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T2 relaxation times of the retrodiscal tissue in patients with temporomandibular joint disorders and healthy volunteers: A comparative study

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Conflict of interest: None

Statement of Clinical Relevance

T2 relaxation time is an important quantitative diagnostic marker, which may be
predictive of temporomandibular disorders. We support this assumption by showing that T2 relaxation times of the retrodiscal tissue in the temporomandibular joint correlate well with progressive temporomandibular disorders.

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Abstract

Objective: The aims of this study were to compare temporomandibular joint (TMJ) retrodiscal tissue T2 relaxation times between patients with temporomandibular disorders (TMDs) and asymptomatic volunteers and to assess their diagnostic potential.

Study Design: Patients with TMD (n = 173) and asymptomatic volunteers (n = 17) were examined using a 1.5 T magnetic resonance (MR) scanner. The imaging protocol consisted of oblique sagittal T2-weighted eight-echo fast spin echo sequences in a closed mouth position. Retrodiscal tissue T2 relaxation times were obtained. Additionally, disc location and reduction, disc configuration, joint effusion, osteoarthritis, and bone edema or osteonecrosis were classified using MR images. The T2 relaxation times of each group were statistically compared.

Results: Retrodiscal tissue T2 relaxation times were significantly longer in patient groups than in asymptomatic volunteers (p < 0.01). T2 relaxation times were significantly longer in all of the morphological categories. The most important variables affecting retrodiscal tissue T2 relaxation times were disc configuration, joint effusion, and osteoarthritis.

Conclusion: Retrodiscal tissue T2 relaxation times of patients with TMD were significantly longer than those of healthy volunteers. This finding may lead to the
development of a diagnostic marker to aid in the early detection of TMDs.

**Keywords:** Retrodiscal tissue; T2 relaxation time; Temporomandibular disorder; Temporomandibular joint (TMJ); Quantitative magnetic resonance imaging (MRI)

**Introduction**

The most widespread clinical symptoms of patients with temporomandibular joint (TMJ) disorders (TMDs) are noise, TMJ pain, and other disturbances associated with closing and opening the mouth. TMDs are characterized by an internal derangement (ID) of the TMJ. ID is a general orthopedic term suggesting a mechanical fault that interferes with the smooth action of a joint.\(^1\) The most common ID is displacement of the articular disc (AD) of the TMJ.\(^2\) This displacement can be easily diagnosed with magnetic resonance imaging (MRI).\(^2\) However, the cause and mechanism of ID have not yet been identified, and it has been suggested that the retrodiscal tissue of the TMJ might be involved.\(^3\)

The retrodiscal tissue of the TMJ contains loosely associated collagen fibers, a branching system of elastic fibers, fat deposits, a specialized arterial blood supply, a large venous plexus, lymphatics, and a profuse nerve supply.\(^4\) Some histological
studies have identified increased retrodiscal tissue vascularization in patients with TMD.\textsuperscript{5}

Several qualitative and morphological studies investigating TMDs with MRI have been reported.\textsuperscript{6} Moreover, clinical MRI studies have reported decreased or increased T2 signal intensity in the retrodiscal tissue of patients with TMD.\textsuperscript{3, 4, 7, 8} The high signal intensity of retrodiscal tissue on T2-weighted images (T2WI) can, in some patients, be clinically observed through visual inspection without advanced assessment (Figure 1). However, visual inspection does not provide an unequivocal answer as to what would statistically constitute significantly high signal intensity on T2WI. Quantitative MR studies investigating the AD of the TMJ or the masseter muscle have been recently reported.\textsuperscript{9-14} Although T2 relaxation time, a quantitative MR parameter, is potentially related to TMDs, a comparison of retrodiscal tissue T2 relaxation times between healthy volunteers and patients with TMD has not yet been reported.

We hypothesize that the T2 relaxation time of TMJ retrodiscal tissue correlates with qualitative and morphological variations in TMJ pathology. Therefore, the aims of the present study were to (1) measure TMJ retrodiscal tissue T2 relaxation times in patients with TMD and healthy volunteers and (2) identify any associations between T2 relaxation time and TMD MRI findings, which could serve as a diagnostic marker.
Materials and methods

Study population

This study was approved by the Institutional Review Board of the Osaka University Graduate School of Dentistry. After explaining the nature of the procedures to the participants, informed consent was obtained from all participants included in the study.

From 2009 to 2014, a total of 183 consecutive patients with TMD were referred for an MRI scan due to TMJ or facial pain, mandibular dysfunction, or suspicion of ID. These patients were registered for the study. Ten patients were excluded from the study due to excessive motion or the presence of metallic artifacts on MR images. Consequently, 173 patients (46 men and 127 women, median age, 35 y; age range, 11–80 y, 50 bilateral and 123 unilateral symptomatic patients) were analyzed.

Additionally, 21 healthy volunteers underwent MR examination. MR images of the TMJs of four volunteers demonstrated abnormal findings, such as anterior disc displacement. Therefore, data from these volunteers were excluded from the present study. The remaining 17 healthy volunteers with superior AD position (12 men and 5 women; median age, 26 y; age range, 23–32 y) were judged as having normal TMJs.

In an earlier study, the T2 relaxation time of the TMJ AD was investigated, whereas in the current study, we report on the T2 relaxation time of TMJ retrodiscal tissue.
MRI

All subjects were examined using a 1.5 T MR scanner (Signa HDxt 1.5T; GE Healthcare, Milwaukee, WI, USA) equipped with a TMJ surface coil. The imaging protocol for TMD diagnosis consisted of oblique sagittal and coronal fast spin echo proton density-weighted image (FSE-PDWI) sequences (TR/TE/echo train length [ETL]/number of excitations [NEX], 2500 ms/20 ms/8/2) and fat-suppressed T2WI sequences (TR/TE/ETL/NEX, 2000 ms/85 ms/16/3) at right angles and parallel to the long axis of the mandibular condyle in a closed mouth position. Additionally, sagittal FSE-PDWI sequences (TR/TE/ETL/NEX, 800 ms/24 ms/4/2) were obtained in closed and open mouth positions using the following parameters: field of view (FOV), 120 × 120 mm; matrix size, 256 × 160; slice thickness, 3 mm; and gap, 1 mm. To measure T2 relaxation times, oblique sagittal eight-echo FSE sequences at right angles to the long axis of the mandibular condyle were obtained in a closed mouth position using the following parameters: TR/TE/NEX, 1000 ms/8.9, 17.8, 26.7, 35.6, 44.5, 53.4, 62.4, 71.3 ms/2; FOV, 120 × 120 mm; matrix size, 256 × 160; slice thickness, 4 mm; and gap, 1 mm. For this sequence, the total acquisition time was 5 min and 22 s.
MR image evaluation

All MR images were independently assessed by two experienced oral and maxillofacial radiologists. Whenever disagreement occurred, the final diagnosis was made by consensus. The radiographic features evaluated were AD position and reduction, AD configuration, joint effusion, osteoarthritis, and bone marrow abnormalities.\(^\text{13}\)

AD position and reduction were classified into five categories, following Tasaki et al.\(^\text{15}\), with some minor modifications. On sagittal PDWIs in closed and open mouth positions, the possible classifications were normal superior (NorSup), partial anterior disc displacement with reduction (PADDWR), partial anterior disc displacement without reduction (PADDWOR), anterior disc displacement with reduction (ADDWR), or anterior disc displacement without reduction (ADDWOR). AD configuration was further divided into six categories, following Murakami et al.\(^\text{16}\) with some slight modifications. On oblique sagittal PDWIs in a closed mouth positions, AD was classified as biconcave, biplanar, hemi-convex, thickening of the posterior band, biconvex, or folded. Following Larheim et al.,\(^\text{17}\) joint effusion was classified into four categories, including none observed or minimal fluid, moderate fluid, marked fluid, or extensive fluid on oblique sagittal fat-suppressed T2WIs in a closed mouth position.
When osteophytes and/or erosion was observed, the joint was classified as positive for osteoarthritis, and when neither was observed, the joint was classified as negative for osteoarthritis (see also\textsuperscript{18}). Following Larheim et al.,\textsuperscript{19} when bone marrow edema and/or osteonecrosis was present on oblique sagittal PDWIs and T2WIs in a closed mouth position, the joint was classified as positive for bone marrow abnormalities, and if these features were absent, the joint was classified as negative.

\textit{Measuring T2 relaxation time}

Eight-echo FSE image data were initially transferred to an independent workstation (Advantage Workstation ver. 4.4; GE Healthcare, Milwaukee, WI, USA). To measure T2 relaxation times, two independent observers (NK and HS) manually and independently generated regions of interests (ROIs) in the retrodiscal tissue, which included the bilaminar zone adjacent to the AD as well as the upper and lower portions of the bilaminar zone (Figure 2). The average T2 relaxation time value of the three retrodiscal tissue ROIs was defined as the retrodiscal tissue T2 relaxation time. The T2 relaxation time of the retrodiscal tissue was calculated using Functool 4.4.5 software (GE Healthcare, Milwaukee, WI, USA). The averages of the T2 relaxation time values determined by the independent observers was defined as the definitive T2 relaxation time.
Statistical analysis

To assess whether reliable intra-observer reproducibility could be obtained, one observer (NK) positioned the ROIs on the retrodiscal tissue of asymptomatic volunteers 10 times on different days. To assess intra-observer reproducibility, the variation coefficient of 10 normal volunteer retrodiscal tissue data sets was calculated. To evaluate the inter-observer reproducibility, an intraclass correlation coefficient was calculated for the normal volunteer and patient retrodiscal tissue T2 relaxation time data obtained by the two observers.

For healthy volunteers, paired t-tests were used to compare retrodiscal tissue T2 relaxation times between the right and left TMJs. A p-value < 0.05 was considered significant. To compare retrodiscal tissue T2 relaxation times between healthy volunteers and patients, Kruskal-Wallis tests were performed. A p-value < 0.05 was considered significant. Post hoc pairwise analysis performed using the Mann-Whitney U test with Bonferroni correction with p-values < 0.05/6 for AD position and reduction, < 0.05/7 for AD configuration, < 0.05/5 for joint effusion, and < 0.05/3 for osteoarthritis and bone marrow abnormalities was considered significant. Stepwise multiple regression analyses were used to identify important variables related to retrodiscal tissue T2 relaxation times between MR image interpretations, and patient age and gender were
considered as potentially confounding variables. Significance needed for removal was set at a p-value of > 0.10, and significance for re-entry was set at a p-value of < 0.05.

All statistical analyses were performed using a commercially available software package (IBM SPSS Statistics version 22.0; IBM-SPSS, Inc., Chicago, IL, USA).

Results

Intra-observer reproducibility determined with a variation coefficient of normal volunteers’ retrodiscal tissue T2 relaxation times ranged from 1.5 to 5.5%.

Inter-observer reproducibility determined with an intraclass correlation coefficient for the normal volunteer and patient retrodiscal tissue T2 relaxation time data obtained by the two observers was 0.818 (p < 0.001).

The TMJ MR findings of normal volunteers and patients are summarized in Table I. The mean retrodiscal tissue T2 relaxation times are shown in Table II. In normal volunteers, there were no significant differences in retrodiscal tissue T2 relaxation times between the left and right TMJs (34.4 ± 3.5 and 34.4 ± 3.0 ms, p = 0.888). There were significant differences in mean retrodiscal tissue T2 relaxation times between the normal volunteers and patients with TMD (34.4 ± 3.2 and 39.3 ± 6.4 ms, respectively, p < 0.001).
Regarding AD position and reduction, mean retrodiscal tissue T2 relaxation times of
the NorSup, PADDWR, PADDWOR, ADDWR, and ADDWOR patient groups were
37.7 ± 5.9, 39.5 ± 5.2, 41.1 ± 5.9, 36.6 ± 4.7, and 42.1 ± 6.8 ms, respectively. The
mean retrodiscal tissue T2 relaxation times of the NorSup, PADDWR, and ADDWOR
patient groups were significantly longer than that of the volunteer group (p < 0.01/6 for
volunteer group vs. PADDWR or ADDWOR patient group; p < 0.05/6 for volunteer
group vs. NorSup patient group). Moreover, the mean retrodiscal tissue T2 relaxation
time of the ADDWOR group was significantly longer than those of the NorSup and
ADDWR patient groups (p < 0.01/6; Figure 3A).

Regarding AD configurations, mean retrodiscal tissue T2 relaxation times of the
biconcave, biplanar, hemicconvex, thickening of the posterior band, biconvex, and folded
groups were 37.7 ± 5.8, 38.2 ± 5.1, 40.3 ± 6.4, 40.9 ± 6.2, 42.4 ± 9.2, and 42.3 ± 7.3 ms,
respectively. The mean retrodiscal tissue T2 relaxation times of the biconcave,
biplanar, hemicconvex, thickening of the posterior band, and folded groups were
significantly longer than that of the volunteer group (p < 0.05/7; Figure 3B). The
mean retrodiscal tissue T2 relaxation times of the thickening of the posterior band and
folded groups were significantly longer than that of the biconcave group (p < 0.01/7;
Figure 3B).
Regarding joint effusion, mean retrodiscal tissue T2 relaxation times of the none observed or minimal fluid, moderate fluid, marked fluid, and extensive fluid patient groups were 38.5 ± 6.0, 38.5 ± 5.9, 42.4 ± 5.9, and 47.0 ± 8.7 ms, respectively. The mean retrodiscal tissue T2 relaxation times of all joint effusion category groups were significantly longer than that of the volunteer group (p < 0.01/5; Figure 3C). The mean retrodiscal tissue T2 relaxation times of the marked and extensive fluid patient groups were significantly longer than those of the the none observed or minimal fluid patient group and the moderate fluid group (p < 0.01/5; Figure 3C).

Regarding osteoarthritis, the mean retrodiscal tissue T2 relaxation times of patients with negative and positive findings were 38.3 ± 5.9 and 43.9 ± 7.2 ms, respectively. The mean retrodiscal tissue T2 relaxation time of the osteoarthritis-positive patient group was significantly longer than those of the volunteer and osteoarthritis-negative patient groups (p < 0.01/3; Figure 3D). The mean retrodiscal tissue T2 relaxation time of the osteoarthritis-negative patient group was significantly longer than that of the normal healthy volunteer group (p < 0.01/3; Figure 3D).

Regarding bone marrow abnormalities, the mean retrodiscal tissue T2 relaxation times of patients with negative and positive findings were 38.8 ± 6.3 and 44.4 ± 6.4 ms, respectively. The mean retrodiscal tissue T2 relaxation time of the bone marrow
abnormality-positive patient group was significantly longer than those of volunteer and bone marrow abnormality-negative patient groups (p < 0.01/3; Figure 3E). The mean retrodiscal tissue T2 relaxation time of the bone marrow abnormality-negative patient group was significantly longer than that of the normal healthy volunteer group (p < 0.01/3; Figure 3E).

According to the stepwise multiple regression analysis, AD configuration (p = 0.033), joint effusion (p < 0.001), and osteoarthritis (p = 0.001) were the most important variables affecting retrodiscal tissue T2 relaxation time (Table III). The multiple correlation coefficient (R), the coefficient of determination (R², which depicts the explanatory power of the model), and the adjusted coefficient of determination (adjusted R², i.e., a version of R² adjusted for the number of predictors in a model) of the stepwise multiple regression analyses concerning retrodiscal tissue T2 relaxation times of were 0.626, 0.392, and 0.384, respectively (p < 0.001).

**Discussion**

The measurement of T2 relaxation times is widely used as a quantitative MRI technique. T2 relaxation times reflect structural changes in the organization of cartilage collagen fibers. The interaction between water and collagen fibers is used to visualize collagen organization, extracellular matrix structure, and water content.
change in T2 relaxation time is an early sign of structural change in tissues. TMJ AD

T2 relaxation times between volunteers and patients with TMD were previously reported to reflect TMD structural and functional properties and correlate with TMD progression.9, 10, 12, 13

The retrodiscal tissue extends from the posterior margin of the posterior band to the retroarticular process.21 This tissue mainly consists of loose connective tissue, such as elastin and collagen fibers, and includes a large venous plexus in its deeper layers.22 Although the AD and its attachments contain the same major histological constituents, the relative amounts of these components vary based on the functional requirements of the tissue.23 Therefore, quantitative measurements of the retrodiscal tissue T2 relaxation time is possible, and pathological changes can be detected at early stages.

Histological studies have shown that pathological TMDs often display increased retrodiscal tissue vascularization.24-27 Kurita et al.26 showed that the number of blood vessels in retrodiscal tissue increased significantly in patients with TMD. Holmlund et al.27 reported findings associated with inflammation, such as hyperemia and perivascular infiltration, in the retrodiscal tissue of patients with TMD. These histological findings might be associated with increased retrodiscal tissue T2 relaxation times. Conversely, Isberg et al.25 observed nerve fibers and thickened adventitia of the
vessels in retrodiscal tissue in a small subset of patients with ADDWOR. Hall et al.\textsuperscript{24} reported that patients with TMD who reported pain did not exhibit inflammation; however, thickened arterial walls were confirmed in 54\% of patients. These histological findings seem to suggest decreased retrodiscal tissue T2 relaxation times. Therefore, histological differences in retrodiscal tissue might be dependent on the exact stage of the disease.

Clinical MRI studies have reported decreased and increased retrodiscal tissue T2 signal intensities in patients with TMD.\textsuperscript{3, 4, 7, 8, 21} Westesson et al.\textsuperscript{3} investigated the posterior attachment of the area near the AD and found that the decreased signal intensity in this area on T2WIs and PDWIs was linked to fibrosis. However, Sakuma et al.\textsuperscript{21} reported that decreased signal intensity on T1-weighted images of retrodiscal tissue did not reflect a dense construction of collagen fibers. Sano et al.\textsuperscript{7} reported that T2WI signal intensity (which is not equivalent to T2 relaxation time) in the retrodiscal tissue of patients with TMD reporting pain was significantly higher than that for patients without pain. Katzberg et al.\textsuperscript{4} reported that T2WI signal intensity in the posterior attachment was typically higher in the patient group than in the healthy volunteer group. Both studies indicated that these findings might be due to retrodiscal tissue vascularity or the presence of edema. Chiba et al.\textsuperscript{28} also connected increased
T2WI signal intensity of the retrodiscal tissue with pain and reported that observations of ADDWOR and osteoarthritis correlated with pain. Lee et al.\(^8\) reported that the signal intensity ratio of the retrodiscal tissue might be linked with disc displacement, joint effusion, condylar degenerative change, and joint pain. In dynamic contrast-enhanced MRI studies, an increase in retrodiscal tissue contrast was confirmed in joints that elicited pain.\(^5,29\) These findings suggest that if contrast accurately reflects increased blood flow, then blood flow to the retrodiscal tissue of the painful joint should increase.

The present results indicate that T2 relaxation time can be a valuable predictor of TMD progression. These findings are consistent with qualitative reports linking pain with increased signal intensity in diagnostic MRI findings and T2WIs. Consequently, retrodiscal tissue T2 relaxation time likely correlates well with perceived TMJ pain\(^7\) and may serve as an early diagnostic marker for TMD.

In a previous study, TMJ AD T2 relaxation times were significantly different with respect to disc position, joint effusion, osteoarthritis, and bone marrow abnormality.\(^13\) However, there were no significant differences in AD configuration. In the current study, retrodiscal tissue T2 relaxation times were significantly different for all morphological categories, including AD configuration. This suggests that retrodiscal
tissue T2 relaxation time might be more sensitive than AD T2 relaxation time. This study had some limitations. First, there was a lack of histological comparison between the T2 relaxation time and retrodiscal tissue. According to a recent treatment plan for patients with TMD, the use of drugs, splinting, and physiotherapy are the primary treatment options, and no patients included in the present study had undergone surgery. Therefore, comparing MRI findings and tissue samples was impossible. Second, subjective clinical findings, such as patient pain and discomfort, were not evaluated and compared to retrodiscal tissue T2 relaxation time. Therefore, future studies comparing clinical findings are necessary. Third, it is possible that the signal of the retrodiscal tissue was influenced by a partial volume effect (i.e., influenced by the surrounding tissue); however, this is difficult to prove. Finally, the number of patients (n = 173) differed significantly from that of healthy volunteers (n = 17). Future studies of T2 relaxation times associated with TMD would benefit from a more balanced ratio of patients and healthy volunteers.
In conclusion, the retrodiscal tissue T2 relaxation times of patients with TMD were significantly longer than those of healthy volunteers. The most important variables affecting retrodiscal tissue T2 relaxation times were AD configuration, joint effusion, and osteoarthritis. Thus, TMJ retrodiscal tissue T2 relaxation time likely correlates with TMD progression and may be used to predict the course of TMDs.

Acknowledgments:

The authors wish to pay their respects to the late Professor Souhei Furukawa for his invaluable guidance.
References


24. Hall MB, Brown RW, Baughman RA. Histologic appearance of the bilaminar


between contrast enhancement of the posterior disk attachment and joint pain.

### Table legends

Table I. Characteristics and magnetic resonance findings of volunteers and patients

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<thead>
<tr>
<th></th>
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<tr>
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<tr>
<td>Female</td>
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<td>Age Median</td>
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Articular disc position and reduction (joints)

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<td>NorSup</td>
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<tr>
<td>PADDWR</td>
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<td>22</td>
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<tr>
<td>PADDWOR</td>
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<td>ADDWR</td>
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<td>53</td>
</tr>
<tr>
<td>ADDWOR</td>
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Articular disc configuration (joints)

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<tr>
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<tr>
<td>Biplanar</td>
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<tr>
<td>Hemiconvex</td>
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<tr>
<td>Thickening of the posterior band</td>
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<tr>
<td>Biconvex</td>
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<td>7</td>
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<tr>
<td>Folded</td>
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Joint effusion (joints)

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<td>Moderate fluid</td>
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<td>Marked fluid</td>
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<td>Extensive fluid</td>
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<tr>
<td></td>
<td>Negative</td>
<td>Positive</td>
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<tr>
<td>Osteoarthritis (joints)</td>
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<td>Bone marrow abnormality (joints)</td>
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<td>Negative</td>
<td>34</td>
<td>317</td>
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<tr>
<td>Positive</td>
<td>0</td>
<td>29</td>
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</table>

NorSup; normal superior
PADDWR; partial anterior disc displacement with reduction
PADDWOR; partial anterior disc displacement without reduction
ADDWR; anterior disc displacement with reduction
ADDWOR; anterior disc displacement without reduction
Table II. T2 relaxation time of the retrodiscal tissue

<table>
<thead>
<tr>
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<th>T2 relaxation time (ms)</th>
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<tr>
<td>Volunteers</td>
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<tr>
<td>Left TMJ</td>
<td>34.4 ± 3.5</td>
<td></td>
</tr>
<tr>
<td>Right TMJ</td>
<td>34.4 ± 3.0</td>
<td>0.888</td>
</tr>
<tr>
<td>All TMJ</td>
<td>34.4 ± 3.2</td>
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<tr>
<td>Volunteers: All TMJ</td>
<td>34.4 ± 3.2</td>
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<tr>
<td>Patients: All TMJ</td>
<td>39.3 ± 6.4</td>
<td>&lt; 0.001*</td>
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*; The T2 relaxation times of all TMJs in patients were significantly different from those of all TMJs in volunteers.

TMJ: temporomandibular joint

Table III. Stepwise multiple regression model for T2 relaxation time of the retrodiscal tissue
<table>
<thead>
<tr>
<th>Variable</th>
<th>Unstandardized coefficient (β)</th>
<th>Unstandardized coefficient (SE)</th>
<th>Standardized coefficient (β)</th>
<th>t (β)</th>
<th>P</th>
<th>95% confidence interval</th>
</tr>
</thead>
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<tr>
<td>Articular disc configuration</td>
<td>1.408</td>
<td>0.658</td>
<td>0.098</td>
<td>2.13</td>
<td>0.03</td>
<td>0.11 2.70</td>
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<tr>
<td>Joint effusion</td>
<td>2.137</td>
<td>0.559</td>
<td>0.161</td>
<td>3.82</td>
<td>&lt; 1</td>
<td>1.03 3.23</td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td>2.646</td>
<td>0.808</td>
<td>0.150</td>
<td>3.27</td>
<td>0.00</td>
<td>1.05 4.23</td>
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Figure legends

Figure 1. A 26-year-old woman (volunteer) and 69-year-old man with a temporomandibular disorder. (A) The retrodiscal tissue (arrow) of the temporomandibular joint (TMJ) in a volunteer shows low signal intensity (T2 relaxation time: 26.9 ms) on T2-weighted image (T2WI). (B) The retrodiscal tissue (arrow) of the TMJ in a patient with anterior disk displacement without reduction shows high signal intensity (T2 relaxation time: 52.7 ms) on T2WI.
Figure 2. A 25-year-old woman (volunteer) and a 37-year-old woman with a temporomandibular disorder. Magnetic resonance images of the retrodiscal tissue of the temporomandibular joint of a volunteer (A, B, and C). The regions of interest used for measuring T2 relaxation time in the retrodiscal tissue included the bilaminar zone adjacent to the articular disc (A) as well as upper (B) and lower (C) portion of the bilaminar zone. T2 relaxation times on a color map ranged from 25 (red color) to 75 ms (blue color) in a volunteer (D) and patient with anterior disc displacement without reduction (E).
Figure 3. Box-and-whisker plots of the distribution of retrodiscal tissue T2 relaxation times (A, B, C, D, and E). Outlier data points are also shown. (A) T2 relaxation times of the retrodiscal tissue according to the articular disc (AD) position and reduction categories (*p < 0.05/6, Mann-Whitney U test with Bonferroni correction). (B) T2 relaxation times of retrodiscal tissue according to AD configuration categories (*p < 0.05/7, Mann-Whitney U test with Bonferroni correction). (C) T2 relaxation times of retrodiscal tissue according to joint effusion categories (*p < 0.05/5, Mann-Whitney U
test with Bonferroni correction). (D) T2 relaxation times of retrodiscal tissue according
to osteoarthritis categories (*p < 0.05/3, Mann-Whitney U test with Bonferroni
correction). (E) T2 relaxation times of retrodiscal tissue according to bone marrow
abnormality categories (*p < 0.05/3, Mann-Whitney U test with Bonferroni correction).
NorVol, normal volunteers; NorSup, normal superior patients; PADDWR, partial
anterior disc displacement with reduction; PADDWOR, partial anterior disc
displacement without reduction; ADDWR, anterior disc displacement with reduction;
ADDWOR, anterior disc displacement without reduction; Thickening, thickening of the
posterior band; None, none observed or minimal fluid; Moderate, moderate fluid;
Marked, marked fluid; Extensive, extensive fluid.