AMERICAN JOURNAL OF DIAGNOSTIC IMAGING
2024; 10(2): 41-49.
10.5455/ajdi.20240417122359

WisdomGale

RESEARCH ARTICLE

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Can a magnetic resonance imaging of the temporomandibular joint predict disc perforation?

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ABSTRACT

Background: Magnetic resonance imaging (MRI) is widely regarded as the gold standard for diagnosing internal derangement; however, its accuracy in detecting disc perforations varies.

Objectives: 1) Identify MRI features correlating with disc perforation, 2) identify preoperative variables correlating with disc perforation, and 3) develop a predictive model to ascertain the presence of disc perforation.

Materials and Methods: This cohort study involved 92 patients who underwent arthroscopic surgery to identify associated variables. Arthroscopically verified disc perforation was considered the primary predictor variable, while MRI interpretation of disc perforation served as the primary outcome variable. Demographic data, patient signs, and symptoms were treated as covariates. Statistical analyses were conducted at a significance level of 5%. Logistic regression models were employed to predict disc perforation and diagnostic accuracy was assessed using receiver operating characteristic curves.

Results: Among the 155 joints analyzed (92 patients: 135 females, 20 males), MRI interpretations did not significantly correlate with verified disc perforation ($p < 0.218$), demonstrating 14.3% sensitivity and 92.5% specificity. Age, symptomatic onset, joint noise type, osteoarthritis diagnosis, altered disc shape, and Wilkes classification exhibited significant associations ($p < 0.05$). A logistic regression model utilized associated variables for predicting disc perforation. Risk factors included symptom onset time, joint crepitus, and osteoarthrosis diagnosis by MRI; joint click was considered protective.

Conclusion: The model demonstrated high diagnostic accuracy (area under the curve of 0.836, 95% CI 0.76–0.91). While MRI interpretation was unreliable, our model accurately predicted disc perforation. Identification of these factors could inform surgical decisions.

ARTICLE HISTORY

Received 17 April 2024
Accepted 10 May 2024
Published May 17, 2024

KEYWORDS

TMJ surgery; TMJ arthroscopic surgery; disc perforation; discectomy

Introduction

Temporomandibular disorders encompass a range of clinical conditions affecting the muscles and the temporomandibular joint (TMJ) [1]. Following chronic low back pain, TMJ disorders rank as the second most common musculoskeletal condition [2–4], with estimates suggesting they affect between 5% and 30% of the North American population [3,5]. Disc perforation, indicative of degenerative joint disease, manifests in the advanced stages of the condition, with reported incidences ranging between 5% and 15% of patients with disc displacement [6,7]. This condition plays a crucial role in treatment planning, as advanced joint disease frequently requires more aggressive surgical interventions like discectomy or joint replacement. Hence, diagnostic accuracy plays a crucial role in decision-making for managing such pathologies.

The gold standard for diagnosing internal derangement (ID) is magnetic resonance imaging (MRI) [3]. MRIs provide insights into disc position, shape, signs of synovitis, condylar bone status (osteoarthrosis, osteoarthritis), and disc

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perforations [1]. However, the accuracy of MRI in diagnosing disc perforations varies [8–12]. Rao et al. reported a mere 3% accuracy in diagnosing disc perforations [8,9]. Conversely, Shen et al. conducted a retrospective study involving 2,524 joints undergoing arthroscopic surgery. They compared operative findings of disc perforation, with surgical exploration serving as the gold standard diagnosis, against pre-surgical MRI reports. The authors reported a high precision level measured with receiver operating characteristic (ROC) curves, with an area under the curve (AUC) of 0.808 (0.77, 0.85, $p < 0.05$) [12]. They outlined an image acquisition protocol that enhanced the accuracy of diagnosing disc perforations, concluding that MRI is a reliable diagnostic tool for TMJ disc perforations [12].

However, employing a uniform MR protocol for all patients is challenging and does not reflect clinical reality. Typically, patients visit imaging centers where their insurance provider dictates coverage, leading to variations in imaging protocols across different centers and radiologists. Consequently, MRI reports and their interpretation may exhibit significant variability. Given this variability in MRI interpretation, identifying imaging and clinical variables associated with disc perforation is crucial for informed decision-making, prognosis, and exploring various management options for this condition.

Considering the unreliability of MRI-based studies, are there preoperative and imaging variables that can predict discal perforation? We hypothesize that signs, symptoms, and imaging findings are related to TMJ disc perforations. Our objectives are to: 1) identify MRI features correlating with disc perforation, 2) identify preoperative variables correlating with disc perforation, and 3) develop a predictive model to ascertain the presence of disc perforation.

Materials and Methods

This study corresponds to a retrospective case series, which included all consecutive patients who underwent arthroscopic TMJ surgery at Clínica Bupa Santiago from July 2020 to July 2022. The inclusion criteria were patients with chronic pain or dysfunction that have failed to respond to conventional non-invasive therapy, or due to preoperative tests or patient preferences, arthroscopic surgery was chosen as the first indication of therapy. Patients without complete preoperative data, TMJ-MRI images, MRI interpretation (at least six weeks), and intraoperative data (video and operation notes) were excluded.

The study was approved by the scientific ethics committee of Clínica Bupa Santiago (No. Res. CEC CBS/01-2022) and followed all tenets of the Declaration of Helsinki for research involving human subjects. The data were obtained from the analysis of clinical records, MRI interpretation, images (pre-surgical MRI), a surgical protocol review, and arthroscopic surgery videos. Patients authorized the review of their clinical records through informed consent.

Our primary predictor variable was arthroscopically diagnosed disc perforation, which we confirmed throw surgical videos (Fig. 1) and surgical operation notes. The video review of the surgery was performed by the co-author (GL), who corroborated the data obtained from the operation notes. If differences were between the operation notes and the video, it was decided to keep what was reviewed in the surgical video. The co-author (GL) was blinded to any information when he assessed the videos, so he had no information on the previous diagnosis of the images.

The primary outcome variable was the MRI interpretation of disc perforation. A bilateral TMJ MRI protocol was performed on each patient according to our protocol (sagittal sequences T1, T2, PD_Fse in occlusion and dynamic. Coronal sequences PD_Fse and T1). The images were acquired in a Siemens Magnetom Sola 1.5 Tesla MR scanner in the Clínica Bupa Santiago imaging service. The images were analyzed by the Clinica Bupa Santiago neuroradiology and maxillofacial radiology team, integrated up of a total of four specialists. From the assessment of the MR images and the MRI interpretation, the following information was obtained, joint effusion, signs of osteoarthrosis/osteoarthritis, disc dislocation, disc reduction, altered disc shape, and if the disc shows signs of perforation. The surgeon interpreted the Wilkes classification from MRI images and preoperative clinical.

The secondary outcome variables were demographic data, anamnesis data, and signs and symptoms of the patient. Through an analysis of clinical records, the following information was obtained: age, gender, surgical side, cause of the disorder, time since the onset of symptoms (approximate in years), history of bruxism, medical therapy (non-steroidal anti-inflammatory drugs, pregabalin, muscle relaxants, others), history of conservative treatment (kinesiology, occlusal splint, intraarticular infiltrations, and arthrocentesis), maximum

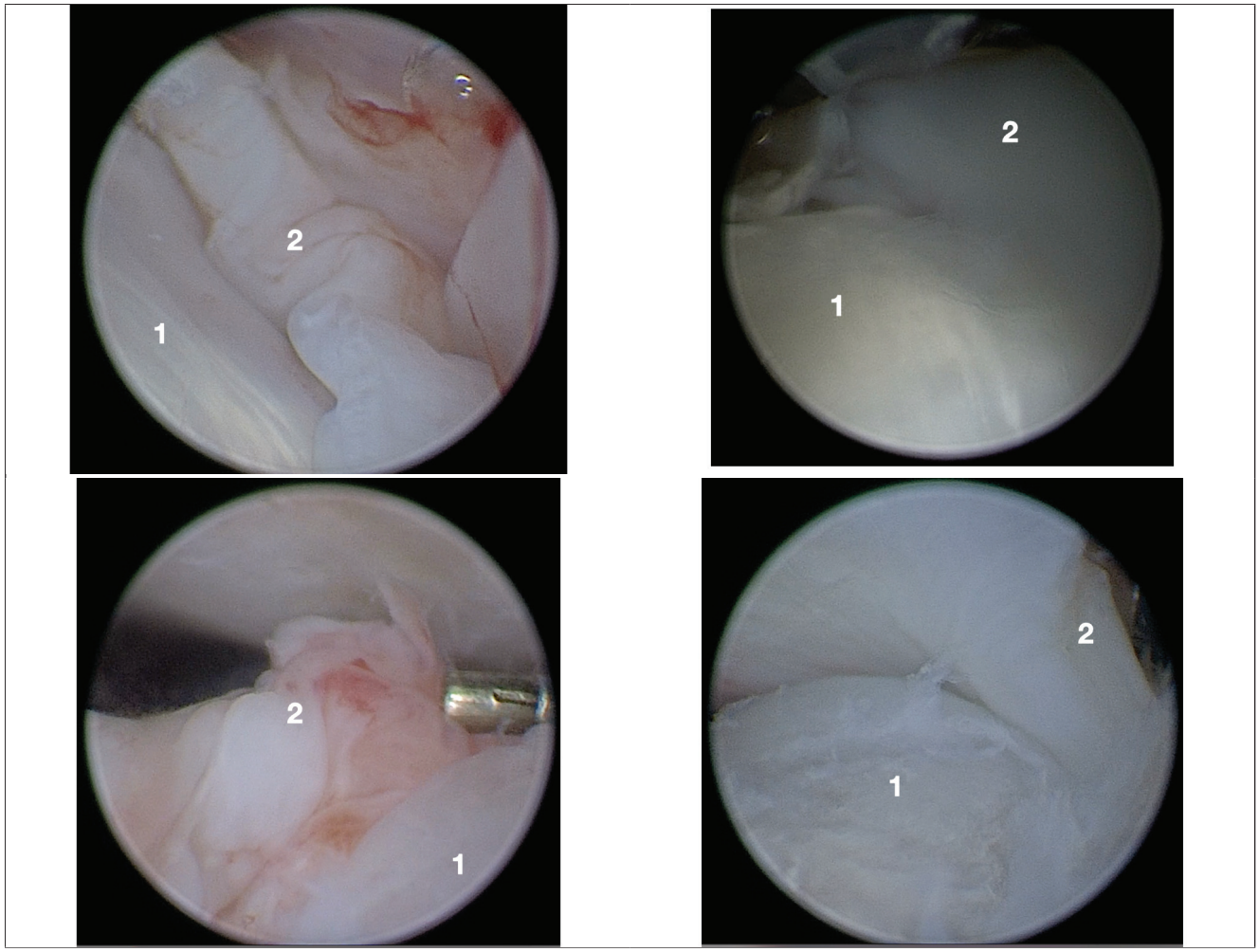


Figure 1. Intraoperative photograph. Different presentation of arthroscopic diagnostic of disc perforation. 1 = mandible condyle, 2 = disc perforation.

preoperative mouth opening, presence of preoperative noise, type of noise (click or crepitus) and postoperative pain (measured on a visual analog scale (VAS) from 0 to 10). Range of motion (maximum mouth opening) was measured with specific mouth opening measurement rulers (Sammons Preston Therabite, Patterson Medical Holdings Inc). The time since the onset of symptoms was measured and approximated in years. For those patients with evolution times of less than six months, a value of 0 was assigned. Those older than six months were assigned a value of 1. Those who reported time since onset of symptoms of more than 20 years were assigned a value of 20.

The data were incorporated into the SPSS program (IBM version 25) to perform the statistical analysis performed by the author (DJ). Descriptive statistics and an analysis of the association between preoperative variables and the intraoperative variable of the arthroscopically diagnosed disc perforation were performed.

Arthroscopic surgery was performed by the author (DJ), under general anesthesia, with an arthroscopy set with a 2.4 mm optic, a 3.2 mm protection sleeve (Karl Storz, Tuttlingen, Germany), and a video tower system (Karl Storz, Tuttlingen, Germany).

For this study, an alpha of 5% was set as the significance level. The statistical tests performed were the Chi2 or T-student test for independent samples appropriate to the variable type. Independent variables were tested for normal distribution with the Shapiro–Wilk test and parametric tests were performed for those with normal distribution. The variables were classified according to categorical or continuous.

The accuracy of the interpretation of disc perforation through MRI, compared with the arthroscopically diagnosed disc perforation, was measured

with likelihood ratios obtained throw sensibility and specificity. Also, the prediction of disc perforation was carried out using statistical models with logistic regression (forward-Wald method), including those variables that present significant levels of association with the arthroscopically diagnosed disc perforation. The model was applied to the entire sample to estimate the probability of disc perforation. From this probability, a ROC was constructed to assess the model's accuracy. From this model, a disc perforation score was constructed. The score was applied to the sample to test the predictive level, and an ROC curve was drawn on the result.

Results

Table 1 summarizes the descriptive statistics of preoperative and MRI variables. A total of 155 joints corresponding to 92 patients were analyzed. The average age was 28.9 years, ranging from 11 to 74 years. Of the total sample, 135 joints correspond to female patients (87.1%) and 20 to men (12.9%). Seventy-five joints corresponded to the right side (48.4%) and 80 to the left (51.6%). The leading identified cause of the disorder was a dentofacial anomaly (32.3%), followed by a history of mandibular trauma (11.6%), after dental treatment (6.5%), bruxism (3.9%), autoimmune pathology (5.2%), after orthognathic surgery (1.9%), overload (1.3%), and septic arthritis (0.6%). Most patients (36.8%) could not identify the disorder's cause. The average time since the onset of symptoms was 8.6. The maximum pre-surgical mouth opening was a mean of 31 mm. The average preoperative pain was six on VAS. Sixty-nine joints had no prior noise (44.5%), while 86 had noise (55.5%), of which 64 were click type. (17.8%) and 22 crepitus type (12.6%). Regarding previous treatment, a total of 133 joints received some type of pre-surgical medical treatment (87.4%), of which the most frequent was the use of NSAIDs (74.1%), followed using muscle relaxants (59.8%) and the use of pregabalin (17.8%). A total of 98 joints (67.2%) had a history of conservative treatment before arthroscopic surgery, of which the most frequent was the use of occlusal splint (53.4%), arthrocentesis with medication infiltration (25.3%), kinesiology (20.7%), Botox infiltrations (7.5%), and prior joint surgery (0.6%). From the MRI report analysis, the main sign described was disc displacement which occurred in 143 joints (92.3%), of which 60 (41.9%) were reported with reduction and 83 (58.1%) without reduction. Joint effusion was the second most reported sign in the images, with a total of 138 joints (89%), followed by osteoarthrosis in 74 joints (47.7%). Seventy-one discs were reported with altered shape (45.8%), and only 14 had signs of perforation (9%). Regarding the Wilkes classification, two joints were classified as Wilkes I (1.3%), 35 as Wilkes II (22.6%), 40 as Wilkes III (25.8%), 53 as Wilkes IV (34, 2%), and 25 as Wilkes V (16.1%). From the intraoperative findings, it was

Table 1. Descriptive statistics.

	Variable name *N*: 155 joints, 92 patients	Mean (range/SD) frequency (percentage)
Preoperative variables	Age	28.9 years (11–74/12.2 years)
	Maximum mouth opening	31 mm (0–50/9.6 mm)
	Preoperative pain (VAS scale)	6 (0–10/2.3)
	Time since symptom onset	8.6 yrs (1–20/2.9 years)
	Sex	
	Men	20 (12.9%)
	Women	135 (87.1%)
	Side	
	Right	75 (48.4%)
	Left	80 (51.6%)
	Conservative treatment	98 (67.2%)
	Noise presence	86 (54.5%)
	Click	64 (74.4%)
	Crepitus	22 (25.6%)
MRI variables	Effusion	138 (89%)
	Osteoarthrosis	74 (47.7%)
	Disc displacement	143 (92.3%)
	Disc reduction	60 (42%)
	Disc shape alteration	71 (45.8%)
	Disc perforation	14 (9%)
Wilkes Classification	Wilkes I	2 (1.3%)
	Wilkes II	32 (22.6%)
	Wilkes III	50 (25.8%)
	Wilkes IV	53 (34.2%)
	Wilkes V	25 (16.1%)
Surgical variables	Disc displacement	144 (92.9%)
	Disc reduction	55 (38.2%)
	Disc shape alteration	59 (38.1%)
	Disc perforation	35 (22.6%)

Table 2. Distribution of covariates by disc perforation in MRI.

Covariate	Not - perforated disc in MRI (*n* = 141)	Perforated disc in MRI (*n* = 14)	*p* value
Age (years)	29.2	35.7	0.118
Maximum mouth opening	30.2	33	0.41
Preoperative pain (VAS scale)	6.3	6.7	0.56
Time since symptom onset	4.3	5.6	0.18
Sex			0.193
Men	11	0	
Women	70	11	
Side			0.563
Right	67	8	
Left	74	6	
Conservative treatment	90	8	0.903
Noise presence	78	8	0.896
Click	59	5	
Crepitus	19	3	
MRI variables			
Effusion	126	12	0.677
Osteoarthrosis	62	12	**0.003**
Disc displacement	129	14	0.256
Disc reduction	57	3	0.124
Disc shape alteration	57	14	<0.001
Wilkes Classification			<0.001
Wilkes I	2	0	
Wilkes II	35	0	
Wilkes III	40	0	
Wilkes IV	51	2	
Wilkes V	13	12	
Surgical variables			
Disc displacement	131	13	0.994
Disc reduction	53	2	0.207
Disc shape alteration	54	5	0.849

observed that 144 joints presented disc displacement (92.9%), of which 55 reduced and 89 did not. 59 discs had shape alterations (38.1%), and 35 had disc perforations (22.6%). Of these 35 perforated discs, 18 (51.4%) were of a size that allowed repair. In contrast, 17 (48.6%) of them were not feasible to repair, in which arthroscopic discectomies were performed (11.1% of the total sample).

Table 2 summarizes the association analysis between preoperative variables, MRI findings variables, and arthroscopically diagnosed disc perforation and Table 3 summarizes the distribution of covariates by disc perforation in arthroscopy. Of the preoperative variables studied, the type of noise (click or crepitus) and the time since symptom onset measured in years showed a significant level of association with the outcome (disc perforation) ($p < 0.001$). In contrast, age ($p < 0.309$), maximum preoperative mouth opening ($p < 0.326$), preoperative pain measured on the VAS scale ($p < 0.99$), gender ($p < 0.767$), side ($p < 0.52$), cause of the disorder ($p < 0.654$), and presence of noise ($p < 0.319$) did not show statistical significance. Furthermore, the history of having undergone previous conservative treatment did not show a significant value either ($p < 0.7$). Of the findings described in the MRI, osteoarthrosis ($p < 0.001$) and the description of disc shape alteration ($p < 0.002$) showed a significant level of association with the disc perforation variable. On the other hand, effusion ($p < 0.184$), disc dislocation

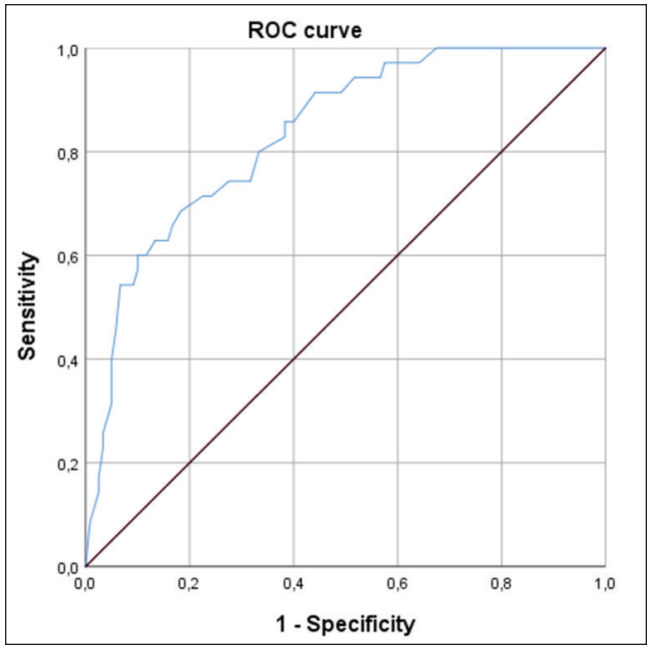


Figure 2. ROC curve of the score for disc perforation. The area under the curve of the score was 0.836 (95% CI 0.76–0.91).

($p < 0.051$), reduction ($p < 0.049$), and the interpretation of disc perforation were not significant ($p < 0.218$). The Wilkes classification showed a significant level of association with the disc perforation variable ($p < 0.001$).

The reported sensitivity and specificity for the MRI interpretation of disc perforation were 14.3% and 92.5%, respectively (Table 4). The positive likelihood rate (LR+) was 1.9, while the negative likelihood rate (LR-) was 0.93.

The risk variables included in the model were: osteoarthrosis, the presence of crepitus, and the time since the onset of symptoms (Table 5). Instead, the only protective variable was the presence of joint click. The model's AUC was 0.836 (95% CI 0.76–0.91). From this model, a score was constructed by adjusting the values. The adjusted disc perforation score model was Disc Perforation Score = 17*osteoarthrosis -3*joint click + 16*joint crepitus + 2* time since onset of symptoms. The score can be interpreted as the higher the value, the greater the risk of disc perforation. The AUC of the score was 0.836 (95% CI 0.76–0.91) (Fig. 2).

Discussion

While MRI is widely regarded as the gold standard for diagnosing TMJ ID, the evidence regarding its role in identifying and measuring the size of disc perforations is inconclusive [12–14]. In our patient series, MRI interpretation for the presence of disc perforations exhibited low diagnostic accuracy (LR+ of 1.9 and LR- of 0.93). However, studying preoperative variables and imaging findings could enable the prediction of disc perforation with high accuracy. Among the analyzed variables, age, time since symptom onset, type of joint noise (click or crepitus), imaging diagnosis of osteoarthritis, altered disc shape, and the Wilkes classification demonstrated significant associations with intra-articular disc perforation confirmation (Table 2).

To mitigate bias, a regression model was conducted. The risk variables included in the model were time since symptom onset (with longer duration increasing the risk of perforation), presence of joint crepitus, and diagnosis of osteoarthrosis via MRI study. Conversely, the presence of an articular click was found to be a protective factor for disc perforation. The model's predictive level was assessed by applying the score to the sample and drawing a ROC curve (Fig. 2). The area under the curve indicated a similar predictive level to the model (0.836, 95% CI 0.76–0.91).

Joint noise is indicative of joint disease, with clicking typically considered an early or intermediate sign and crepitus indicating an advanced pathology stage. The association between time since symptom onset and disc perforation was notably high. Additionally, the Wilkes classification showed a significant association with the disc perforation variable ($p < 0.001$). Except for time since symptom onset, the other variables included in the score (osteoarthrosis, joint click, and joint crepitus) are part of the Wilkes classification, further supporting its application in decision making for TMJ surgical pathology.

Traditionally, patients with TMJ ID start with conservative treatments (NSAIDs, occlusal splints, physiotherapy, infiltrations, and arthrocentesis). However, prolonged conservative treatment increases the risk of chronicity and, as per our study results, the likelihood of developing disc perforation. Current evidence suggests avoiding delaying surgery [15,16], with some proposing arthroscopic surgery as the primary treatment option [15], challenging the dogma of conservative treatment as the initial approach. Tran et al. reviewed systematic reviews and clinical guidelines for ID treatment published in the last 5 and 10 years, respectively [16]. They recommend limiting conservative treatments to three months, with intra-articular

Table 3. Distribution of covariates by disc perforation in arthroscopy.

Covariate	Not - perforated disc in Artroscopy (*n* = 141)	Perforated disc in Artroscopy (*n* = 35)	*p* value
Age (years)	28.2	34.5	0.035
Maximum mouth opening	31.2	29.5	0.45
Preoperative pain (VAS scale)	6.3	6.5	0.78
Time since symptom onset	3.8	6.3	0.001
Sex			0.429
Men	9	2	
Women	57	24	
Side			0.052
Right	53	22	
Left	67	13	
Conservative treatment	75	23	0.729
Noise presence	64	22	
Click	55	9	
Crepitus	9	13	
MRI variables			
Effusion	109	29	0.184
Osteoarthrosis	46	28	**<0.001**
Disc displacement	108	35	0.051
Disc reduction	49	11	0.049
Disc shape alteration	47	24	0.002
Wilkes Classification			<0.001
Wilkes I	2	0	
Wilkes II	35	0	
Wilkes III	33	7	
Wilkes IV	38	15	
Wilkes V	12	13	
Surgical variables			
Disc displacement	110	34	0.627
Disc reduction	50	5	
Disc shape alteration	31	28	<0.001

treatment (arthrocentesis or arthroscopy) indicated if improvement is lacking [16].

In our patient series, the mean time since symptom onset was 8.6 years, with 67.2% having undergone some form of prior conservative treatment, indicating prolonged conservative management and increased risk of irreversible degenerative pathology.

Treatment consensus dictates open surgery for disc perforations, involving repair (when feasible), discectomy (with or without replacement), or joint replacement [17]. However, minimally invasive surgical management, particularly arthroscopic surgery, has shown promising results [18,19] Quinn and Stover reported positive outcomes with level I arthroscopy (lysis and lavage) and margin remodeling for perforations [18]. They observed improvements in mouth opening and pain reduction, suggesting this procedure is a potential alternative to open discectomy [18]. Conversely, Liu et al. [19] reported a series of patients undergoing disc perforation closure with arthroscopic surgery (Yang's technique), with a success rate of 90.4% at 12-month follow-up. Although these results are excellent, the success rate is lower than that of patients undergoing the same surgery without disc perforation [20–22], highlighting the challenge posed by the degenerative state accompanying disc

Table 4. Reported sensitivity and specificity for the MRI interpretation of disc perforation.

		Arthroscopic disc perforation		
		+	-	Total
Predicted disc perforation	+	14	6	20
	-	21	114	135
	Total	35	120	155

```
Classified + if predicted Pr(D) >= .5
True D defined as Perforacion_Disc != 0

Sensitivity                     Pr( +| D)   40.00%
Specificity                     Pr( -|~D)   95.00%
Positive predictive value       Pr( D| +)   70.00%
Negative predictive value       Pr(~D| -)   84.44%

False + rate for true ~D        Pr( +|~D)    5.00%
False - rate for true D         Pr( -| D)   60.00%
False + rate for classified +   Pr(~D| +)   30.00%
False - rate for classified -   Pr( D| -)   15.56%

Correctly classified                        82.58%
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Table 5. The adjusted disc perforation score model was Disc Perforation Score = 17*osteoarthrosis -3*joint click + 16*joint crepitus + 2* time since onset of symptoms.

Covariates	Odds ratio	95% confidence interval
Time since onset of symptoms	1.22	1.055025–1.420266
Click	0.72	.2635474–1.963449
Crepitus	5.01	1.508458–16.61426
Osteoarthrosis	5.34	2.008327–14.19214

perforation and underscoring the importance of early intervention.

It is important to mention that the arthroscopic procedure outlined by Liu et al. (known as Yang's technique) is recognized as the most stable yet also the most intricate, necessitating specialized instruments [20]. However, a technical report by the author (DJ) proposed a modification to perform the procedure without such instruments [23]. In our patient series, 35 joints presented disc perforation, with 18 undergoing disc repair using Yang's technique (51.4%), and 17 undergoing arthroscopic discectomy (11.1% of the total sample), utilizing a two-portal coblation probe and Radius 2.0 motorized shaver. Further details of these techniques fall beyond the scope of this work and will be described in a separate study.

Limitations of our study include its retrospective nature, potentially introducing bias. Patient-reported symptom onset reduces the reliability of this variable, and varying MRI interpretations by different radiologists could lead to inconsistent reports. Despite these limitations, the study serves as a valuable foundation for evaluating more reliable disc perforation diagnostic methods.

In conclusion, our patient series highlights the unreliability of MRI interpretation in determining disc perforation presence. Identifying predictive variables before treatment decision-making allows surgeons to adapt surgical indications based on their preferences, potentially improving joint disease prognosis. Additionally, arthroscopic surgery may be considered as the primary treatment, challenging the traditional conservative-first approach.

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