

# Diagnosis and classification of chondral knee injuries: comparison between magnetic resonance imaging and arthroscopy

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## Abstract

**Purpose** To compare the magnetic resonance imaging (MRI) findings of patients undergoing knee arthroscopy for chondral lesions. The hypothesis was that MRI displays low sensitivity in the diagnosis and classification of chondral injuries.

**Methods** A total of 83 knees were evaluated. The MRIs were performed using the same machine (GE SIGNA HDX 1.45 T). The MRI results were compared with the arthroscopy findings, and an agreement analysis was performed. Thirty-eight of the 83 MRI exams were evaluated by another radiologist for inter-observer agreement analysis. These analyses were performed using the kappa ( $\kappa$ ) coefficient.

**Results** The highest incidence of chondral injury was in the patella (14.4 %). The  $\kappa$  coefficient was 0.31 for the patellar surface; 0.38 for the trochlea; 0.46 for the medial femoral condyle; 0.51 for the lateral femoral condyle; and 0.19 for the lateral plateau. After dividing the injuries into two groups (ICRS Grades 0–II and Grades III and IV), the following  $\kappa$  coefficients were obtained as follows: 0.49 (patella); 0.53 (trochlea); 0.46 (medial femoral condyle); 0.43 (medial plateau); 0.67 (lateral femoral condyle); and 0.51 (lateral plateau). The MRI sensitivity was 76.4 % (patella), 88.2 % (trochlea), 69.7 % (medial femoral condyle), 85.7 % (medial plateau), 81.8 % (lateral femoral

condyle) and 75 % (lateral plateau). Comparing the radiologists' evaluations, the following  $\kappa$  coefficients were obtained as follows: 0.73 (patella); 0.63 (trochlea); 0.84 (medial femoral condyle); 0.72 (medial plateau); 0.77 (lateral femoral condyle); and 0.91 (lateral plateau).

**Conclusion** Compared with arthroscopy, MRI displays moderate sensitivity for detecting and classifying chondral knee injuries. It is an important image method, but we must be careful in the assessment of patients with suspected chondral lesions.

**Level of evidence** III.

**Keywords** Articular cartilage · Injury · Arthroscopy · Magnetic resonance imaging · Knee

## Introduction

The diagnosis and classification of chondral injuries are extremely important for guiding the treatment and prognosis [31]. These injuries frequently occur in the knee [2, 7, 20]. Chondral injuries may cause pain and functional deficits [5, 7, 24]. Shelbourne et al. [24] demonstrated in 2770 anterior cruciate ligament reconstruction cases that patients with more severe chondral injuries (Outerbridge Grades III and IV) exhibited lower objective scores after surgery.

Magnetic resonance imaging (MRI) is the optimal non-invasive procedure for chondral injury diagnosis. However, MRI displays low sensitivity and accuracy, even using modern equipment or current techniques [10, 14, 15, 31], particularly for early lesions [7, 8, 17, 22, 28, 29]. Hence, arthroscopy remains the gold standard examination [7, 21]. Despite this fact, MRI is more accurate than physical and radiographic examinations for detecting chondral injuries

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[8, 13]; therefore, MRI is an important complementary tool to evaluate the symptomatic knee.

Based on this fact, we compared the MRI findings of patients who underwent arthroscopic surgery in which a chondral injury was found during the surgical procedure. We hypothesized that MRI displays low sensitivity for detecting and classifying chondral knee injuries.

## Materials and methods

Between 2011 and 2013, 100 patients in whom a chondral injury of any grade was detected during knee arthroscopy were retrospectively selected. The patients included in this study had the MRI exams performed in the same MR equipment up to 3 months before surgery. The surgical evaluation was performed via an analysis of the video recording and surgical description (chondral lesion and probe palpation description) by an evaluator who was blinded to the MRI results. Patients with severe cartilage loss (osteoarthritis) were not included. Twenty patients were excluded because of video recording issues. Eighty patients remained, and three patients had both knees included, resulting in the inclusion of 83 knee joints. For a more specific evaluation, the knees were divided into six articular surfaces as follows: patella, trochlea, medial femoral condyle, medial plateau, lateral femoral condyle and lateral plateau. Thus, 498 articular surfaces were evaluated. The International Cartilage Repair Society (ICRS) classification was used, without subgroups, as follows: Grade 0 represents absence of a lesion; Grade I represents superficial lesions, including chondromalacia, superficial fissures and cracks or soft indentations; Grade II includes lesions extending to less than 50 % of the cartilage depth; Grade III indicates cartilage defects extending to more than 50 % of the cartilage depth, as well as to the calcified layer but not through the subchondral bone; and Grade IV represents lesions that extend through the subchondral bone [4]. The MRI exam was always performed using the same MR equipment (GE SIGNA HDX 1.45 T) for the T1- and T2-weighted sequences according to the following parameters: fast spin echo; FOV 14–16; sagittal: DP, 2000–2500/30–40; fat-saturated T2, 2000–4500/60–80; coronal: T1, 400–700/8–20; fat-saturated T2, 2000–4500/60–80; axial: fat-saturated T2, 2000–4500/60–80; axial oblique: 1000–2000/30–60.

To perform a better chondral evaluation with the MR images, the same division into six articular surfaces was made, and the ICRS classification (for MRI) was applied in which Grade 0 is normal cartilage; Grade I, the cartilage has a normal surface with an abnormal signal increase; Grade II, the presence of erosions or superficial ulcerations extending to less than 50 % of the cartilage depth; Grade III, the presence of lesions extending to more than 50 % of

cartilage depth; and Grade IV, cartilage defects that affect the subchondral bone [4]. The MRI evaluation results were compared to the arthroscopy findings, which are considered the gold standard evaluations, for agreement analysis.

MRIs of the 83 knees were evaluated by one experienced radiologist, and 38 MRIs were randomly selected to be evaluated by an additional radiologist; subsequently, the agreement between the radiologists was analysed. The radiologists were blinded to the arthroscopy findings.

To calculate the sensitivity, specificity, accuracy, and positive and negative predictive value, the lesions were divided into two groups: ICRS Grades 0–II lesions and Grades III and IV lesions. This procedure was important because Grades I and II lesions typically cause few symptoms, and Grades III and IV lesions are predominantly symptomatic, quite often requiring surgical treatment and long-term follow-up [18]. Grade 0 was grouped with Grades I and II to simplify the statistical analysis.

The study was previously approved by the ethics research committee of the Irmandade Santa Casa de Londrina—BIOISCAL (Protocol Number: 38020114.7.0000.0099).

## Statistical analysis

A sample size calculation was not done. It was just established a time period of two years, and the patients that met the described inclusion criteria were selected.

Sensitivity, specificity, accuracy, and positive and negative predictive value were calculated for the lesions divided into two groups (ICRS Grades 0–II and Grades III and IV).

The agreement analysis was performed using the kappa ( $\kappa$ ) coefficient to each surface with the complete ICRS classification and with the grouped classification to compare the MRI results and arthroscopy findings and between radiologists. The  $\kappa$  coefficient is expressed as follows:  $\leq 0.20$ , low agreement; between 0.21 and 0.40, mild agreement; between 0.41 and 0.60, moderate agreement; between 0.61 and 0.80, good agreement; between 0.81 and 0.99, very good agreement; and 1.00, perfect agreement. The statistical analysis was performed using SAS software, v9.13 (Cary, NC).

## Results

A total of 52 men and 31 women were included in this study, with mean age of 45.18 years, ranging from 11 to 79 years. Furthermore, 48 right knees and 35 left knees were evaluated, with 15 ACL reconstructions, 68 partial meniscectomies, five patellar instabilities and one high tibial osteotomy as associated injuries.

The arthroscopy findings were as follows: 105 Grade I lesions (21 %), 70 Grade II lesions (14 %), 95 Grade III

**Table 1** Arthroscopic lesion distribution according to the ICRS classification by surface

ICRS	Patella	Trochlea	MFC	MP	LFC	LP	Total
Grade 0	11	50	31	34	62	25	213
Grade I	12	7	12	32	6	36	105
Grade II	26	9	7	10	4	14	70
Grade III	32	15	28	5	10	5	95
Grade IV	2	2	5	2	1	3	15
Total	83	83	83	83	83	83	498

*MFC* medial femoral condyle, *MP* medial plateau, *LFC* lateral femoral condyle, *LP* lateral plateau

**Table 2** Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of the MRI for chondral lesions by surface (ICRS grouped classification: Grades 0–II and Grades III–IV)

Surface	Sensitivity	Specificity	PPV	NPV	Accuracy
Patella	76.4	73.4	66.6	81.8	74.6
Trochlea	88.2	78.7	51.7	96.3	80.7
MFC	60.7	82.0	71.8	80.3	77.1
MP	85.7	85.5	35.2	98.4	85.5
LFC	81.8	93.0	64.2	97.1	91.5
LP	75.0	90.6	46.1	97.1	89.1

*MFC* medial femoral condyle, *MP* medial plateau, *LFC* lateral femoral condyle, *LP* lateral plateau

**Table 3**  $\kappa$  coefficient values for grouped lesions (ICRS Grades 0–II and Grades III and IV) for each surface (MR image  $\times$  arthroscopy)

Surface	$\kappa$ coefficient value	Agreement
Patella	0.49	Moderate
Trochlea	0.53	Moderate
MFC	0.46	Moderate
MP	0.43	Moderate
LFC	0.67	Good
LP	0.51	Moderate

*MFC* medial femoral condyle, *MP* medial plateau, *LFC* lateral femoral condyle, *LP* lateral plateau

lesions (19 %) and 15 Grade IV lesions (3 %). Table 1 shows the lesion distribution according to the articular surface. The  $\kappa$  coefficient for each surface when comparing MRI and arthroscopy findings were as follows: 0.31 for the patella (mild agreement); 0.38 for the trochlea (mild agreement); 0.46 for the medial femoral condyle (moderate agreement); 0.51 for the lateral femoral condyle (moderate agreement); and 0.19 for the lateral plateau (low agreement). The  $\kappa$  coefficient for the medial plateau could not be calculated because of the absence of Grade I lesions on MRI.

The sensitivity, specificity, accuracy, positive and negative predictive value of MRI for detecting a chondral lesion based on the ICRS grouped classification, by surface, are

listed in Table 2. The  $\kappa$  coefficient values when comparing the MRI and arthroscopy with grouped ICRS classification (Grades 0–II and Grades III and IV lesions) for each surface are listed in Table 3.

Regarding the comparison between radiologists with grouped ICRS classification (Grades 0–II and Grades III and IV), the  $\kappa$  coefficient of the inter-observer agreement was as follows: 0.73 for the patella (good agreement); 0.63 for the trochlea (good agreement); 0.84 for the medial femoral condyle (very good agreement); 0.72 for the medial plateau (good agreement); 0.77 for the lateral femoral condyle (good agreement); and 0.91 for the lateral plateau (very good agreement).

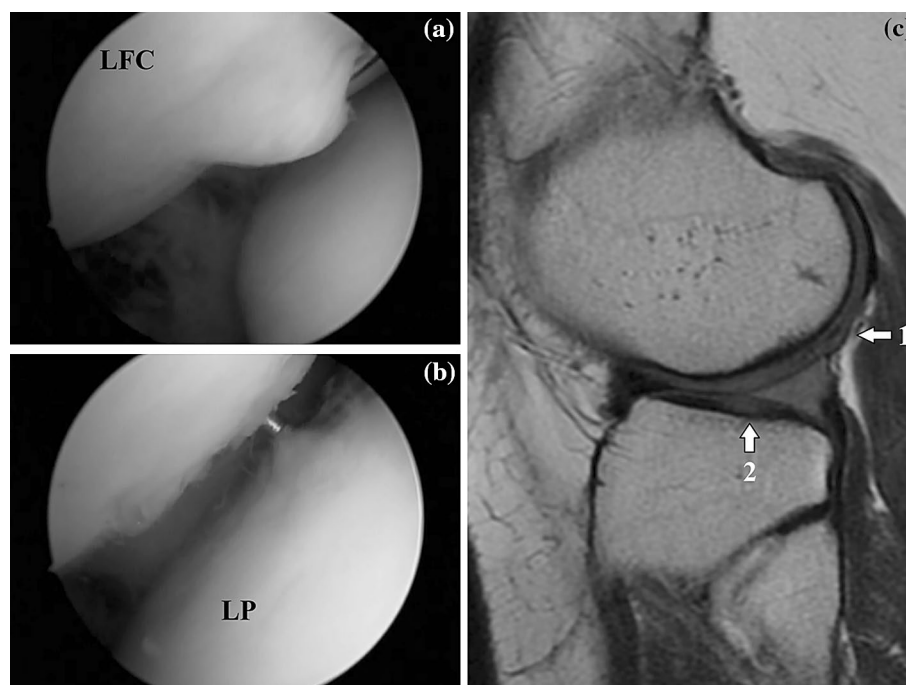
## Discussion

The most important finding of the present study was that MRI has a moderate sensitivity to detect chondral lesions in the knee, so care must be taken when evaluating and planning the treatment of a chondral lesion.

Articular cartilage lesions frequently occur in the knee. The more affected regions are the medial femoral condyle and the patellar surface [2, 3, 5, 7], which are high-load distribution areas. Based on an evaluation of asymptomatic basketball athletes (mean age, 26.15 years), Kaplan et al. [13] found 47.5 % of subjects with chondral knee injuries, and the patella and trochlea were the most affected sites. The surface displaying the highest injury incidence in our study was the patella, with 72 lesions (14.4 %), followed by the lateral plateau, with 58 lesions (11.6 %) and the medial femoral condyle, with 52 lesions (10.4 %).

Because of its high frequency, symptoms and treatment complexity, the diagnosis and classification of chondral injuries are crucial, particularly for guiding the most appropriate treatment for each lesion type [31]. Appropriate tools to follow the course of an injury are needed [5, 7]. Diagnosis and classification are more important for Grades III or IV lesions, which must be followed up to determine whether there is improvement or worsening in the repaired tissue after some treatment. De Windt et al. [6] suggested

**Fig. 1** Arthroscopic image of an ICRS Grade II lesion in the lateral femoral condyle (a) and a Grade I lesion in the lateral plateau (b). The lateral femoral condyle lesion was correctly classified by MRI (c, arrow 1); however, the lateral plateau lesion was not detected (c, arrow 2)



that there is a strong correlation between MRI parameters and the subjective IKDC score after chondral injury treatment.

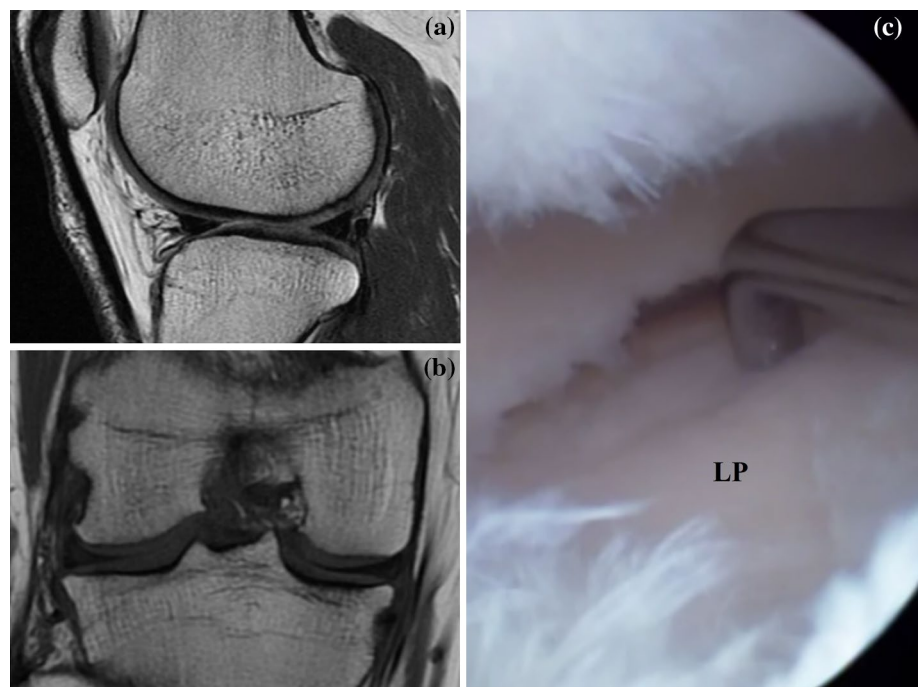
Studies have shown that MRI, the optimal non-invasive imaging test, displays low sensitivity, predominantly for initial Grades I and II injuries [3, 7, 8, 16–18, 27–29, 31]. The MRI sensitivity varies from 14 to 100 % [1, 7–9, 12, 14, 16, 19, 23, 25–27, 29–31], but it typically displays slightly higher specificity values, ranging from 55.9 to 100 % [1, 7–9, 12, 14, 16, 19, 23, 25–27, 29–31], and accuracy values ranging from 56 to 93 % [1, 9, 12, 14, 16, 19, 23, 25–27, 29]. Our results were in agreement with previous studies, as we detected MRI sensitivity ranging from 69.7 % (medial femoral condyle) to 88.2 % (trochlea), a specificity ranging from 73.4 % (patella) to 93 % (lateral femoral condyle) and accuracy ranging from 74.6 % (patella) to 91.5 % (lateral femoral condyle). The  $\kappa$  coefficients indicated that the diagnosis and classification of chondral lesions by arthroscopy differ significantly from the MRI evaluation. We found that the  $\kappa$  coefficients ranged from 0.19 (lateral plateau) to 0.51 (lateral femoral condyle), i.e. the MRI evaluation ranged from low to moderate agreement. These results indicate, in agreement with the literature, that MRI displays limited value for the diagnosis and classification of chondral injuries [14, 22, 25, 29, 30]. The lateral plateau is cited as a difficult location for chondral evaluation by MRI, and its convex surface and small chondral thickness could be the cause of this difficulty [22, 25, 27] (Figs. 1, 2). When the lesions were grouped (Grades 0–II and Grades III and IV), a higher  $\kappa$  coefficient was obtained, ranging from 0.49 (patella) to 0.67 (lateral

femoral condyle), i.e. moderate to good agreement. Grades III and IV lesions are more symptomatic, many times requiring surgical treatment (Fig. 3), and a more sensitive imaging test for detecting these Grades might be remarkably beneficial.

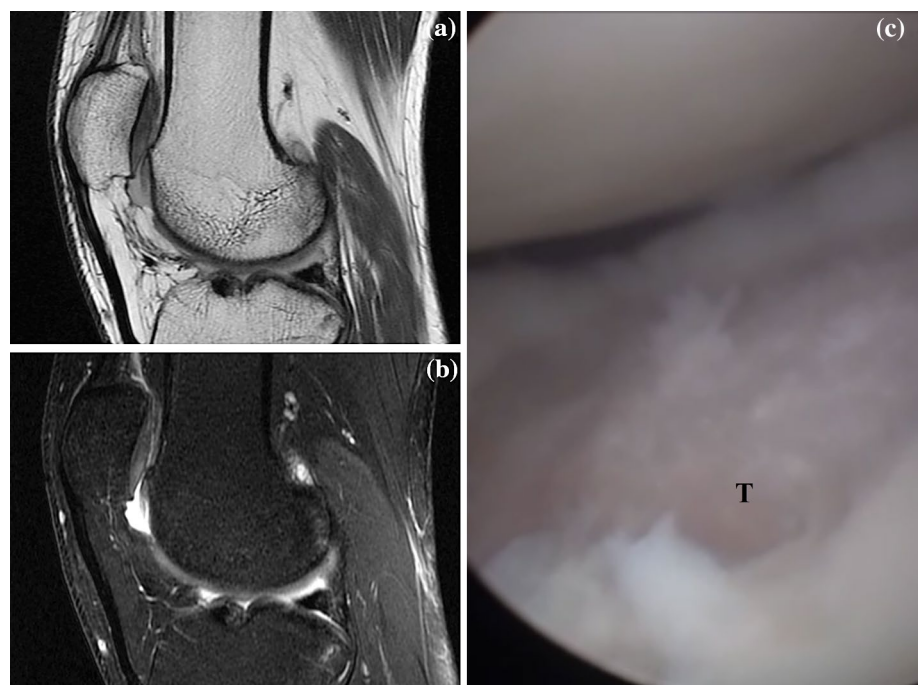
MRI sensitivity for chondral injuries could be lower due to partial volume artefacts, cartilage thickness (<4 mm) and the curved chondral knee surfaces [11]. It varies depending on the injury type, place and size, and on the MRI sequence, field strength and contrast agent used [7]. Other factors not detected on the MRI may affect the imaging results, including inflammation and vascular or nerve penetration [6]. Arthroscopy must be carefully used as the gold standard for diagnosing chondral injuries because there is a possibility that only the superficial layer is evaluated and deeper injuries might be hidden [16]. We selected 38 MRI exams to be evaluated by another radiologist to verify the agreement between radiologists. Only a sample of the exams (i.e. not all) was chosen as this was not the main objective of the study. The  $\kappa$  coefficient for the comparison between radiologists ranged from 0.63 (trochlea) to 0.91 (lateral plateau), i.e. from good to very good agreement. This finding confirms that MRI evaluations are uniform and that arthroscopy evaluations may result in failures and may not be the gold standard they are believed to be. Thus, MRI and arthroscopy are complementary, arthroscopy is optimal for articular surface evaluations and MRI is optimal for deep injuries and bone evaluations [11]. Figueroa et al. [7] suggested that when a chondral lesion is suspected, one should be prepared to perform any type of treatment because MRI is not completely reliable.



**Fig. 2** Lateral plateau lesion was not detected by MRI (a, b) and was classified as ICRS Grade II by arthroscopy (c)



**Fig. 3** MRI of an ICRS Grade III lesion in the trochlea (a, b), which was confirmed by arthroscopy (c)



This study has some limitations. Our sample may be biased because only patients with surgically confirmed cartilage injuries were selected, which was the ideal method to optimize the purpose of evaluating the potential of MRI to diagnose and classify chondral injuries. Dividing the lesions into two groups could have impaired the data analysis; however, this categorization was performed because Grade III and IV lesions cause more symptoms and quite often requires surgical treatment; therefore, it is more

important that these lesions be appropriately diagnosed and classified. The lack of a lesion size evaluation could have induced a bias because smaller lesions have a greater tendency to be undiagnosed by MRI. However, the size evaluation was not an objective of our study. The lesion evaluation might have been biased by evaluating the video recording and the surgical description. It can be difficult to determine the depth of the injury by viewing alone, i.e. without palpating the injury with a probe or if the palpation

was not appropriately performed or described. Finally, it is well known that traumatic and degenerative chondral injuries have different behaviours. Although patients at advanced ages (up to 79 years) were included, an attempt was made to avoid bias by not including patients with severe cartilage loss (osteoarthritis).

An efficient non-invasive imaging exam to diagnose, classify and evaluate knee cartilage injuries with high sensitivity, specificity and accuracy is still lacking. However, MRI is more efficient for detecting severe injuries (Grades III and IV) and is therefore an extremely useful tool.

This study demonstrates that a critical analysis of the patient's MRI exams is necessary for the proper treatment and surgical planning.

## Conclusion

MRI displays moderate sensitivity for detecting and classifying chondral knee lesions compared with arthroscopy, which is considered the gold standard.

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**Ethical standard** The study was previously approved by the ethics research committee of the Irmandade Santa Casa de Londrina—BIO-ISCAL (Protocol Number: 38020114.7.0000.0099).

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