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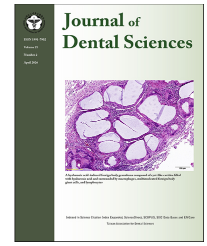

Original Article

Correlation between signal intensity ratio of magnetic resonance imaging and arthroscopic findings in temporomandibular joint synovitis

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Abstract *Background: /purpose*: Temporomandibular joint (TMJ) disorders commonly involve intra-articular synovitis, which causes pain and limits function. This study investigated the associations of signal intensity ratios (SIRs) on T2-weighted magnetic resonance imaging (MRI) with the arthroscopic grading of synovitis for both anterior and posterior joint recesses.
Materials and methods: This study included 118 patients (131 joints) who presented with TMJ disorder symptoms and underwent both T2-weighted MRI and arthroscopic surgery. Regions of interest were identified on MRI by the same oral and maxillofacial surgeon, and SIRs were calculated for the anterior and posterior synovial spaces, with cerebral white and gray matter used as references. All surgical procedures were performed by the same oral and maxillofacial surgeon. Arthroscopic synovitis grading was independently conducted by two experienced oral and maxillofacial surgeons using McCain's classification system. The association between synovitis grade and SIRs in the anterior and posterior TMJ recesses was analyzed using the Kruskal—Wallis test followed by the Wilcoxon rank-sum post hoc test.
Results: For the 131 joints evaluated, the SIRs of the anterior and posterior joint recesses increased progressively with an increase in the synovitis grade. Significant positive correlations

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were discovered between synovitis grade and the SIRs in the two regions, indicating a strong association between T2-weighted MRI findings and arthroscopically observed severity of synovitis.
Conclusion: T2-weighted MRI SIRs were strongly correlated with arthroscopic synovitis grading in the anterior and posterior TMJ recesses. These findings suggest that quantitative MRI evaluation can increase diagnostic accuracy in cases of TMJ synovitis.

Introduction

Temporomandibular joint (TMJ) disorder is a highly prevalent disease characterized by pain in the head and neck region, joint sounds during mouth opening, and limited mandibular movement. According to one study, approximately 31 % of adults and approximately 11 % of adolescents and children are affected by a TMJ disorder. Of the various subtypes, disc displacement with reduction is reportedly the most common.[1]

The Diagnostic Criteria for Temporomandibular Disorders remain the internationally accepted standard for the diagnosis of TMJ disorders, enabling clinicians to make accurate diagnoses on the basis of both clinical and imaging findings. For intra-articular TMJ disorders, magnetic resonance imaging (MRI) is considered essential for accurate diagnosis.[2] Specifically, MRI is regarded as the gold standard for the identification of disc displacement.[3] However, systematic reviews have demonstrated that the diagnostic accuracy of MRI varies when it is used to assess other intra-articular TMJ disorders.[4]

Treatments for TMJ disorders are generally categorized into conservative and surgical approaches. Conservative treatments typically include patient education, occlusal splint therapy, and the administration of nonsteroidal anti-inflammatory drugs (NSAIDs). For patients who do not respond to conservative management or who experience frequent recurrence, surgical intervention may be required. The surgical treatment options include arthrocentesis, arthroscopic surgery, and open joint surgery, among which arthroscopic surgery has been widely adopted by clinicians because it is minimally invasive, the postoperative recovery time is short, and it can serve both diagnostic and therapeutic purposes. Arthroscopic procedures enable direct visualization of the internal structures of the TMJ, providing valuable information for definitive diagnosis.

Most patients who undergo TMJ surgery have undergone MRI of the TMJ. Although MRI and arthroscopy are distinct, both facilitate assessment of pathological changes to the internal structures of the TMJ. The potential correlation between these techniques has become an area of interest for researchers. Nevertheless, few studies have investigated this topic. Few studies have investigated the relationship between T2-weighted MRI findings and arthroscopic observations of TMJ synovitis, and most related studies have not used objective or quantitative indicators.[6,7] In clinical practice, MRI interpretation is often influenced by observer subjectivity, and achieving accurate evaluations can be challenging for less-experienced clinicians. Therefore, the present study established a standardized and quantitative approach for MRI evaluation and investigated the associations between signal intensity ratios (SIRs) on T2-weighted MRI and TMJ synovitis arthroscopic grading results. Employing this quantitative approach may help clinicians achieve more objective and precise preoperative assessment of synovial inflammation. Integrating artificial intelligence—assisted image analysis into assessments of synovial inflammation may further enhance the diagnostic accuracy and clinical applicability of MRI in TMJ disorders.

Materials and methods

Patient selection

This retrospective observational study was approved by the Research Ethics Committee of China Medical University (approval no. CMUH111-REC3-087). All patients included in the study were referred to the Department of Oral and Maxillofacial Surgery at China Medical University Hospital for TMJ syndrome and underwent TMJ arthroscopy between August 2020 and August 2024. Patients who (1) had undergone preoperative MRI for TMJ, (2) had subsequently undergone TMJ arthroscopy, and (3) had high-quality intraoperative imaging documentation were included. Those with (1) poor MRI image quality, (2) prior other surgery for TMJ, or (3) more than 3 months recorded between the date of imaging examination and arthroscopic surgery were excluded.

A total of 118 patients met the aforementioned criteria—91 women and 27 men, ranging in age from 14 to 79 years (average age: 37.2 years). Of the 118 patients, 13, 56, and 49 underwent bilateral, right, and left TMJ arthroscopy, respectively. A total of 131 joints were assessed. Bilateral joints from the same patient were analyzed as independent samples, which is consistent with the procedures in other TMJ imaging studies. All surgeries were performed by the same oral and maxillofacial surgeon, and TMJ examination and treatment were performed using a Karl Storz TMJ arthroscope (HOPKINS Telescope 0°, 2.4 mm, 10 cm; Karl Storz GmbH & Co. KG, Tuttlingen, Germany).

Interpretation of MRI and TMJ arthroscopic findings

All MRI scans were acquired using a 3.0-T scanner (SIGNA Architect, GE Healthcare, Chicago, IL, USA) equipped with a dedicated head and neck coil. T2-weighted fast spin-echo sequences (FAST_GEMS) were obtained with the following imaging parameters: repetition time, 400–600 ms; echo time, 6–10 ms; flip angle, 20°; field of view, 140 × 140 mm; acquisition matrix, 260 × 220; slice thickness, 2.0 mm; interslice gap, 0.2 mm; and total coverage, 46.6 mm.

For each patient, T2-weighted MRI findings were interpreted by the same oral and maxillofacial surgeon, who identified the regions of interest (ROIs) for signal intensity (SI) measurement. ROIs were selected at four sites: cerebral white matter, cerebral gray matter, the anterior recess of the TMJ space, and the posterior recess of the TMJ space. The boundary between the anterior and posterior recesses was defined on the basis of the articular eminence of the temporal bone. Image analysis was performed using INFINITT PACS software (INFINITT Healthcare, Seongnam, Republic of Korea; Fig. 1). SIRs were calculated using the following formula: SIR=(SIROI − SIwhite matter)/(SIgray matter − SIwhite matter). This equation was used to determine the SIRs for both the anterior (SIRanterior) and posterior (SIRposterior) recesses of the TMJ space.

The surgeon who interpreted the MRI findings and the surgeons who evaluated the arthroscopic images were blinded to each other's assessments to minimize potential bias. Two oral and maxillofacial surgeons retrospectively evaluated arthroscopic images obtained during TMJ surgeries. The surgeons reached a consensus on the diagnostic criteria for TMJ synovitis. The severity of synovitis was graded using the classification system proposed by Dr. McCain, with scores ranging from 1 (lowest severity) to 4 (highest severity) (Fig. 2).[8] One senior surgeon evaluated images twice; the other surgeon assigned scores on the basis of a single evaluation.

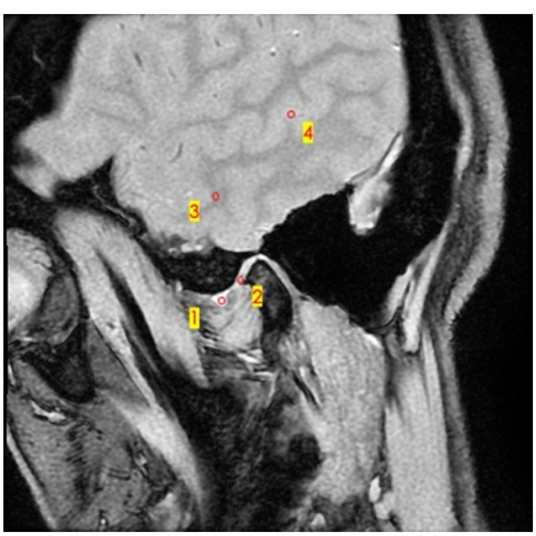

Figure 1 Numbers correspond to the following regions: 1, anterior recess of the temporomandibular joint (TMJ) space; 2, posterior recess of the TMJ space; 3, cerebral white matter; 4, cerebral gray matter. The articular eminence of the temporal bone defines the boundary between the anterior and posterior recesses. The measured area of each region of interest (ROI) was 1 mm^2.

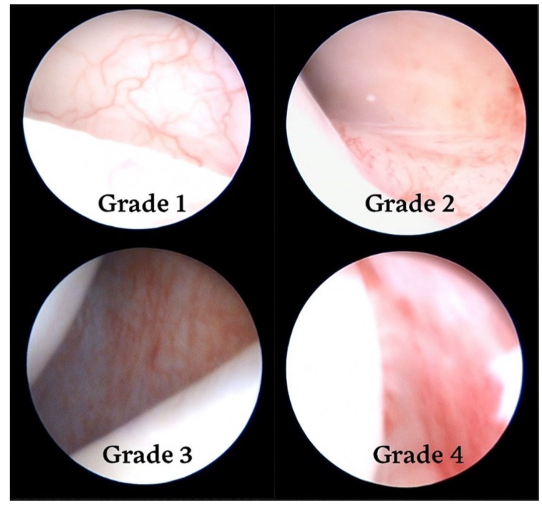

Figure 2 Images depicting grades 1 to 4 of temporomandibular joint (TMJ) synovitis. Images were taken during arthroscopy of study participants. Grade 1 is characterized by vascular dilation without hyperemia. Grades 2 and 3 represent intermediate stages, exhibiting vascular dilation accompanied by evident hyperemia. Grade 4 corresponds to advanced-stage synovitis, exhibiting extensive hyperemia.

Statistical analysis

Intraclass correlation coefficient (ICC) analysis was performed to assess the reliability of TMJ synovitis grading based on arthroscopic image interpretation, including both intraobserver and interobserver agreement.

The Kruskal–Wallis test was performed to evaluate the association between synovitis grading and the SIRs of the anterior and posterior recesses of the TMJ space. When overall significance was detected ($P < 0.05$), post-hoc pairwise comparisons were performed using the Wilcoxon rank-sum test with Bonferroni correction to control for multiple comparisons (adjusted $\alpha = 0.0083$).

Results

The ICC for repeated assessments performed by the same surgeon was 0.976, and the ICC for assessments performed by two different surgeons was 0.936. These results indicate that the synovitis grading was highly reliable.

Table 1 summarizes the descriptive statistics of the SIRs for the anterior and posterior recesses of the TMJ space across the four arthroscopic synovitis grades. The table presents the sample size (n), mean ± standard deviation (SD), and median with the first and third quartiles (Q1–Q3) values for the SIRs. Effect sizes (Cohen's d, calculated relative to grade 1 by using the pooled SD) are also reported for both recesses, with positive values indicating higher SIRs compared with grade 1. A progressive increase in SIR was observed with advancing synovitis grade, consistent with the visual trends noted in the box plots. The corresponding effect sizes demonstrated a progressive strengthening of differences between grades, supporting the discriminative value of SIRs in assessing synovial inflammation severity.

Table 1 Signal intensity ratio (SIR) descriptive statistics and effect sizes across arthroscopic synovitis grades.

Synovitis grade	N	Anterior SIR mean ± SD	Anterior SIR median (Q1—Q3)	Posterior SIR mean ± SD	Posterior SIR median (Q1—Q3)	Effect size (anterior)	Effect size (posterior)
1	13	0.162 ± 0.240	0.200 (0.056—0.328)	0.094 ± 0.502	0.125 (−0.138 −0.201)	0.00	0.00
2	60	0.690 ± 0.390	0.676 (0.504—0.816)	0.621 ± 0.371	0.572 (0.381—0.856)	1.63	1.19
3	36	1.030 ± 0.360	0.999 (0.856—1.211)	1.038 ± 0.459	0.936 (0.760—1.300)	2.84	1.96
4	22	1.425 ± 0.448	1.479 (1.175—1.668)	1.561 ± 0.457	1.548 (1.249—1.917)	3.52	3.05

Note. Data are presented as means ± standard deviations (SDs) and medians (Q1—Q3). N = sample size; SIR = signal intensity ratio; Q1 = first quartile; Q3 = third quartile. Effect sizes (Cohen's d) were calculated using grade 1 as the reference.

Box plots illustrating the SIRs of the anterior and posterior TMJ recesses across synovitis grades are presented in Fig. 3. As indicated, the median SIR values increased sequentially from grades 1 to 4 in both recesses. In total, 131 joints (13 grade-1 joints, 60 grade-2 joints, 36 grade-3 joints, and 22 grade-4 joints) were included in the analysis. In the anterior recess, the lowest SIR values were discovered for grade 1, and the SIR increased with an increase in the grade. A comparable upward trend was noted in the posterior recess, with the separation being more pronounced in the higher grades. Additionally, the interquartile ranges expanded with increasing synovitis severity, indicating greater variability in signal intensity in more advanced cases.

Table 2 presents intergroup differences between synovitis grades and SIR values in the anterior and posterior recesses. In all anterior recess comparisons, higher SIR values were associated with a higher synovitis grade, and the differences between grades were significant. Likewise, for all posterior recess comparisons, higher SIR values corresponded to a higher synovitis grade, with significant differences noted between grades.

Table 2 Significance of differences in SIRs in anterior and posterior recesses of the TMJ space between synovitis grades.

Intergroup Differences	Anterior Recess of TMJ	Posterior Recess of TMJ
Synovitis grade 1 vs 2	<0.001	<0.001
Synovitis grade 1 vs 3	<0.001	<0.001
Synovitis grade 1 vs 4	<0.001	<0.001
Synovitis grade 2 vs 3	<0.001	<0.001
Synovitis grade 2 vs 4	<0.001	<0.001
Synovitis grade 3 vs 4	0.001	<0.001

Discussion

Synovitis is a common TMJ disorder, often associated with pain and functional impairment. Accurate identification of synovitis severity is crucial for guiding the transition from conservative management to surgical treatment. This study is novel in presenting a quantitative evaluation of synovitis that is based on SIRs from T2-weighted MRI, which were correlated with arthroscopic grading; this approach has not been reported previously. The significant correlations discovered between arthroscopic grade and the SIRs for both anterior and posterior TMJ recesses underscore the promise of SIRs as an objective adjunct to diagnosis. Clinical assessment of both compartments on T2-weighted MRI may improve diagnostic accuracy, enable earlier detection, and support tailored treatment planning.

TMJ disorders are highly prevalent, affecting individuals of all ages.[1] Temporomandibular disorders are broadly classified in accordance with the origin of the pathology into masticatory muscle disorders and TMJ disorders. Accurate clinical diagnosis of TMJ disorders remains a major

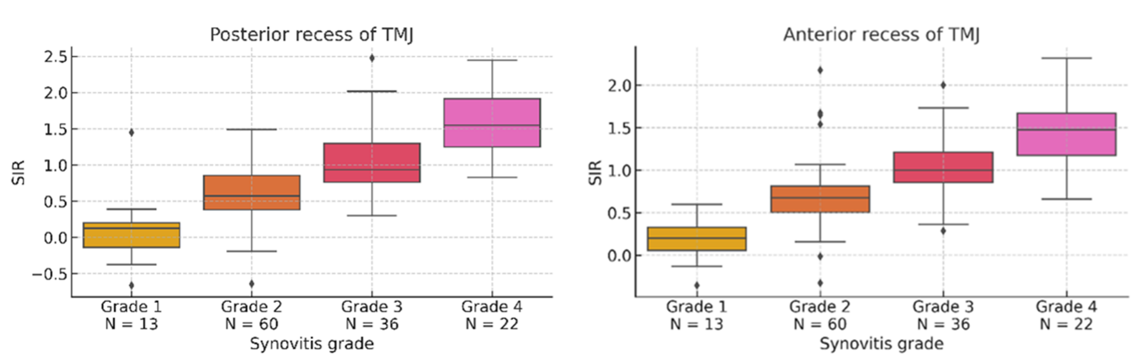

Figure 3 Box plots of signal intensity ratios (SIRs) for the anterior and posterior recesses of the temporomandibular joint (TMJ) space, categorized on the basis of synovitis grade. The observed differences remained significant after Bonferroni correction for multiple comparisons.

challenge because different diagnostic outcomes lead to distinct treatment strategies. Therefore, precise and reliable diagnosis is essential for the treatment of TMJ disorders. However, overlapping symptoms in the TMJ region frequently confound clinical judgment. Pf the various TMJ disorders, synovitis is a common inflammatory condition often associated with recurrent pain, requiring further diagnostic evaluation and appropriate therapeutic intervention by clinicians. The current internationally recognized protocol for diagnosing these disorders is the Diagnostic Criteria for Temporomandibular Disorders, proposed by Schiffman et al., in 2014.[2]

Conservative therapy is generally regarded as the first-line treatment for TMJ disorders. For patients who do not respond to conservative approaches or experience frequent recurrence, minimally invasive interventions are considered, such as arthrocentesis or arthroscopic surgery. Open joint surgery is reserved as a last-resort treatment.[9] As a minimally invasive procedure, arthroscopic surgery is associated with small incisions and enables direct visualization of the superior joint space, thereby serving both diagnostic and therapeutic purposes. For patients requiring an invasive intervention, advanced MRI is typically performed to assist clinicians in diagnosis and in selecting the appropriate surgical method.[5,20]

MRI enables reliable assessment of disc displacement in the TMJ and has been described as the gold standard of evaluation in TMJ soft tissue structures.[3] However, the diagnostic value of MRI in TMJ disorders other than disc displacement remains under debate. A systematic review concluded that the odds ratios obtained through MRI are low when it is used to diagnose degenerative joint diseases and intra-articular inflammatory conditions, suggesting that MRI may not be essential for the diagnosis of degenerative TMJ disorders.[4] Nevertheless, recent research demonstrated that convolutional neural networks trained on MRI images can effectively classify TMJ disorder severity with higher than 84 % accuracy, which highlights the potential for MRI-based evaluation in a broader range of TMJ conditions.[22]

Despite technological advances, the interpretation of intra-articular TMJ pathology on the basis of MRI alone remains challenging. Both MRI and TMJ arthroscopy are commonly performed for the same patient to evaluate intra-articular TMJ conditions. The establishment of a significant correlation between these two distinct diagnostic modalities would greatly increase the clinical utility of MRI in the interpretation of TMJ pathology. Over the years, numerous studies have examined the relationship between MRI findings and arthroscopic observations of TMJ synovitis.[10,11] However, it was not until 2021 that Verhelst et al. first applied the SIR as an objective quantitative parameter in such comparisons.[5] Notably, their investigation employed T1-weighted rather than T2-weighted imaging. T2-weighted imaging is generally considered to offer greater diagnostic value than does T1-weighted imaging in the evaluation of synovial inflammation.[12,13] Significant correlations between T2-weighted MRI findings and arthroscopic grading of TMJ synovitis have been observed in the literature. Nevertheless, no studies obtaining such findings have incorporated objective quantitative measures such as the SIR.[18,19,21] Therefore, the present study sought—for the first time—to investigate the relationship between SIRs derived from T2-weighted imaging and the arthroscopic grading of TMJ synovitis.

In our study, T2-weighted MRI SIRs in the posterior joint space differed significantly across synovitis grades, reflecting significant correlations between posterior joint space SIRs and the severity of TMJ synovitis. In a cohort of 50 joints, Verhelst et al. demonstrated that T1-weighted SIRs in the posterior joint space increased with an increase in synovitis severity.[5] Although their imaging sequences differed from those applied in the present investigation, the overall trend was the same. Similarly, Luis et al. examined T2-weighted MRI sequences and reported a significant association between joint effusion and synovitis, further supporting the progressive increase in SIR values observed in our study.[18] To our knowledge, the relationship between T2-weighted MRI SIRs and synovitis grading has not been investigated in any previous study, precluding direct quantitative comparison. Notably, several scholars have suggested that in advanced stages of TMJ disorders, fibrosis of the retrodiscal tissue may cause a pseudodisc to form, which can paradoxically reduce SIRs on T2-weighted MRI sequences.[16,17] Therefore, although this study determined a significant correlation between posterior joint SIRs and synovitis grading, the effects of retrodiscal tissue changes on posterior SIRs warrant further investigation. Inflammatory alterations within retrodiscal tissue may be reflected in MRI signal characteristics,[23] which may partially account for the progressive increase in SIR values observed with increasing disease severity.

In addition to these findings regarding the posterior joint space, this study discovered significant differences in T2-weighted MRI SIRs in the anterior joint space across synovitis grades, indicating significant correlations between anterior SIRs and the severity of TMJ synovitis. In contrast to the study by Verhelst et al., which employed only T1-weighted sequences and focused on findings for the posterior joint space,[5] our study revealed a robust and significant association of MRI SIRs in the anterior joint space with synovitis severity, suggesting that the diagnostic value of this modality may have been underestimated. T1-weighted sequences have limited utility for assessing anterior SIRs, and this may have contributed to the underrecognition of this region in earlier work. Moreover, studies in which T2-weighted MRI has been used to evaluate TMJ synovitis or joint effusion have similarly tended to focus on the posterior joint space, whether through subjective interpretation[7,18] or quantitative SIR analysis.[13] This emphasis may be related to the hyperemic changes frequently observed in the retrodiscal tissue of patients with TMJ disorders. These changes prolong T2 relaxation times and increase both signal intensity[14,15] and the difficulty of distinguishing posterior joint space from retrodiscal tissue in cases of anterior disc displacement. Thus, our findings qualitatively align with the literature and provide novel quantitative evidence regarding both the anterior and posterior compartments, indicating that the anterior joint space should not be overlooked in evaluations of TMJ synovitis.

This study has several limitations that should be acknowledged. First, the number of patients with grade 1 synovitis was relatively small, possibly because patients with mild synovitis often present with minimal or no clinical symptoms and may therefore lack clinical indication for surgical intervention. Second, the average interval between the MRI examination and subsequent arthroscopic surgery was 53 days. During this period, some patients continued to receive conservative treatments, such as NSAIDs or occlusal splint therapy, which may have altered their clinical condition and introduced discrepancies between the MRI and arthroscopic findings. In other similar studies, the average interval between MRI and arthroscopic evaluation ranged from 3 weeks to 71 days. Those studies also noted that prolonged intervals were a methodological limitation. This aspect could be further optimized in future research.[5,18] Third, because this investigation employed a retrospective single-center design, all cases were derived from the same medical institution, possibly introducing selection bias. This limits the generalizability of the findings to other populations. The single-center nature of the study also restricted the diversity of the patient cohort and clinical practices, reducing the representativeness of the results. The retrospective design limited control over confounding factors such as variations in disease duration, treatment response, and imaging conditions, and precluded standardized data collection. These methodological constraints may have influenced the observed associations between MRI and arthroscopic grading. Lastly, although this study focused on the correlations between synovitis and SIRs in the anterior and posterior joint spaces, other intra-articular pathologies and the progression of TMJ disorders may have influenced the accuracy of the results, which should be taken into consideration in the interpretation of our findings.

The present findings provide valuable insights into imaging-based assessment of TMJ synovitis and suggest several potential directions for future research. Looking forward, the advancement of quantitative MRI offers substantial potential to enhance the objectivity and reproducibility of TMJ evaluation. Standardized quantification of SIRs may serve as a valuable adjunct to conventional arthroscopic grading, thereby improving diagnostic accuracy and supporting evidence-based clinical decision-making. In parallel, the integration of artificial intelligence into TMJ imaging has demonstrated promising capability, with several contemporary studies reporting high accuracy in detecting and classifying TMJ disorders on MRI.[24,25] The combined application of quantitative imaging and artificial intelligence—based analytical approaches may provide a more precise, automated, and reproducible diagnostic framework. Furthermore, incorporating these imaging innovations into clinical training could enhance clinicians' understanding of TMJ pathology and diagnostic proficiency, and including these innovations in dental education may promote translational learning and better prepare future practitioners for technology-assisted diagnosis and management.[26]

In conclusion, this retrospective study demonstrated significant correlations between SIRs on T2-weighted MRI sequences and the arthroscopic grading of synovitis in both the anterior and posterior recesses of the TMJ. SIRs of the anterior joint space, which have been neglected in other studies, were significantly associated with synovitis severity. Posterior SIRs were likewise consistently correlated with synovitis grades. These findings support the use of T2-weighted MRI SIRs as an objective and quantitative tool for the assessment of TMJ synovitis.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article to declare.

Acknowledgments

None.

References

1. Valesan LF, Da-Cas CD, Réus JC, et al. Prevalence of temporomandibular joint disorders: asystematic review and meta-analysis. *Clin Oral Invest* 2021;25:441—53.
2. Schiffman E, Ohrbach R, Truelove E, et al. Diagnostic criteria for temporomandibular disorders (DC/TMD) for clinical and research applications: recommendations of the international RDC/TMD consortium network and orofacial pain special interest group. *J Oral Facial Pain Headache* 2014;28:6—27.
3. Talmaceanu D, Lenghel LM, Bolog N, et al. Imaging modalities for temporomandibular joint disorders: an update. *Clujul Med* 2018;91:280—7.
4. Koh KJ, List T, Petersson A, Rohlin M. Relationship between clinical and magnetic resonance imaging diagnoses and findings in degenerative and inflammatory temporomandibular joint diseases: a systematic literature review. *J Orofac Pain* 2009; 23:123—39.
5. Verhelst PJ, Vervaeke K, Orhan K, et al. The agreement between magnetic resonance imaging and arthroscopic findings in temporomandibular joint disorders. *Int J Oral Maxillofac Surg* 2021;50:657—64.
6. Schellhas KP, Wilkes CH. Temporomandibular joint inflammation: comparison of MR fast scanning with T1- and T2-weighted imaging techniques. *AJR Am J Roentgenol* 1989;153:93—8.
7. Segami N, Nishimura M, Kaneyama K, et al. Does joint effusion on T2 magnetic resonance images reflect synovitis? Comparison of 20 arthroscopic findings in internal derangements of the temporomandibular joint. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2001;92:341—5.
8. McCain JP, de la Rua H, Le Blanc WG. Correlation of clinical, radiographic, and arthroscopic findings in internal derangements of the TMJ. *J Oral Maxillofac Surg* 1989;47:913—21.
9. Renapurkar SK. Surgical versus nonsurgical management of degenerative joint disease. *Oral Maxillofac Surg Clin* 2018;30: 291—7.
10. Leschied JR, Smith EA, Baker S, et al. Contrast-enhanced MRI compared to direct joint visualization at arthroscopy in pediatric patients with suspected temporomandibular joint synovitis. *Pediatr Radiol* 2019;49:196—202.
11. Peacock ZS, Vakilian P, Caruso P, et al. Quantifying synovial enhancement of the pediatric temporomandibular joint. *J Oral Maxillofac Surg* 2016;74:1937—45.
12. Otonari-Yamamoto M, Imoto K. Differences in signal intensities of temporomandibular joint (TMJ) effusion on fluid-attenuated inversion recovery (FLAIR) images. *Oral Radiol* 2018;34:245—50.
13. Kuroda M, Otonari-Yamamoto M, Sano T, et al. Diagnosis of retrodiscal tissue in painful temporomandibular joint (TMJ) by fluid-attenuated inversion recovery (FLAIR) signal intensity. *Cranio* 2015;33:271—5.
14. Kakimoto N, Shimamoto H, Kitisubkanchana J, et al. T2 relaxation times of the retrodiscal tissue in patients with temporomandibular joint disorders and in healthy volunteers:

a comparative study. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2019;128:311—8.
15. Lee SH, Yoon HJ. The relationship between MRI findings and the relative signal intensity of retrodiscal tissue in patients with temporomandibular joint disorders. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009;107:113—5.
16. Katzberg RW, Tallents RH. Normal and abnormal temporomandibular joint disc and posterior attachment as depicted by magnetic resonance imaging in symptomatic and asymptomatic subjects. *J Oral Maxillofac Surg* 2005;63:1155—61.
17. Bristela M, Schmid-Schwap M, Eder J, et al. Magnetic resonance imaging of temporomandibular joint with anterior disk dislocation without reposition — long-term results. *Clin Oral Invest* 2017;21:237—45.
18. Gonzalez LV, Lopez JP, Díaz-Baez D, et al. Correlation between MRI-diagnosed joint effusion and demographic, clinical, imaging, and arthroscopic findings of the temporomandibular joint. *J Craniomaxillofac Surg* 2021;49:1169—74.
19. Fernández-Ferro M, Fernández-González V, Salgado-Barreira Á, et al. Correlation between the main clinical, imaging, and arthroscopy findings in patients with temporomandibular disorders. *Int J Oral Maxillofac Surg* 2023;52:237—44.
20. Vervaeke K, Verhelst PJ, Orhan K, et al. Correlation of MRI and arthroscopic findings with clinical outcome in temporomandibular joint disorders: a retrospective cohort study. *Head Face Med* 2022;18:2.
21. Bertotti M, de la Sen Ó, Encinas Bascones A, et al. Correlation of temporomandibular joint effusion on MRI with Wilkes staging, arthroscopic findings, and synovial fluid biomarkers in temporomandibular disorders. *J Craniomaxillofac Surg* 2025;53:1543—7.
22. Su TY, Wu JC-H, Chiu WC, et al. Automatic classification of temporomandibular joint disorders by magnetic resonance imaging and convolutional neural networks. *J Dent Sci* 2025;20: 393—401.
23. Zhang J, Zhao Y, Wang W, et al. Potential pathological and molecular mechanisms of temporomandibular joint osteoarthritis. *J Dent Sci* 2023;18:959—71.
24. Sankar H, Alagarsamy R, Lal B, et al. Role of artificial intelligence in magnetic resonance imaging-based detection of temporomandibular joint disorder: a systematic review. *Br J Oral Maxillofac Surg* 2025;63:174—81.
25. Manek M, Maita I, Bezerra Silva DF, et al. Temporomandibular joint assessment in MRI images using artificial intelligence tools: where are we now? A systematic review. *Dentomaxillofacial Radiol* 2025;54:1—11.
26. Yu CH, Chiang CP. A survey study for the dental students' satisfaction with the "needling therapies for temporomandibular disorders" lectures. *J Dent Sci* 2024;19:1143—6.