RESEARCH

Effectiveness of bone scans in the diagnosis of osteoarthritis of the temporomandibular joint

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Objective: The objective of this study was to evaluate the usefulness of bone scan procedures for the diagnosis of temporomandibular joint (TMJ) osteoarthritis.

Methods: From February 2009 to June 2009, 22 patients (4 males and 18 females) from Seoul National University Bundang Hospital, Republic of Korea, were diagnosed with TMJ disorder. They were examined by clinical examination, plain radiograph and bone scan and were categorized into three groups: normal, internal derangement and osteoarthritis. TMJ uptake ratios and asymmetrical indices were calculated.

Results: There were no significant differences in uptake ratios associated with pain and bone change. However, significant results were obtained when comparing uptake ratios between the osteoarthritis and non-osteoarthritis groups.

Conclusion: It was concluded from this study that bone scans may help to diagnose osteoarthritis when increased uptake ratios are observed.

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Introduction

Osteoarthritis, previously referred to as the degenerative joint disease of the temporomandibular joint (TMJ), is a physical response to increased force on the TMJ and refers to the degenerative state associated with secondary inflammation.¹ Osteoarthritis occurs in most people, but is nonetheless more prevalent in females than in males and has been shown to be highly associated with increasing age.² According to Dworkin and LeResche,³ criteria for the diagnosis of osteoarthritis include the presence of pain, both subjective and palpatory, and auscultation of crepitus. Radiological characteristics such as structural changes, including erosion of the cortical bone of the condyle or mandibular fossa, sclerosis and flattening of the condyle, and osteophytes could also indicate a diagnosis of osteoarthritis.

For the diagnosis of TMJ diseases, useful imaging techniques include plain radiological tests such as

panoramic and transcranial radiography, tomography, arthrography, CT and MRI.^{4,5} Nuclear medical test methods include bone scan and single photon emission CT (SPECT).¹ However, plain radiography has some limitations, including the fact that it cannot evaluate the centre and medial side of the condyle and that a difference in bone mineral content of at least 30–50% is required for the detection of a bone lesion.^{6,7} Bone scans show positive detectable signals even with the increase in osteoblast activity of approximately 10%, and their sensitivity is very high, making bone scans advantageous for the early diagnosis of lesions. However, the specificity of bone scans is relatively low.^{8,9}

Standard radiography has several limitations for the evaluation of the bone structure of the TMJ. Nonetheless, after the diagnosis of osteoarthritis based on previous clinical assessment and radiography, if bone scan results are applied as an additional diagnostic tool, an accurate and rapid diagnosis can be made and treatment could be initiated more quickly. In our study, the association of diagnosis based on clinical symptoms and general radiographs with the results of bone scan was examined.

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Materials and methods

Subject

Among patients who visited the Bundang Seoul University dental clinics from February 2009 to June 2009 and were clinically diagnosed with TMJ impairment, 22 patients (44 TMJs) were suspected to have osteoarthritis and standard bone scan procedures were performed. These patients (4 males and 18 females) were selected as the subjects for this study. The age distribution ranged from 18 years to 70 years, with a mean age of 36.2 years. Diagnostic methods included consideration of clinical findings, the research diagnostic criteria for temporomandibular disorders (RDC/TMD) chart, standard panoramic radiography, TMJ panoramic radiography and bone scan results. Clinical diagnosis was based on RDC/TMD Axis I (clinical physical examination) and the clinical findings—amount of mouth opening, pain, joint sound, tenderness etc. Internal derangement (ID) of the TMJ can be defined as an abnormal relationship between the articular disc and the mandibular condyle, articular fossa and the articular eminence.¹⁰ In patients with symptoms of joint noise during normal function, mouth opening limitations, temporary joint locking and pain were defined as ID. Osteoarthritis was defined if there was palpation pain, subjective pain report, any coarse crepitus sound during any movement, bony change on radiography and increased uptake on bone scan. Patients received a diagnosis of normal joint, ID or osteoarthritis (Table 1). Detailed diagnostic groups are listed in Figure 1. There was an additional myofascial pain group which was characterized by the existence of palpation pain on the muscle site and more than 40 mm of pain-free opening. However, in our study, myofascial pain diagnosis was excluded because of the pathological state related to soft tissue.

Standard and TMJ panoramic radiography was interpreted by two clinicians who majored in radiology and oral and maxillofacial surgery. Diagnostic agreement of radiological interpretation was measured by the kappa statistic, which was 0.530. This is interpreted as moderate agreement beyond chance.

The acquisition and analysis of bone scan images

Image acquisition

⁹⁹Tc^m hydroxymethylene diphosphonate (HDP) 1 295 MBq (35 mCi) was injected intravenously and bone scan images were obtained after 3 h. Using a double-head gamma camera equipped with a low-energy,

Table 1 Temporomandibular joint distribution according to temporomandibular disorder diagnosis and bone changes

	Normal	ID	OA
No bony change	5	12	0
Bone change	0	9	18

ID, internal derangement; OA, osteoarthritis.

Figure 1 Distribution of diagnostic groups according to multiple categories. OA, osteoarthritis; ID, internal derangement; MP, myofascial pain

high-resolution collimator (ADAC Forte; Philips Healthcare, Andover, MA), 500 000 counts from each patient were obtained from the lateral side of the right and left regions of the cranium.

Image analysis

Qualitative analysis: Experienced nuclear medicine clinicians evaluated the uptake level of ⁹⁹Tc^m-HDP by the TMJ through visual analysis. The uptake values of the TMJ were compared with the uptake of the contralateral joint. The change in the appearance of the mandibular condyle was observed by orthopantomography and panoramic TMJ radiography and was classified by a dentist as one of the following: no change, sclerosis, erosion, deformity, flattening or osteophyte.

Quantitative analysis: To quantitate the ⁹⁹Tc^m-HDP uptake level of the TMJ, a square region of the area of interest (13 × 13 pixels) was designated for evaluation and the counts in both the TMJ and parietal bones were measured (Figure 2). For the right and left TMJ regions, the uptake ratio using the parietal bone as a background measurement was obtained and the asymmetrical index of the normal joint (contralateral to the TMJ) was calculated using the following formulas:¹¹

- TMJ uptake ratio = (TMJ counts – background counts)/background counts.
- Asymmetrical index for the involved TMJ joint = TMJ uptake ratio of the involved joint/TMJ uptake ratio of the non-involved joint.

Statistical analysis

Statistical analysis was performed by the Kruskal–Wallis test or the Mann–Whitney test using SPSS 12.0 (IBM Corporation, Armonk, NY). By the analysis of the receiver operating characteristic (ROC) curve, the optimal cut-off values for the diagnosis of osteoarthritis from specific bone scan parameters were obtained. Values of *p* < 0.05 were considered to be significant.

Figure 2 How to draw region of interests (ROIs) on bone scan planar images. On the right (Rt) and left (Lt) lateral skull images, 13 × 13 pixel-square ROIs were located at the bilateral temporomandibular joints (TMJ) and parietal skull areas. BG, background

Results

Comparison of the simple uptake rate of bone scan according to the pattern of arthralgia

13 patients presented with subjective joint pain and 2 presented with joint pain during palpation in the vicinity of the TMJ. 21 patients presented with both subjective and palpatory pains and 8 presented without joint pain. With regards to the simple uptake rates of the bone scan, the patients who presented with both subjective and palpatory pains showed a tendency towards lower simple uptake rates than the patients who presented with subjective pain only or palpatory pain only. Nonetheless, statistically significant differences between these two groups were not observed ($p = 0.328$) (Table 2).

Comparison of the simple uptake rates of bone scans according to the presence or absence of bone change

The simple uptake was shown to be lower in the cases where bone change in the mandibular condyle was detected by standard and TMJ panoramic radiography ($n = 27$) than in the cases that did not show bone

changes ($n = 17$) and these differences were not statistically significant ($p = 0.262$) (Table 3).

Comparison of the simple uptake rates of bone scans according to diagnosis

The simple uptake rates of normal joints ($n = 5$), temporomandibular ID ($n = 21$) and osteoarthritis ($n = 18$) as diagnosed on the basis of clinical symptoms and radiographs were compared. Osteoarthritic joints showed a tendency towards higher simple uptake rates, and in temporomandibular ID cases the uptake rates were lower than those of normal joints. Nevertheless, statistically significant differences between these two groups were not observed ($p = 0.098$) (Table 4). However, when the subjects studied were divided into osteoarthritis ($n = 18$) and non-osteoarthritis ($n = 26$) groups, the former group showed significantly higher uptake rates than the latter group ($p = 0.034$) (Table 5).

Comparison of the asymmetric indices between the unilateral osteoarthritis group and the bilateral osteoarthritis group

The asymmetrical indices of the unilateral osteoarthritis group ($n = 6$) and the bilateral osteoarthritis group ($n = 22$) were compared. The unilateral osteoarthritis group showed a tendency towards slightly higher indices but statistically significant results between these two groups were not observed ($p = 0.222$) (Table 6).

ROC curve

ROC analysis on the effectiveness of bone scan procedures for the diagnosis of osteoarthritis was performed. Although the asymmetrical index indicated that bone scan was not effective ($p = 0.377$), the uptake ratio showed effective results ($p = 0.034$). The diagnosis of osteoarthritis is therefore indicated when the uptake rate is higher than 3.88, sensitivity is 72.2% (13/18) and specificity is 57.7% (15/26) (area under the curve = 0.690, $p = 0.034$) (Figure 3).

Discussion

Temporomandibular arthritis includes osteoarthritis, osteoarthrosis and polyarthritides.¹ Osteoarthritis shows a pattern of slow progression of temporomandibular arthralgia and gradual deterioration of the joint. If such pain is not treated within a reasonable time frame, it

Table 2 Temporomandibular joint uptake ratio according to subjective and palpatory arthralgia

	Subjective arthralgia ($n = 13$)	palpatory arthralgia ($n = 2$)	Both ($n = 21$)	No arthralgia ($n = 8$)	p^*
Uptake ratio	4.09 ± 0.51	4.46 ± 0.45	3.63 ± 0.83	3.85 ± 0.87	NS

NS, not significant.

* p -Value calculated with Kruskal–Wallis test.

Table 3 Comparison of uptake ratio between bone changed group and bone not changed group at panorama

	Bone not changed (n = 17)	Bone changed (n = 27)	p*
Uptake ratio	4.06 ± 0.61	3.71 ± 0.85	NS

NS, not significant.

*p-Value calculated with Mann–Whitney *U*-test.

induces physical, behavioural, psychological and social problems such as anxiety, sleep disorders, depression and inertia, so its accurate diagnosis and treatment are essential.⁷ For the diagnosis of osteoarthritis, diverse clinical, radiological, nuclear and medical tests have been applied. Among them, the sensitivity of bone scan procedures is comparatively high; hence, it has been used as an effective diagnostic tool for TMD.¹²

In bone scan procedures, ⁹⁹Tc^m is injected and after 3 h the uptake of ⁹⁹Tc^m is examined. Uptake measurements depend on the blood flow volume and the amount of calcium contained in the phosphate binding sites on bone crystals; the uptake is increased in the areas where osteoblast activity is high with abundant blood flow.¹² It has been reported that in bone scans, the uptake rate is highest in younger patients and in menopausal women, the uptake in the cranial area is higher than that observed in non-menopausal women.^{8,13} Kigami *et al*¹⁴ have reported that uptake rates are noticeably higher in females than in males.

Epstein *et al*¹² have reported that bone scans are very useful to assess the stability of the TMJ and the presence or absence of active inflammatory reactions. Goldstein *et al*⁷ have reported that for the diagnosis of deformities in the TMJ, bone scan is a better method than orthopantomography, transcranial radiography or tomography. In our study, we obtained similar results demonstrating that the osteoarthritis group showed significant increases in uptake rates when compared with the non-osteoarthritis group, confirming that bone scans are useful tools for the diagnosis of osteoarthritis. Numerous cases that have applied bone scan procedures for the evaluation of the TMJ such as the remodelling of the mandibular condyle, bone resorption and metastatic lesions have been reported.¹² However, although the sensitivity of bone scans is very high and lesions can be detected early, specificity is low and squamous cell carcinoma, chondrosarcoma, metastatic disease, eosinophilic granuloma, cysts, osteomyelitis, trauma, Paget's disease, metabolic disorders such as hyperthyroidism, fibrous dysplasia, osteoporosis, arthritis, bone graft and other diverse bone and soft tissue diseases may show identical results. Therefore, it is necessary to confirm diagnoses by combining the clinical findings of patients,

Table 4 Distribution of bone scan results upon diagnostic results

	Normal (n = 5)	ID (n = 21)	Osteoarthritis (n = 18)	p*
Uptake ratio	3.71 ± 0.95	3.63 ± 0.73	4.12 ± 0.69	NS

ID, internal derangement; NS, not significant.

*p-Value calculated with Kruskal–Wallis test.

Table 5 Uptake ratio distribution between osteoarthritis and no osteoarthritis group

	No osteoarthritis (n = 26)	Osteoarthritis (n = 18)	p*
Uptake ratio	3.65 ± 0.79	4.12 ± 0.69	.034

*p-Value calculated with Mann–Whitney *U*-test.

other radiological results and symptoms.¹⁵ Kircos *et al*¹⁶ have reported that in patients with TMD, the sensitivity of bone scan procedures was 93% and the specificity was 86%. In our study, the results show that sensitivity of bone scans was 72.2% and specificity was 57.7%.

According to Pertes *et al*,¹⁷ temporomandibular osteoarthritis may occur in cases with chronic disc displacement. The shape of discs can change over time and after the appearance of intermittent as well as continuous disc lock, soft tissues and hard tissues change, resulting in the development of osteoarthritis. Keller¹⁸ has reported that bone scans are helpful in the diagnosis of disc displacement and other research has suggested that bone scan procedures are effective in distinguishing disc displacement from osteoarthritis.¹⁹ However, Creaemer and Ficara⁸ have reported that bone scans are not a reliable means to diagnose disc placement.

At the time of osteoarthritis diagnosis, the presence or absence of subjective and palpatory pain becomes an important clinical marker for differential diagnosis. In both osteoarthritis and osteoarthrosis, structural changes of the condyle are detected by radiography. However, these disorders can also be determined by the presence or absence of subjective and palpatory pains. In our study, in patients who presented with subjective or palpatory pains, the uptake rates were higher than those in patients without pain. In patients who presented with both subjective and palpatory pains, the uptake was shown to be lower. Notably, patients with, for example, capsulitis, retrodiscitis or myalgia may present with pain, and increased uptake in bone scan is the reaction of bones, not the inflammatory area.²⁰ Therefore, the diagnosis of osteoarthritis simply by the presence or absence of pain and the result of increased of bone scan uptake may be erroneous; therefore, it is recommended that clinicians consider these limitations in the diagnosis of osteoarthritic conditions. Ogus *et al*²¹ have also reported that the association of pain with radiological changes in the TMJ is low.

The cases with structural changes such as erosion of the condyle, sclerosis, flattening of the condyle, and osteophytes on panoramic radiographs were assigned

Table 6 Comparison of asymmetric index between unilateral osteoarthritis and bilateral osteoarthritis group

	Unilateral osteoarthritis (n = 6)	Bilateral osteoarthritis (n = 12)	p*
Asymmetric index	1.07 ± 0.11	1.01 ± 0.14	NS

NS, not significant.

*p-Value calculated with Mann–Whitney *U*-test.

Figure 3 Receiver operating characteristic (ROC) curve of uptake ratio (UR) and asymmetrical index (AI); the closer the curve follows the left-hand border and then the top border of the ROC space, the more accurate the test

as the bone structure change group and were compared with other groups. The results demonstrate that the bone scan uptake rates were higher in the group without structural bone changes. In a study by Bush *et al*,²² the results of a bone scan were reported to be in disagreement with panoramic radiography, thus confirming that bone scan procedures are not absolute standards for the assessment of the condylar change of the TMJ. Therefore, bone scans should be applied as supplement indices for early diagnosis of osteoarthritis, not the absolute index for the diagnosis of osteoarthritis, which should be determined in combination with the results of clinical testing, radiological evaluation and CT.

The presence or absence of subjective or palpatory pains does not correlate with bone changes on plane radiographs. Nonetheless, bone scan evaluation is considered effective if patients are diagnosed by combining the results of bone scan procedures with

clinical observations and plain radiological testing. However, the limitations of our study include a small sample size, and thus significant results could not be derived from the data we obtained. In this study, only one clinician did the clinical and panoramic radiographic examinations and later diagnosed the interpretations of the bone scans. However, since panoramic radiographs are known to have poor inter- and intraobserver reliability in the diagnosis of TMJ changes, a second observer reviewed the panoramic radiographs. The interobserver reliability was 0.520 using the kappa statistic, which showed moderate agreement. This could also have affected the results.

Therefore, future studies focusing on larger patient cohorts and more joints are required. In addition, TMD has symptoms that can change with time and thus comparison and examination of bone scan uptake rates from the initial diagnosis through to long-term follow-up periods is considered to be meaningful.

Conclusion

This study was conducted to assess the usefulness of bone scan procedures for the diagnosis of osteoarthritis of the TMJ. The results of clinical tests, radiological tests and bone scans of 22 patients (44 TMJs) were analysed and the following results were obtained:

- (1) In the cases diagnosed as temporomandibular osteoarthritis, the uptake rates of the TMJ increased; however, the presence or absence of arthralgia or bone alterations was not significantly associated with the uptake rates observed in the bone scans.
- (2) Patients received a diagnosis of osteoarthritis when the uptake rate exceeded 3.88, sensitivity was 72.2% and specificity was shown to be 57.7%.

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