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Using only MRI is moderately reliable in the prediction of meniscal tear reparability

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Abstract

Purpose The purpose of this study was to evaluate the role of surgeons' experience with meniscal repairs and meniscectomy decisions, and to determine the factors affecting the disagreement between meniscal repairs and meniscectomy decisions.

Methods In total, 223 patients with meniscal tears, 106 meniscal repairs, and 117 meniscectomies were included. Six orthopedic surgeons (3: > 5 years; 3: < 5 years' arthroscopy experience) were blinded, and they independently reviewed all preoperative MR images for over a month. Their reviews were compared with arthroscopic interventions performed by a surgeon with > 10 years' arthroscopy experience. Reparability-associated factors were also evaluated using multivariate logistic regression.

Results The first and second evaluation results did not differ significantly between groups (n.s.). There was good agreement between MRI predictions and arthroscopic interventions for both groups (< 5 years' experience: $k = 0.248$, agreement 62.3%; > 5 years' experience: $k = 0.351$, agreement 67.3%). Sex, side, and distance of tear from the meniscocapsular junction were not significantly different between agreements and disagreements. Disagreement regarding meniscectomy was significantly higher than those regarding meniscus repair ($p = 0.002$). Concomitant anterior cruciate ligament (ACL) injury, osteochondral lesions, and medial meniscal tear increased the likelihood of meniscal repair ($p = 0.0063$, $p = 0.0010$, and $p = 0.0369$, respectively). An increased risk of disagreement between MRI and surgical procedure was found in the presence of bucket-handle, horizontal or complex tear, chronic tear, high sports activity and expectation level.

Conclusion Surgeon's experience level may influence the prediction of meniscus reparability. Concomitant ACL injury, osteochondral lesions, and presence of medial meniscal tear increase the likelihood of meniscal repair. Tear type, tear chronicity, patient's activity and expectation level may influence the surgeon's operative decision in addition to MRI.

Level of evidence III.

Keywords Concomitant lesion · Experience · Surgeon · Meniscal repair · Meniscectomy · Reparability · Disagreement

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Introduction

Every year, at least 500,000 arthroscopic procedures are performed for meniscal tears in the USA [19]. Meniscus repair and partial meniscectomy are the most common among these procedures [6]. Meniscal tears should always be repaired whenever possible because meniscectomy has long-term side effects, including chondral damage and osteoarthritis [14]. Magnetic resonance imaging (MRI) is a useful method in the pre- and postoperative evaluation of meniscal tears [9]. It has a diagnostic accuracy value of up to 92% [2]. Also, it plays an important role in assessing the reparability of meniscal tears, for which a 60–74% accuracy was previously reported [3, 21].

This accuracy may rise to 92–94% in selected tear patterns, such as vertical longitudinal and bucket-handle tears [14, 17, 18]. The tear pattern is a strong predictor of meniscal tear reparability [1]. Vertical and bucket-handle tears are more suitable for repair, while horizontal tears, which are often located in the white zone may not always be repairable. Incomplete radial tears are commonly debrided, while complete radial tears, equivalent to total meniscectomy, should be repaired [5]. Complex and degenerative meniscus tears have poor healing potential and are thus not candidates for repair. Flap tears may be repaired following removal of the fragment which is located in the white zone [17].

Meniscal repair is recommended in tears located in the red–red and red–white zones [12]. Age and concomitant injuries strongly affect this decision [22]. Since meniscus reparability is influenced by many factors, and proper decision making prior to arthroscopic surgery is important because the postoperative healing period, patient's expectations, and rehabilitation protocols will be affected [6].

While MRI predictability for meniscal tear reparability has been previously studied, the results have been controversial [3, 6, 14, 21]. Also, the surgeon's experience and factors affecting disagreement were not previously evaluated. It was hypothesized that the decision for meniscus reparability is directly related to a surgeon's experience. The secondary hypothesis was that various factors might affect the disagreement between reparability by MRI and arthroscopic procedure. This study aimed to assess the role of surgeons' experience level on meniscal repair and meniscectomy decision, as well as determine the factors affecting the disagreement between reparability by MRI and arthroscopic procedure.

This study was designed to evaluate the role of the operative surgeon's experience level on meniscal reparability decision and the factors affecting disagreement between reparability by MRI and arthroscopic procedure. Results of this study might be used as a reference in the development of preoperative meniscal reparability decision approaches and algorithms in the future.

Materials and methods

The records of patients who underwent arthroscopic meniscal repair or partial meniscectomy between 2014 and 2017 were evaluated. Patients were included if they had undergone arthroscopic meniscal repair or partial meniscectomy, were aged less than 45 years and had undergone MRI within 1 month preoperatively. Patients with a previous history of knee surgery, osteoarthritis of the knee joint, low-quality MRI images (including low-resolution images and knee effusion that were affecting image quality), and insufficient operative records were excluded. In total, 223 subjects fulfilled the inclusion criteria. Fifty one females and 172 males (mean age 24.2 ± 13.3 years; range 14–45 years) were included in this study.

MRI investigations were performed with a 1.5-T scanner (Magnetom Symphony, Siemens AG, Erlangen, Germany), with a dedicated array coil. All images had a 3-mm slice thickness. The entire knee anatomy, from the proximal end of the patella to the distal end of the tibial tubercle, was included in the images.

Tears involving the red–red zone, tears with an intact inner fragment, vertical tears within the red–red zone, acute bucket-handle tears with viable displaced fragments in the red–red zone, radial and horizontal tears encompassing the red–red zone, and discoid tears encompassing the red–red zone were considered repairable. Complex or flap tears, as well as degenerative tears, were considered irreparable.

Three orthopedic surgeons with less than 5 years' knee arthroscopy experience (2 years, 2 years, and 4 years of experience) and three with more than 5 years' experience (6 years, 6 years, and 8 years of experience) prospectively reviewed all MRI images and provided predictions for each tear. An experienced musculoskeletal radiologist trained all orthopedic surgeons. They were blinded to the patient name, original MRI report, and surgical procedure performed. For all tears, reviewers measured the distance from the meniscocapsular junction to the edge of the tear on the tibial or femoral side in coronal, sagittal, and axial MRI images [6].

The affected meniscus (medial or lateral), affected side (right or left), tear region (anterior-corpus-posterior horn), and concomitant lesions were also recorded.

An arthroscopic procedure performed by a surgeon with more than 10 years' arthroscopy experience was accepted as the reference standard. The surgeon decided the procedure based on MRI, physical examination, patient background, and expectations. For all patients, the surgeon used the same arthroscopic reparability criteria which were previously established in the literature [3]. All-inside or inside-out technique was used in the meniscal repairs.

This study was approved by Baltalimani Bone and Joint Diseases Training and Research Hospital institutional review board (Approval ID number: 22032018/26).

Statistical analysis

The mean, standard deviation, median, lowest and highest values, frequency, and ratio values were used in the descriptive statistics of the data. The distribution of the variables was measured using the Kolmogorov–Smirnov test. The independent sample t test and Mann–Whitney U test were used in the analysis of independent quantitative data. The Chi-square test was used in the analysis of independent qualitative data, while the Mc Nemar test [15] was used for the change of the qualitative dependent data. The Cohen's kappa analysis test [8] was used for the agreement analysis. The coefficient obtained was defined according to the guidelines by Landis and Koch [13] as follows: poor (<0.2), fair (0.21–0.40), moderate (0.41–0.60), good (0.61–0.80), and excellent (0.81–1.00). A multivariate logistic regression model was created to define the reparability associated parameters and factors affecting the disagreement between the MRI and the surgical procedure. A p value of less than 0.05 was considered statistically significant. SPSS version 22.0 (IBM corp., Armonk, NY) was used in all statistical analyzes.

A sample size including 206 participants was calculated to be necessary to detect a difference in measurements with 0.80 statistical power. The type 1 error rate associated with the null hypothesis test was 0.05.

Results

Patients' demographics and meniscal tear characteristics are summarized in Table 1.

In both the more than 5 years' and less than 5 years' experience groups, the first and second evaluation results did not differ significantly (n.s.).

The agreement between MRI predictions and arthroscopic intervention was good for both groups (below 5 years' experience: $k=0.256$, agreement 67.7%; above 5 years' experience: $k=0.351$, agreement 67.3%) (Table 2).

The results of the first and second evaluation were not significantly different in both groups (n.s.). However, there was a significant difference in the first and second evaluations of both groups ($p=0.018$ and $p=0.022$) (Table 3).

Sex, side, distance to the meniscocapsular junction, and concomitant lesions were not significantly different between agreement and disagreement responses (Table 4). Disagreement in meniscectomy responses was significantly higher than meniscus repair responses ($p=0.002$).

Table 1 Patient demographics and meniscal tear characteristics

	n	%	Mean±SD
Age	223		24.2±13.3
Sex			
Female	51	22.9%	
Male	172	77.1%	
Affected side			
Right	120	53.8%	
Left	103	46.2%	
Distance from meniscocapsular junction			
Axial			4.3±1.1
Coronal			4.9±2.6
Sagittal			4.7±2.9
Meniscus			
Medial	168	75.3%	
Lateral	55	24.7%	
Arthroscopic procedure			
Meniscal repair			
Medial	83	78.3%	
Lateral	23	21.7%	
Meniscectomy			
Medial	85	72.6%	
Lateral	32	27.4%	
Tear type			
Vertical	75	33.6%	
Bucket-handle	54	24.2%	
Horizontal	35	15.7%	
Radial	13	5.8%	
Discoid	11	5%	
Flap	6	2.7%	
Complex	16	7.2%	
Degenerative	13	5.8%	
Tear localization			
Anterior horn	51	22.9%	
Body of meniscus	138	61.9%	
Posterior horn	143	64.2%	
Concomitant lesion			
No	72	32.3%	
Yes	151	67.7%	
ACL tears	77	51%	
OCD	66	43.7%	
MCL tears	4	2.7%	
PCL tears	2	1.3%	
PLC tears	2	1.3%	

Meniscus root tears were not included in this study

ACL Anterior cruciate ligament, *OCD* osteochondritis dissecans, *MCL* medial collateral ligament, *PCL* posterior cruciate ligament, *PLC* posterolateral corner

Table 2 MRI predictions and arthroscopic intervention correlation for both groups

	Meniscal repair	Meniscectomy	Agreement	k	p
More than 5-year experience					
Meniscal repair	247	148	67.3%	0.351	*0.000*
Meniscectomy	71	203			
Less than 5-year experience					
Meniscal repair	206	140	62.3%	0.248	*0.000*
Meniscectomy	112	211			

Bold-italic values indicate statistical significance

k kappa agreement coefficient

Table 3 Intra- and interobserver agreement results

	First evaluation		Second evaluation		p^*
	n	%	*n*	%	
More than 5-year experience					
Meniscal repair	395	59.0%	384	57.4%	(n.s.)[N]
Meniscectomy	274	41.0%	285	42.6%	
Less than 5-year experience					
Meniscal repair	353	52.8%	346	51.7%	(n.s.)[N]
Meniscectomy	316	47.2%	323	48.3%	
p^{**}	*0.018*[N]		*0.022*[N]		

Bold-italic values indicate statistical significance

(n.s.) Not significant

p^* Intra-class comparison

p^{**} Inter-class comparison

[N]MC Nemar test

According to the multivariate logistic regression model, concomitant anterior cruciate ligament (ACL) injury, osteochondral lesions, and the presence of medial meniscal tear increased the likelihood of meniscal repair (Table 5).

Age was inversely proportional to reparability. In our study, 57 out of 75 (76%) vertical tears were repaired, compared to 6 out of 35 (17.2%) horizontal, 32 out of 54 (59.3%) bucket-handle, 1 out of 16 (6.3%) complex, 4 out of 13 (30.7%) radial, 4 out of 11 (36.4%) discoid meniscal, and 1 out of 6 (16.7%) flap tears (Table 6).

In the evaluation of factors affecting the disagreement between the MRI and the surgical procedure, 7 of 18 variables were selected for multiple logistic regression analysis after univariate analysis. According to our results, six of seven variables were found to be positively correlated with disagreement between MRI and the surgical procedure (Table 7).

Discussion

The most important findings in this study were that using only MRI was found moderately reliable in the prediction of meniscal tear reparability. Concomitant ACL injury, osteochondral lesions, and medial meniscus tear increased the likelihood of meniscal repair. Surgeons experience affected the prediction of meniscus reparability. In patients who had bucket-handle, horizontal, complex or chronic meniscal tear, high sports activity level and high expectation level, an increased risk of disagreement between MRI and surgical procedure were found.

Although arthroscopy has been accepted as the gold standard method in both the diagnosis and management of meniscal injuries, MRI is the most widely accepted initial diagnostic method [13, 14]. Results of various studies have indicated that the effectiveness of MRI in the prediction of meniscal reparability remains controversial [3, 4, 7, 10, 14, 17, 20, 21]. In specific subgroups of meniscal injuries, especially in longitudinal and bucket-handle tears, the ability of MRI to predict reparability was found to be better [18].

In our study, the average accuracy, sensitivity, specificity, positive predictive value, and negative predictive values of MRI in predicting meniscal reparability were 67.3%, 77.7%, 57.8%, 62.5%, and 74.1%, respectively. These values were 65.9%, 57.8%, 77.7%, 74.1%, and 62.5%, respectively, for the prediction of meniscectomy. Based on our results, MRI is found to be moderately reliable for the prediction of meniscus reparability and meniscectomy. Importantly, the experience of the reader significantly influenced the results. In most of the studies, isolated tear types were included [14, 17, 18]. Few studies have evaluated the ability of MRI to predict meniscal reparability for all tear types. Matava et al. [11] reported a fair overall correlation of three examiners, which included a musculoskeletal radiologist, a senior orthopedic surgeon, and a general radiologist, in the correct prediction of the treatment method. They reported that the average accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of MRI in predicting meniscal reparability were 74%, 29%, 89%, 50%, and 80%, respectively. These values were 69%, 68%, 75%, 90%, and 43%, respectively, for the prediction of meniscectomy. They found no significant differences between the three examiners regarding the accuracy of their treatment predictions. They concluded that MRI was only moderately reliable in predicting meniscal reparability. In their study, Bernthal

Table 4 Comparative results of agreement and disagreement results between MRI findings and surgical procedure

	Agreement			Disagreement			p
	n	%	Mean $\pm$ sd	n	%	Mean $\pm$ sd	
Age			21.9 $\pm$ 12.5			26.4 $\pm$ 13.7	**0.009**[m]
Sex							
Female	24			27			(n.s.)[χ^2]
Male	86			86			
Affected side							
Right	63			57			(n.s.)[χ^2]
Left	47			56			
Distance from meniscocapsular junction							
Axial			4.3 $\pm$ 1.0			4.3 $\pm$ 1.1	(n.s.)[t]
Coronal			4.0 $\pm$ 2.7			4.4 $\pm$ 2.5	(n.s.)[m]
Sagittal			3.9 $\pm$ 1.8			4.1 $\pm$ 1.8	(n.s.)[m]
Meniscus							
Lateral	28	25.5%		27	23.9%		(n.s.)[χ^2]
Medial	82	74.5		86	76.1%		
Concomitant lesion							
No	39	35.5%		33	29.2%		(n.s.)[χ^2]
Yes	71	64.5%		80	70.8%		
Arthroscopic procedure							
Meniscal repair	64	58.2%		42	37.2%		**0.002**[χ^2]
Meniscectomy	46	41.8%		71	62.8%		

Bold-italic values indicate statistical significance

(n.s.) Not significant

[m]Mann–Whitney U test

[t]t test

[χ^2]Chi square test

Table 5 The multivariate logistic regression model with four independent variables

Variable	Odds ratio	p
Age	0.8975	(n.s.)
Medial meniscus	11.6282	**0.0063**
ACL rupture	10.9936	**0.0010**
Osteochondral lesion	3.0799	**0.0369**

Bold values indicate statistical significance

Presence of medial meniscal tear, concomitant ACL rupture and osteochondral lesions positively correlated with meniscal tear reparability. Age is negatively correlated with reparability

(n.s.) Not significant

et al. [3] evaluated the use of MRI to predict the reparability of meniscal tears according to arthroscopic criteria. Using two radiologists, they demonstrated 60% accuracy, 47% sensitivity, and 74% specificity in predicting meniscal tear reparability. On the other hand, Felisaz et al. [6] showed 83% accuracy, 85% sensitivity, and 79% specificity values.

When the meniscal tear subtypes were considered, we found the accuracy of the repair of vertical and bucket-handle tears 92.05% and 89.8%, respectively. Our results

were compatible with previous reports, in which 93–94% accuracy were found [14, 17, 18].

In our study, it was found that 76% of vertical tears were repaired, compared to 17.2% horizontal, 59.3% bucket-handle, 6.3% complex, 30.7% radial, 36.4% discoid meniscal, and 16.7% flap tears. Our results are compatible with previous reports in which it was shown that vertical and bucket-handle tears are repaired more frequently than other meniscal tear patterns [6].

In our study, the mean distance from the meniscocapsular junction was found 4.1 $\pm$ 1.3 mm in tears given a repairable decision when all tears were included. It was found 4.2 $\pm$ 0.9 mm, 3.9 $\pm$ 1.7 mm, 4.6 $\pm$ 2.0 mm, and 3.5 $\pm$ 2.4 mm in vertical, bucket-handle, horizontal, and discoid meniscal tears, respectively. Our results were compatible with previous reports which evaluated the effect of distance from the meniscocapsular junction using 3-, 4-, and 5-mm cutoff values [3, 6, 14, 17, 21].

Pre-existing chondral damages were associated with arthritis development and poor clinical and radiological outcomes [12, 16]. According to our results, the presence of concomitant ACL injury, osteochondral lesions, and medial meniscal tear increased the likelihood of meniscal repair.

Table 6 MRI predictions in specific subtypes of meniscal tears

	Meniscal repair (n)	Meniscectomy (n)	Correct predictions		
			More than 5-year experience	Less than 5-year experience	Mean
Total	106	117	150/223 (67.3%)	139/223 (62.3%)	(64.8%)
Meniscus					
Medial	83	85	114/168 (67.8%)	101/168 (60.1%)	(63.9%)
Lateral	23	32	39/55 (70.9%)	34/55 (61.8%)	(66.4%)
Meniscal tear subtype					
Vertical	57	18	70/75 (93.4%)	68/75 (90.7%)	(92.05%)
Bucket-handle	32	22	49/54 (90.7%)	48/54 (88.9%)	(89.8%)
Horizontal	6	29	27/35 (77.2%)	28/35 (80%)	(78.6%)
Radial	4	9	9/13 (69.2%)	8/13 (61.6%)	(65.4%)
Discoid	4	7	7/11 (63.6%)	6/11 (54.5%)	(59.1%)
Flap	1	5	5/6 (83.4%)	5/6 (83.4%)	(83.4%)
Complex	1	15	13/16 (81.3%)	10/16 (62.5%)	(71.9%)
Degenerative	1	12	10/13 (76.9%)	8/13 (61.6%)	(69.3%)

Table 7 Factors affecting disagreement between MRI evaluation and surgical procedure

Variable	Odds ratio	p
Age	0.9950	(n.s.)
Bucket-handle meniscus tear	6.892	**0.0067**
Horizontal meniscus tear	3.0067	**0.0319**
Complex meniscus tear	2.1048	**0.0406**
Chronic meniscus tear	10.7023	**0.0018**
High sports activity level	11.8106	**0.0152**
High expectation level	7.9955	**0.0015**

Bold values indicate statistical significance

The multivariate logistic regression model with seven independent variables

(n.s.) Not significant

In the present study, we evaluated the effectiveness of MRI in predicting meniscal reparability with orthopedic surgeons of different experience levels. Previous works were focusing on the effectiveness of MRI in predicting meniscal reparability involved mostly musculoskeletal radiologists [3, 6, 18]. We believe that meniscectomy or meniscus repair decisions by orthopedic surgeons outweigh the decisions of radiologists in the surgical management of meniscal lesions. Contrary to the interpretation of MRI images obtained during diagnosis and follow-up, we found that it was more appropriate for the surgeons to decide on the reparability during the decision for the surgical procedure. Further comparative studies including radiologists and orthopedic surgeons are required.

This study has several limitations. First, it was a retrospective study that included only operated patients. Second, meniscal root tear repairs which consist of almost 20% of meniscus repairs were not included. Third, MRI was read without any patient background, such as chronicity, occupation, sports activity level, patient expectations. However, the operated surgeon decided the procedure based on MRI, patient background, and expectations. Therefore, the final decision by an operating surgeon based on MRI, patient background, and expectations could make the comparison results less meaningful. Prospectively designed studies with preoperative evaluation, as well as assessment and comparison of decisions, may be more valuable. Second, we MRI images conducted with a 1.5-T MRI. A 3-T MRI scanner may provide higher resolution images, which may affect examinations.

Increasing the surgeon's experience level may increase the rate of meniscal repair decisions. This may reflect as cost-effectivity and improved prognosis of the patients in daily clinical work. Factors affecting the disagreement may be used as a reference in the development of preoperative meniscal reparability decision approaches and algorithms in the future.

Conclusion

Surgeon's experience level may influence the prediction of meniscus reparability. Concomitant ACL injury, osteochondral lesions, and presence of medial meniscal tear increase the likelihood of meniscal repair. Tear type, tear chronicity, patient's activity and expectation level may influence the surgeon's operative decision in addition to MRI.

Compliance with ethical standards

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