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RESEARCH ARTICLE

Assessment of MRI findings and clinical symptoms in patients with temporomandibular joint disorders

[1]Risa Matsubara, [2]Yoshinobu Yanagi, [3]Kazuhiro Oki, [4]Miki Hisatomi, [5]Karina CP Santos, [1,6]Babatunde O Bamgbose, [7]Mariko Fujita, [4]Shunsuke Okada, [3,8]Shogo Minagi and [1,4,7]Junichi Asaumi

[1]Department of Oral and Maxillofacial Radiology, Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, Okayama University, Okayama, Japan; [2]Department of Dental Informatics, Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, Okayama University, Okayama, Japan; [3]Department of Occlusal and Oral Functional Rehabilitation, Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, Okayama University, Okayama, Japan; [4]Department of Oral Diagnosis and Dentomaxillofacial Radiology, Okayama University Hospital, Okayama, Japan; [5]Department of Stomatology, School of Dentistry, University of Sao Paulo, Sao Paulo, Brazil; [6]Oral Diagnostic Sciences, Faculty of Dentistry, Bayero University, kano, Nigeria; [7]Preliminary Examination Room, Okayama University Hospital, Okayama, Japan; [8]Department of Occlusal and Oral Funtional Rehabilitation, Okayama University Hospital, Okayama, Japan

Objectives: To investigate the correlations among various temporomandibular joint (TMJ) findings on MRI and the relationships between MRI findings and symptoms.
Methods: 425 patients (850 TMJs) with temporomandibular joint disorders (TMDs) who underwent MRI were enrolled. Oblique sagittal proton density-weighted and T_2 weighted images in open- and closed-mouth positions were evaluated. MRI findings included disc configuration, disc position, condylar morphology, bone marrow pattern, and joint effusion. Symptoms included TMJ pain, TMJ noise, and limitation of mouth opening. For statistical analyses, Spearman's rank correlation coefficient and logistic regression analysis were applied.
Results: Folded disc, disc displacement without reduction (DDWOR), and osteophytes had significant negative correlations with other normal MRI findings ($p < 0.01$). DDWOR and marrow edema were associated with TMJ pain. Conversely, osteophytes [odds ratio (OR): 0.52; 95%CI (0.30–0.90)] and combination-type condylar degeneration [OR: 0.45; 95%CI (0.24–0.83)] were associated with decreased risk of TMJ pain. Condylar flattening was positively associated with TMJ noise [OR: 5.25; 95%CI (1.44–19.07)] and negatively associated with limitation of mouth opening [OR: 0.34; 95%CI (0.11–0.99)]. High-grade joint effusion was significantly associated with TMJ pain and noise.
Conclusions: DDWOR and high-grade joint effusion (an indicator of inflammation in the articular cavity) were associated with TMD symptoms. This finding suggests that treatment strategy for DDWOR and decreasing inflammation might lessen clinical TMD symptoms. Condylar degeneration was not associated with indicators of inflammation or TMJ symptoms. These results suggest that patients with TMD symptoms should undergo initial MRI to allow rapid selection of appropriate therapies.
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Correspondence to: Prof Yoshinobu Yanagi, E-mail: ya7@okayama-u.ac.jp
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Introduction

Temporomandibular joint disorders (TMDs) present with characteristic clinical signs and symptoms, including temporomandibular joint (TMJ) and facial pain, joint noise, and irregular jaw movement. MRI is widely used to evaluate TMJ characteristics, such as disc configuration, disc position, condylar morphology, bone marrow signal pattern, and the presence of joint effusion. Complicated associations among various MRI findings of the TMJ have been reported.[1–7] Deformity of disc configuration is associated with internal derangement of the TMJ[1–3] and condylar degenerative change.[1] Internal derangement is associated with condylar degenerative change[1,4,5] and joint effusion.[6,7] However, these associations have involved only two or three MRI findings. A comprehensive study that includes more MRI findings and more detailed classification is necessary. An analysis of correlations among various changes in TMJ structures may reveal key abnormalities that are important for clinical treatment.

Relationships between the clinical signs and symptoms of TMD and MRI findings have also been reported.[8–15] TMJ pain, the most common clinical symptom, correlates with internal derangement,[7–10] bone marrow abnormality,[9,11–13] condylar degenerative change,[9,10,14,15] and joint effusion.[7,9,10,13] Bone marrow edema has been associated with increased pain in TMDs.[13] However, few reports have described the relationships between joint noise or irregular jaw movements and MRI findings. An evaluation of the relationships between TMD symptoms and MRI findings with detailed classifications may reveal which symptoms warrant MRI examination, thus reducing unnecessary radiographic examinations prior to MRI.

The aim of this this study was to comprehensively assess (1) the correlations among various MRI findings, including disc configuration, disc position, condylar morphology, bone marrow signal pattern, and joint effusion, and (2) the relationships between symptoms of TMD and MRI findings in a relatively large number of patients.

Methods and materials

Patients

The study included 850 TMJs in 425 participants (97 males and 328 females) with TMDs who underwent MRI at the Department of Occlusal and Oral Functional Rehabilitation at our university hospital from August 2011 to July 2014. Clinical diagnosis was made according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD).[16] Patients with a history of TMJ trauma or systemic disease were excluded.

Clinical assessment included patient-reported functional pain in the TMJ region (TMJ pain), TMJ noise, and limitation of mouth opening. TMJ pain was defined as pain with jaw movement or during mastication. TMJ noise was defined as any joint noise during jaw opening or closing. Limitation of mouth opening was defined as jaw opening limitation severe enough to interfere with the ability to eat.

MRI

MRI was performed with head coils on one of four machines: 1.5 T Magnetom Vision (Siemens Healthineers, Erlange, Germany), 1.5 T Achieva (Philips Healthcare, Best, Netherlands), 3.0 T Magnetom Skyra (Siemens Healthineers, Erlange, Germany), 3.0 T Magnetom Verio (Siemens Healthineers, Erlange, Germany) (Table 1). The use of different machines for scanning did not affect the results of the study. Sagittal plane imaging parallel to the long axis of the mandibular ramus was carried out using proton density-weighted and T_2 weighted sequences in the open-mouth and closed-mouth positions. Multiple radiologists certified by the Society for Oral and Maxillofacial Radiology of our country evaluated the MRIs. All diagnoses were confirmed by at least two radiologists.

Disc configuration was classified according to Arayasantiparb et al[2] as biconcave ("bow tie" shape with thick anterior and posterior bands and a narrow intermediate zone), flattened (anterior band, intermediate zone, and posterior band of the same thickness), convex (roundish disc shape with convex upper or lower surface), or folded (disc with any folded portion). All disc configurations were evaluated in the closed-mouth position (Figure 1).

Internal derangements were classified according to Koh et al[4] as normal (posterior band located above the apex of the condylar head in the closed-mouth position and thin intermediate zone located between the

Table 1 MRI parameters and coils

	TR/TE/TE[a]	*FOV (cm)*	*Thickness (mm)*	*Matrix*	*NEX*	*Coil*
1.5 T Magnetom Vision	2000/14/85	6–13	3	160 × 512	2	CP Head coil
1.5 T Achieva	1500/16/100	15–15	3	145 × 192	3	Flex-M coil
3.0 T Magnetom Skyra	2940/22/98	9–12	3	110 × 192	2	20-channel Head coil
3.0 T Magnetom Verio	2940/22/98	9–12	3	108 × 192	2	20-channel Head coil

[a]TR/TE/TE, TR of both proton density-weighted and T_2 weighted sequences/ TE of proton density-weighted sequences/ TE of T_2 weighted sequences.

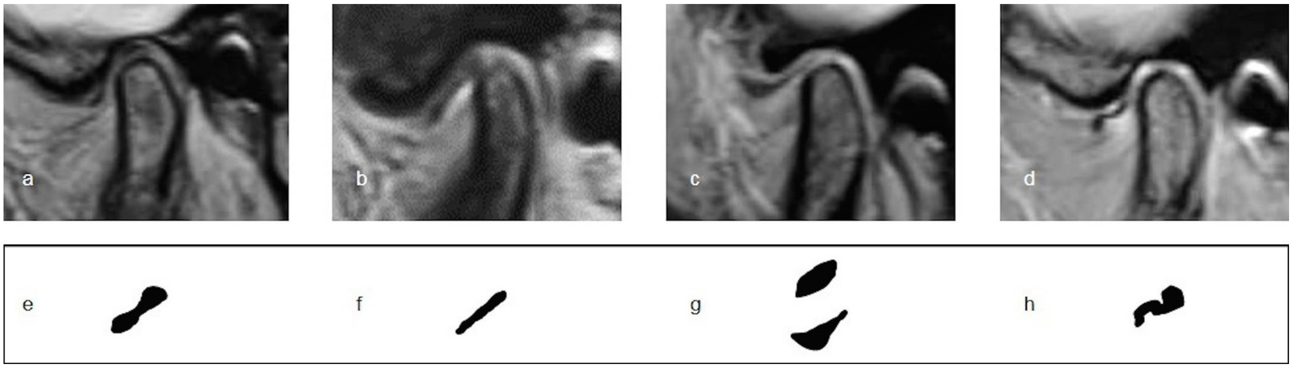

Figure 1 Types of disc configurations on proton density-weighted images. (a, e) Biconcave disc. (b, f) Flattened disc. (c, g) Concave disc. (d, h) Folded disc.

condyle and the articular eminence in the open-mouth position), disc displacement with reduction (DDWR; posterior band located anterior to the condylar head in the closed-mouth position, but with a normal disc–condyle relationship in the open-mouth position), or disc displacement without reduction (DDWOR; posterior band positioned anterior to the condyle in both the closed-mouth and open-mouth positions).

Degenerative condylar morphology was classified according to Roh et al[6] as erosion (interruption or absence of cortical lining), sclerosis (dense and thickened variations of subchondral bone shown as thickening of cortical bone on proton density-weighted images), flattening (loss of round contour), osteophytes (marginal hypertrophic bone formation), or combination type (combinations of the previous morphologies) (Figure 2).

Condylar bone marrow signal pattern was classified according to Larheim et al[17] as normal (homogeneous bright signal on proton density-weighted images and homogeneous intermediate signal on T_2 weighted images), marrow edema (increased signal on T_2 weighted images), marrow sclerosis (decreased signal on proton density-weighted and T_2 weighted images), or combined edema and sclerosis (Figure 3).

Joint effusions were classified into four degrees based on previous reports[6,17] as follows: Grade 0, no bright T_2 signal intensity in joint space; Grade 1, dots or lines of bright T_2 signal intensity along articular surface; Grade 2, bands of bright T_2 signal intensity; and Grade 3, collection with pooling of bright T_2 signal intensity in joint space (Figure 4).

Data analysis

Descriptive analyses of central tendencies were reported as mean, median, and percentile. Inferential statistical analyses were evaluated with Spearman's rank correlation coefficient and logistic regression analysis. All analyses were carried out with IBM SPSS Statistics Base 24.0 (Tokyo, Japan).

Results

The ratio of females to males was 3.38:1. The median patient age was 49 years (25th percentile: 29 years; 75th percentile: 63 years; range: 12–86 years). MRI findings are shown in Table 2. DDWR was seen in 42.8% of participants with internal derangement. The patterns of disc configuration, condylar morphology, bone marrow signal, and joint effusion were predominantly normal. TMJ pain and noise occurred in 44.1% (375/850 TMJs) and 45.8% (389/850 TMJs), respectively. Limitation of mouth opening was present 51.8% of participants (220/425 patients).

The correlations among MRI findings according to Spearman's rank correlation coefficients are shown in Table 3. There was a strong positive correlation between biconcave disc and normal disc position (r = 0.706, p < 0.01). Folded disc had a moderate positive correlation with DDWOR (r = 0.467, p < 0.01), whereas flattened disc had a weak positive correlation with DDWR (r = 0.320, p < 0.01).

DDWOR had weak negative correlations with normal disc configuration (r = −0.323, p < 0.01),

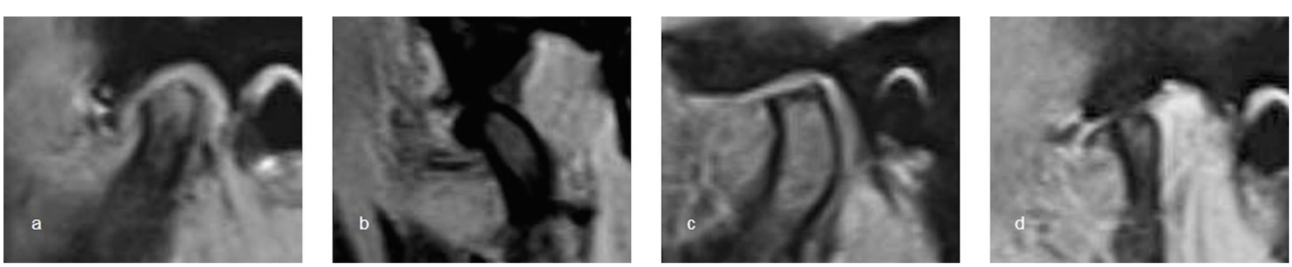

Figure 2 Proton density-weighted images show condylar degenerative morphologies. (a) Erosion. (b) Sclerosis. (c) Flattening. (d) Osteophytes.

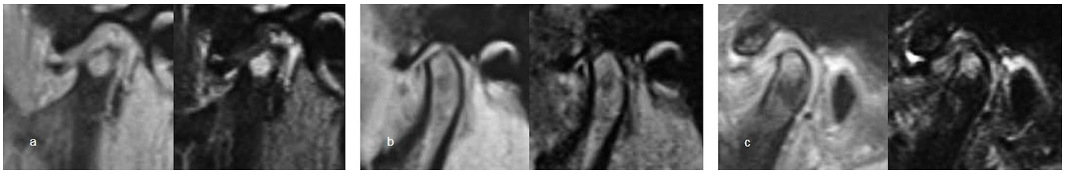

Figure 3 Proton density-weighted images (left) and $T2$ weighted images (right) show condylar bone marrow abnormalities. (a) Bone marrow edema. (b) Bone marrow sclerosis. (c) Bone marrow edema with sclerosis.

condylar morphology ($r = -0.375$, $p < 0.01$), bone marrow signal pattern ($r = -0.369$, $p < 0.01$), and joint effusion ($r = -0.390$, $p < 0.01$) and had moderate positive correlations with osteophytes ($r = 0.418$, $p < 0.01$), marrow edema with and without sclerosis ($r = 0.213$, $p < 0.01$ and $r = 0.281$, $p < 0.01$, respectively), and Grade 3 joint effusion ($r = 0.296$, $p < 0.01$). Folded disc configuration had negative correlations with normal disc position ($r = -0.421$, $p < 0.01$), bone marrow signal pattern ($r = -0.244$, $p < 0.01$), and joint effusion ($r = -0.352$, $p < 0.01$). Osteophytes had positive correlations with DDWOR ($r = -0.418$, $p < 0.01$) and with marrow edema with and without sclerosis ($r = 0.260$, $p < 0.01$ and $r = 0.232$, $p < 0.01$, respectively).

Table 4 shows the odds ratios (ORs) and 95% confidence intervals (CIs) for MRI findings according to TMD symptom. TMJ pain was significantly associated with DDWOR [OR: 2.95; 95% (CI 1.85–4.68)], marrow edema [OR: 3.13; 95% CI (1.66–5.90)], Grade 2 joint effusion [OR: 1.80; 95% CI (1.13–2.87)], and Grade 3 effusion [OR: 2.46; 95% CI (1.33–4.55)]. However, osteophytes [OR: 0.52; 95% CI (0.30–0.90)] and combination-type condylar degeneration [OR: 0.45; 95% CI (0.24–0.83)] were negatively associated with TMJ pain. TMJ noise was significantly associated with DDWOR [OR: 1.95; 95% CI (1.24–3.06)], flattening of the condylar surface [OR: 5.25; 95% CI (1.44–19.07)], Grade 2 joint effusion [OR: 2.59; 95% CI (1.64–4.11)], and Grade 3 joint effusion [OR: 3.79; 95% CI (2.03–7.05)]. Limitation of mouth opening was positively associated with DDWR [OR: 1.91; 95% CI (1.36–2.67)] and DDWOR [OR: 1.97; 95% CI (1.27–3.17)] and was negatively associated with flattening of the condylar surface [OR: 0.34; 95% CI (0.11–0.99)].

Discussion

Correlations among MRI findings in the TMJ were comprehensively analyzed in a large number of patients in this study. Biconcave disc configuration correlated strongly with normal disc position, as previously reported.[1] Positive correlations were found between DDWOR and folded disc and between DDWR and flattened disc. Given the hypothesis that internal derangement precedes disk deformation,[18] DDWOR and DDWR appear to be responsible for folded and flattened deformation, respectively.

DDWOR had a moderate positive correlation with osteophytes and folded disc, and negatively correlated with other normal MRI findings. In contrast, there were no significant correlations between DDWR and abnormalities of the condylar surface, bone marrow signal pattern, or joint effusion. Moreover, the risk of each TMD symptom was significantly higher in joints with DDWOR. Conversely, the ORs for TMJ pain and noise were not higher in joints with DDWR. Both DDWR and DDWOR have been reported to increase the risks of condylar degenerative change.[5,6] The different findings for DDWR in this study are interesting. It appears that when the disc intervenes between the temporal fossa and the condylar surface in the open-mouth position, the damage during jaw function is minimized. Retaining DDWR status seems to be beneficial in maintaining a normal condylar surface, bone marrow, and joint effusion. These findings suggest that treatment strategy for DDWOR to reduce strain and/or injury to the TMJ may effectively lessen the clinical symptoms of TMDs.

Folded disc correlated with abnormalities of disc position, condylar morphology, and bone marrow signal pattern. Osteophytes correlated with folded disc, DDWOR, and bone marrow edema with and without sclerosis. High-grade (Grades 2 and 3) joint effusions, which reflect the inflammatory reaction in the articular cavity,[19,20] correlated with folded disc and DDWOR. Based on these observations, DDWOR, folded disc, and osteophytes appear to be the key MRI abnormalities in patients with TMDs. However, we found no significant correlation between condylar degeneration and joint effusion. This finding suggests that condylar

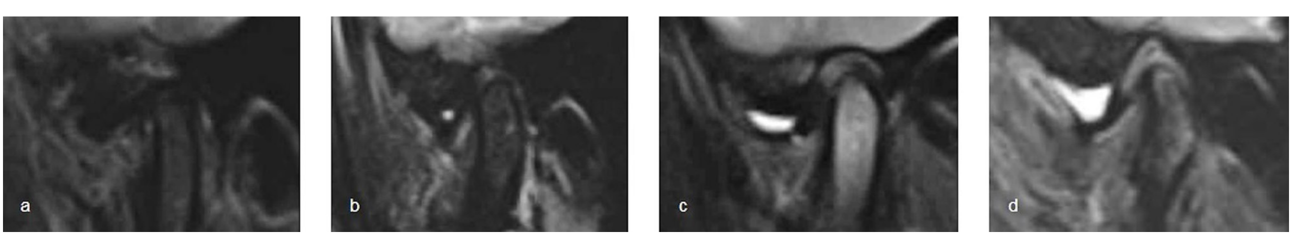

Figure 4 $T2$ weighted images show joint effusions. (a) Grade 0. (b) Grade 1. (c) Grade 2. (d) Grade 3.

Table 2 Characteristics of TMJs (n = 850)

		No.	*%*
	Biconcave	257	30.2
	Flattened	191	22.5
	Convex	89	10.5
Disc configuration	Folded	313	36.8
	Normal	245	28.8
	DDWR	364	42.8
Internal derangement	DDWOR	241	28.4
	Normal	584	68.7
	Flattening	67	7.9
	Erosion	28	3.3
	Sclerosis	17	2.0
	Osteophyte	86	10.1
Condylar morphology	Combination	68	8.0
	Normal	726	85.4
	Edema	67	7.9
Condylar bone marrow signal pattern	Sclerosis	12	1.4
	Edema with sclerosis	45	5.3
	Grade 0	371	43.6
	Grade 1	285	33.5
	Grade 2	124	14.6
Joint effusion	Grade 3	70	8.2

TMJ, temporomandibular joint.

degeneration is not related to inflammatory conditions in the articular cavity.

Patients with TMJ pain had higher ORs for DDWOR, bone marrow edema, and high-grade joint effusion. These findings suggest that abnormalities in the articular cavity and condylar bone marrow cause TMJ pain. Moreover, in contrast with previous studies,[9,14,15] osteophytes and combination-type condylar degeneration were associated with a decreased risk of TMJ pain. Isberg described changes in the soft tissues during the chronic progression of condylar degeneration, with soft-tissue proliferation allowing the contours to adapt morphologically to various mechanical stresses.[21] In the late stages of condylar degeneration, osteophytes and combination-type degeneration seem to lessen TMJ pain because of the compensatory changes in the surrounding soft tissues.

In a small study involving autopsy specimens, Widmalm et al[22] reported that clicking occurred in TMJs with DDWR, DDWOR, and arthrosis, while crepitation occurred only in joints with arthrosis and perforation. Our observations are similar to those findings, except that we only found significant associations with DDWOR and condylar flattening. Flattening change (disappearance of round contour) may lead to friction between the mandibular fossa and the condyle, causing crepitus. Significant increases in the risk of TMJ pain and noise occurred with Grade 2 and Grade 3 joint effusion. It appears that joint effusion, as an indicator of inflammation in the articular cavity, correlates with joint symptoms.

We found a significant relationship between limitation of mouth opening and both DDWR and DDWOR. Therefore, we infer that internal derangements mainly affect mandibular movements. In contrast, patients with condylar flattening tended not to have limitation of mouth opening.

Conclusion

In this study, condylar degeneration did not strongly affect TMD symptoms. However, DDWOR, bone marrow abnormalities, and high-grade joint effusion, which can only be observed with MRI examination, were risk factors for TMD symptoms. Panoramic radiography, tomography, and CBCT/CT, which mainly reveal condylar morphology, may not be very useful for evaluating the TMJ in most patients with TMDs. Initial MRI examination to evaluate the articular cavity should be considered in patients with TMD symptoms, allowing clinicians to choose appropriate therapies (medical therapy, physical therapy, or splinting) and reducing redundant medical radiation exposure and costs.

Table 3 Correlations among various MRI findings in temporomandibular disorder, according to Spearman's rank correlation coefficient (n = 850)

	Biconcave	*Flattened*	*Convex*	*Folded*	*Normal ID*	*DDWR*	*DDWOR*	*Normal CM*	*Erosion*	*Sclerosis*	*Flattening*	*Osteophytes*	*Combi nation*	*Normal BM*	*BM edema*	*BM sclerosis*	*Edema with sclerosis*
Normal ID	0.706	−.137	−.209	−.421													
p-value	0.00	0.00	0.00	0.00													
DDWR	−.352	0.320	0.154	−0.040													
p-value	0.00	0.00	0.00	0.25													
DDWOR	−.323	−.214	0.041	0.467													
p-value	0.00	0.00	0.24	0.00													
Normal CM	0.190	0.072	−.076	−.195	0.250	0.112	−.375										
p-value	0.00	0.04	0.03	0.00	0.00	0.00	0.00										
Erosion	−.128	0.009	−0.009	0.119	−.140	−0.045	0.191										
p-value	0.00	0.79	0.80	0.00	0.00	0.19	0.00										
Sclerosis	−0.008	−0.027	0.100	−0.032	−0.034	−0.010	0.045										
p-value	0.81	0.43	0.00	0.35	0.32	0.77	0.19										
Flattening	−.136	−0.042	0.103	0.101	−.133	−0.026	0.162										
p-value	0.00	0.22	0.00	0.00	0.00	0.45	0.00										
Osteophytes	−.123	−.105	0.012	0.201	−.201	−.196	0.418										
p-value	0.00	0.00	0.73	0.00	0.00	0.00	0.00										
Combination	−.111	−0.067	0.067	0.121	−.123	−.127	.262										
p-value	0.00	0.05	0.05	0.00	0.00	0.00	0.00										
Normal BM	0.156	0.071	0.054	−.244	0.160	0.189	−.369	0.390	−.277	−.086	−.185	−.351	−.292				
p-value	0.00	0.04	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00				
BM edema	−.107	−0.053	−0.043	0.175	−.109	−.156	0.281	−.311	0.217	0.052	.168	.232	.217				
p-value	0.00	0.12	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00				
BM sclerosis	−0.035	0.031	−0.008	0.012	−.076	0.017	0.057	−.070	0.080	0.097	−0.049	0.027	0.001				
p-value	0.30	0.36	0.81	0.73	0.03	0.61	0.09	0.04	0.02	0.01	0.16	0.44	0.98				
Edema with sclerosis	−.098	−0.064	−0.029	0.168	−.081	−.120	0.213	−.203	0.134	0.021	.114	.260	.199				
p-value	0.00	0.06	0.39	0.00	0.02	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.00				
JE Grade 0	.206	0.168	0.017	−.352	0.257	0.120	−.390	0.185	−.113	−0.041	−.101	−.178	−.149	.196	−.134	0.015	−.155
p-value	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.66	0.00
JE Grade 1	−0.055	−0.024	0.001	0.073	−.078	−0.010	.090	−0.037	0.027	−0.020	0.039	0.056	.072	−0.031	0.033	−0.022	0.021
p-value	0.11	0.48	0.97	0.03	0.02	0.76	0.01	0.29	0.43	0.55	0.26	0.10	0.04	0.36	0.34	0.53	0.54
JE Grade 2	−.091	−.143	0.011	0.203	−.138	−0.055	0.198	−.124	0.074	0.086	0.061	0.065	0.060	−.150	.089	0.007	.126
p-value	0.01	0.00	0.75	0.00	0.00	0.11	0.00	0.00	0.03	0.01	0.08	0.06	0.08	0.00	0.01	0.84	0.00
JE Grade 3	−.160	−.079	−0.047	0.250	−.153	−.130	0.296	−.112	0.062	−0.001	0.037	.141	.068	−.107	.071	0.000	.082
p-value	0.00	0.02	0.18	0.00	0.00	0.00	0.00	0.00	0.07	0.97	0.28	0.00	0.05	0.00	0.04	0.99	0.02

BM, bone marrow; CM, condylar morphology; DDWOR, disc displacement without reduction; DDWR, disc displacement with reduction; ID, internal derangement; JE, joint effusion.

Table 4 Odds ratios for MRI findings according to temporomandibular joint symptom (n = 850)

		Pain			*Noise*			*Limitation*		
		OR	*(95% Cl)*	*p-value*	*OR*	*(95% Cl)*	*p-value*	*OR*	*(95% Cl)*	*p-value*
Internal derangement	Normal	1.00			1.00			1.00		
	DDWR	0.87	(0.62–1.24)	0.45	1.10	(0.78–1.56)	0.58	1.91	(1.36–2.67)	0.00
	DDWOR	2.95	(1.85–4.68)	0.00	1.95	(1.24–3.06)	0.00	1.97	(1.27–3.07)	0.00
Condylar morphology	Normal	1.00			1.00			1.00		
	Erosion	0.59	(0.33–1.06)	0.08	1.07	(0.62–1.83)	0.81	1.14	(0.68–1.92)	0.62
	Sclerosis	0.42	(0.17–1.05)	0.06	0.93	(0.40–2.16)	0.86	1.61	(0.70–3.74)	0.26
	Flattening	1.46	(0.51–4.17)	0.48	5.25	(1.44–19.07)	0.01	0.34	(0.11–0.99)	0.05
	Osteophytes	0.52	(0.30–0.90)	0.02	0.91	(0.54–1.54)	0.74	1.11	(0.67–1.83)	0.69
	Combination	0.45	(0.24–0.83)	0.01	0.65	(0.36–1.16)	0.15	0.93	(0.53–1.63)	0.80
Bone marrow signal pattern	Normal	1.00			1.00			1.00		
	Edema	3.13	(1.66–5.90)	0.00	1.67	(0.92–3.05)	0.09	1.06	(0.60–1.87)	0.84
	Sclerosis	3.13	(0.81–12.17)	0.10	1.44	(0.41–5.03)	0.57	1.05	(0.31–3.50)	0.94
	Edema with sclerosis	1.94	(0.97–3.90)	0.06	1.03	(0.53–2.02)	0.93	0.93	(0.48–1.78)	0.82
Joint effusion	Grade 0	1.00			1.00			1.00		
	Grade 1	1.11	(0.79–1.57)	0.55	1.23	(0.88–1.72)	0.22	1.13	(0.81–1.56)	0.47
	Grade 2	1.80	(1.13–2.87)	0.01	2.59	(1.64–4.11)	0.00	1.49	(0.95–2.33)	0.09
	Grade 3	2.46	(1.33–4.55)	0.00	3.79	(2.03–7.05)	0.00	1.13	(0.64–1.99)	0.68

Cl, confidence interval; DDWOR, anterior disc displacement without reduction; DDWR, anterior disc displacement with reduction; OR, odds ratio.
Adjusted for internal derangement, condylar morphology, bone marrow signal pattern and joint effusion.
Pain (Hosmer and Lemeshow test; $p = 0.873$); noise (Hosmer and Lemeshow test; $p = 0.513$); limitaion (Hosmer and Lemeshow test; $p = 0.644$).

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