Juvenile Osteochondritis Dissecans of the Knee

Does Magnetic Resonance Imaging Instability Correlate With the Need for Surgical Intervention?

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Background: Several magnetic resonance imaging (MRI) classification systems have been developed to determine the degree of instability of juvenile osteochondritis dissecans (JOCD) lesions. Our current practice involves correlating the patients' symptoms with their MRI findings, but there are many cases in which this correlation is poor and results in incorrect classification of the stability of a JOCD lesion.

Purpose: To determine whether certain MRI findings of JOCD instability are associated with the necessity for arthroscopic intervention to assess lesion stability. A secondary objective was to determine the interobserver agreement of the Kijowski et al (2008) MRI criteria for osteochondritis dissecans (OCD) instability.

Study Design: Case series; Level of evidence, 4.

Methods: A retrospective review was performed of patients who had documented femoral condyle OCD lesions, had open growth plates, and had been evaluated with serial MRI examinations. Each OCD lesion on MRI was classified according to the Kijowski classification as either stable or likely unstable.

Results: The study included 16 patients (17 knees) with 49 MRI examinations. The initial MRI lesion was graded as stable in 59% (10/17), and 7 of these remained stable throughout the study period, with only 1 requiring operative intervention. Two became unstable on MRI, with 1 requiring surgery and 1 reverting back to stable with nonoperative management. The initial MRI lesion was graded as unstable in 41% (7/17) of the knees, with 2 of these becoming stable on MRI during the follow-up period with nonoperative management. The other 5 lesions remained unstable, with 3 eventually requiring surgery. The most important finding in this study was that MRI instability is a poor predictor of the necessity for surgery for JOCD lesions. The correlation between a nonradiologist and a trained musculoskeletal radiologist in the interpretation of the MRI criteria by Kijowski et al showed only substantial agreement for multiple cysts.

Conclusion: MRI criteria for OCD instability in the pediatric knee do not always correlate with the necessity for surgery. They are, at times, a helpful adjunct to the management of these patients; however, care must be taken to interpret all available clinical and radiographic information in surgical decision making.

Keywords: knee; osteochondritis dissecans; MRI; pediatric

Osteochondritis dissecans (OCD) includes a spectrum of joint disease involving articular cartilage,[1,6,12,26] with the subchondral bone lesion having the potential to progress to varying degrees of osseous resorption, collapse, detachment, and violation of the overlying articular cartilage, which may result in intra-articular loose body formation.[8,17] Several diagnostic techniques, including radiography, bone scintigraphy, and magnetic resonance imaging (MRI), have been employed to assess the magnitude of bony separation of the OCD lesion and to document progression. Radiographs are often able to diagnose OCD of the knee, thus making them the ideal initial evaluation when a patient presents with a clinical history and physical examination symptoms consistent with this abnormality.[2,11] However, frequent discrepancies between radiographic and surgical information have been noted, including fragments that appear separated from their docking site on radiographs that are noted during arthroscopic

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surgery to be stable and covered by normal cartilage.[2,3,19,20,22] Therefore, MRI has become increasingly more important in an attempt both to identify the location of the suspected lesion and to ascertain whether there is instability or detachment of the fragment.[2,9,11,15,19,21,27] MRI has also been found to be advantageous as a noninvasive means to document lesion progression or healing.[14,16]

Several MRI classification systems have been developed to determine the degree of instability of OCD lesions.[2,9,11,14-16,20] Recently, Kijowski et al[16] retrospectively compared the sensitivity and specificity of previously described MRI signs of instability with findings during subsequent arthroscopy in 32 skeletally immature patients with juvenile OCD (JOCD). Results showed 100% sensitivity and specificity for diagnosing lesion instability in this population if the following 3 signs were all present: (1) a high T2 signal intensity rim surrounding a JOCD lesion of the same signal intensity as adjacent joint fluid, (2) a secondary outer rim of low T2 signal intensity, and (3) multiple breaks in the subchondral bone plate. Perilesional cysts were also found to be indicators of instability if they were either multiple or single but larger than 5 mm.[16]

Our current indications for surgery on a patient with a JOCD lesion include (1) MRI evidence of lesion instability in a patient who presents with significantly limited function (eg, pain with ambulation, inability to perform sports), (2) failure of nonoperative management (eg, physical therapy, activity modification) after 6 months if consecutive MRI findings are similar to or worse than the index MRI findings, and (3) a loose body.

OCD lesion stability appears to be an important prognostic factor for determining whether a lesion will heal with nonoperative measures or if it will require surgical intervention.[14,15,22] Salci et al[23] performed a systematic review to document and assess the surgical indications for OCD of the knee in the pediatric population. While many of the authors represented in this review described their surgical treatments based on lesion stability, expressively indicating "stable" or "unstable" lesions, there was a clear lack of consistency for surgical indications for the management of OCD in these young patients. This may be partly related to the lack of a universal method to determine OCD lesion stability. Unfortunately, the gold standard for the diagnosis of stability, arthroscopic surgery, is invasive and involves visualizing the lesion to detect cartilage breach and probing the lesion to detect motion. MRI is becoming a popular surrogate for arthroscopic surgery; however, there are no studies that have clearly identified the degree of lesion instability on preoperative MRI that must be present before an OCD lesion is deemed unable to heal spontaneously in skeletally immature patients. Furthermore, there are no randomized controlled trials that have compared operative versus nonoperative management of unstable cartilage-intact lesions found at arthroscopic surgery.

Our current practice involves correlating the patients' symptoms with their MRI findings. However, there are many cases in which this correlation is poor, with relatively asymptomatic patients having clearly unstable lesions on MRI and vice versa. Therefore, the potential exists to perform unnecessary surgery on some patients who probably have other reasons for their knee pain, and conversely, there is the potential for an unstable lesion in a relatively asymptomatic patient to become an irreparable loose body.

The primary objective of this retrospective review was to determine if certain MRI findings of JOCD instability are associated with the necessity for arthroscopic intervention to assess lesion stability and subsequent healing of the OCD lesion. A secondary objective was to determine the interobserver agreement of the criteria developed by Kijowski et al[16] for MRI indicators of OCD instability.

METHODS

Screening and Eligibility

This study involved a retrospective review of patients in the senior author's (D.P.) database who had distal femoral OCD lesions of the knee from 2009 to 2015. Ethics approval was approved through the Hamilton Integrated Research Ethics Board (No. 14-832). Patients were identified through an electronic billing system according to their diagnostic code ("732"). Inclusion criteria were the following: male or female patients younger than 15 years at the initial visit, OCD of the distal femur, open growth plates on initial MRI, patients with at least 2 consecutive MRI examinations of their knee, and patients who had not undergone prior OCD knee surgery. Patients older than 15 years were excluded, as they were deemed to be too close to skeletal maturity to have sequential MRI follow-ups.

Data Extraction

Data extracted included age and sex at the initial visit, age at the first and subsequent MRI examinations, growth plate status on each MRI examination, and classification of each lesion on MRI according to Kijowski et al.[16]

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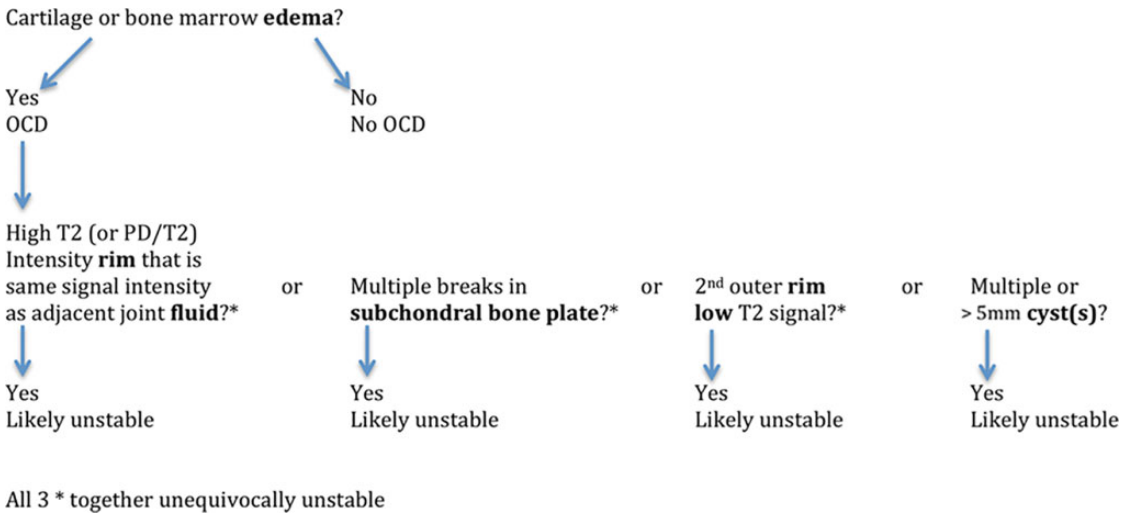

Figure 1. Flowchart depicting the grading method as described by Kijowski et al.[16] OCD, osteochondritis dissecans; PD, proton density.

Bilateral OCD lesions were distinguished with an "L" or "R," indicating the left or right knee, respectively.

OCD Lesion Stability

Serial MRI examinations were graded using the system by Kijowski et al.[16] Figure 1 outlines the criteria from Kijowski et al[16] for secondary MRI findings that are useful in diagnosing potentially unstable JOCD lesions as well as the criteria for unequivocally diagnosing these lesions. Cartilage or bone marrow edema was first assessed. If edema existed, an OCD lesion could be confirmed. Subsequently, growth plates were assessed to determine if this was truly JOCD. Each MRI examination was subsequently reviewed for the following criteria: a high T2 signal intensity rim that had the same signal intensity as adjacent joint fluid, a secondary outer rim of low T2 signal intensity, multiple breaks in the subchondral bone plate on T2-weighted MRI, and the existence of multiple cysts or a single cyst greater than 5 mm in diameter. If any of these criteria were present, the lesion was classified as "likely unstable" (the word "unstable" is used throughout the rest of this article for simplicity). The 4 criteria from Kijowski et al[16] were later added to other proposed criteria of potential instability or poor prognosis, cartilage breach,[18] and lesion size (>160 mm^2)[10] in an attempt to see if the presence of multiple criteria could better predict the failure of nonoperative management. For simplicity, a 6-point instability score was then created to compare unstable lesions that stabilized without surgery with those that required surgery. One point was given for each 1 of the 4 criteria from Kijowski et al[16] as well as 1 point for cartilage breach and 1 point for lesion size >160 mm^2. Intuitively, a higher instability score should indicate a more unstable lesion that is less likely to stabilize without surgery. If none of the criteria from Kijowski et al[16] were met but bone edema was present, the lesion was considered stable.

Statistical Analysis

Descriptive statistics were used to calculate the mean age of patients and mean follow-up time between MRI examinations, with 95% CIs. Preoperative, intraoperative, and postoperative clinical notes were assessed to determine the clinical outcomes of the patients who underwent surgical intervention.

Each of the following 7 criteria were graded as either present or absent by 2 independent reviewers (D.d.S. and K.A.): bone marrow edema, high T2 signal intensity rim, secondary rim of low T2 signal intensity, multiple breaks in the subchondral bone plate, presence of single cysts greater than 5 mm, presence of multiple cysts, and overall stability. Agreement between the reviewers in the grading of OCD lesions was assessed using the kappa statistic. A kappa value of $\geq$0.61 is considered to indicate substantial agreement, 0.41 to 0.60 indicates moderate agreement, 0.21 to 0.40 indicates fair agreement, and $\leq$0.20 indicates slight agreement.[25] SPSS for Windows version 22 (IBM) was used to calculate the kappa value. K.A. is a radiologist who underwent a pediatric radiology fellowship with special interest in musculoskeletal radiology, and D.d.S. was a senior orthopaedic resident (PGY3) who underwent training by K.A. until he was comfortable with the interpretive guidelines.

RESULTS

Demographics

The final analysis included 16 patients (17 knees), with 49 MRI examinations without any surgical intervention and 4 MRI examinations after surgery. All MRI examinations confirmed open growth plates except for the postsurgical MRI of patient 092. Fourteen patients were male, and 2 were female. The mean age was 11.4 ± 1.0 years, and there were 8 left and 9 right knees. The mean follow-up for all

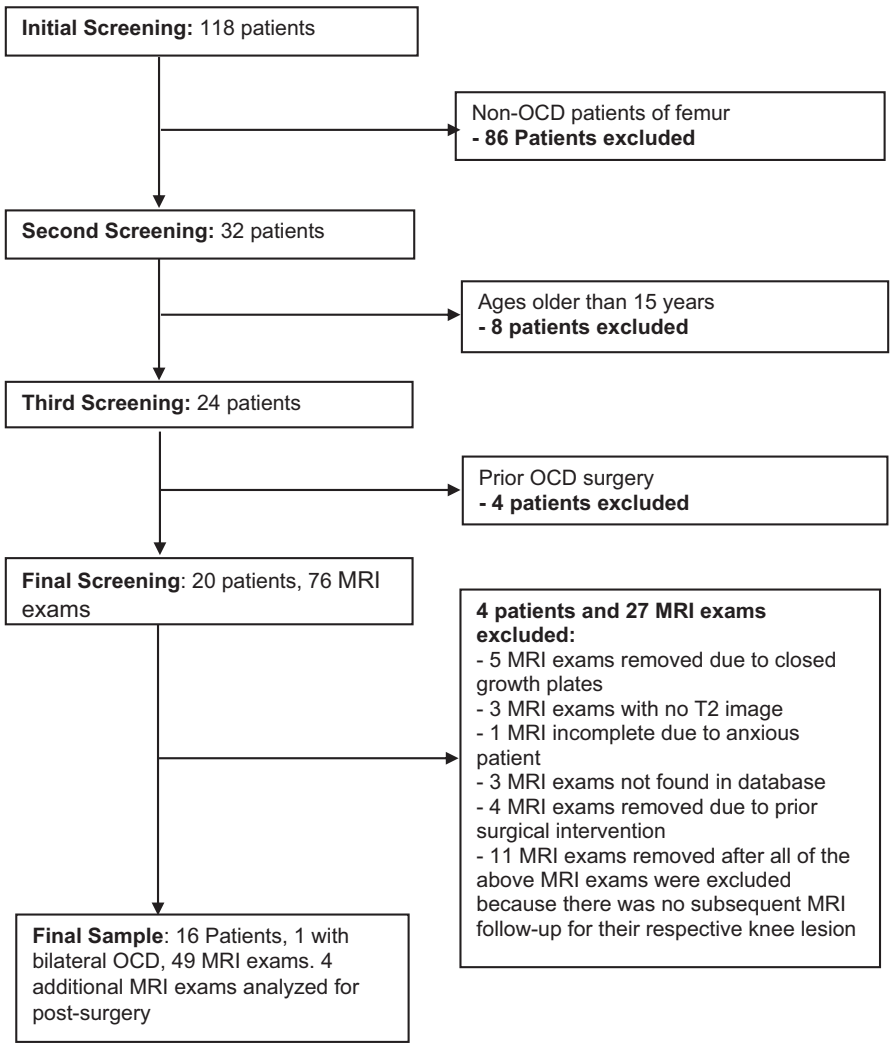

Figure 2. Flowchart depicting the screening process. MRI, magnetic resonance imaging; OCD, osteochondritis dissecans.

TABLE 1
Kappa Agreement Between Reviewers

	Kappa Value	95% CI
Bone marrow edema	0.39	–0.74 to 0.66
High T2 signal intensity rim	0.15	–0.51 to 0.52
Second outer rim of low T2 signal intensity	0.39	–0.74 to 0.66
Multiple breaks in subchondral bone plate	0.15	–0.50 to 0.52
Single cyst >5 mm	0.33	–0.19 to 0.62
Multiple cysts (≥2 cysts)	0.67	0.42 to 0.82
Overall stability	0.57	0.24 to 0.76

patients was 14.4 ± 5.9 months. The mean follow-up between each MRI examination for all patients was 6.4 ± 1.2 months. The majority of the lesions were on the medial femoral condyle (13/17, 76%), while 4 of the 17 (24%) were on the lateral femoral condyle. Figure 2 outlines the screening process.

Kappa Agreement for MRI Findings

The MRI diagnosis of lesion instability and the requirement for surgery were relatively poor, as was the kappa agreement between the reviewers (Table 1). The data did not allow for meaningful analysis regarding the ability of the reviewers to predict which lesions were more likely to require surgery.

OCD Lesion Stability

Table 2 summarizes the OCD lesion stability for all patients according to the MRI criteria of Kijowski et al.[16] If an OCD lesion on MRI only had bone marrow edema and met no other criteria, the lesion was deemed stable. If bone marrow edema was indicated along with 1 other criterion, the lesion was deemed unstable. Of the 49 MRI examinations that were graded, there were 26 MRI examinations showing stable lesions and 23 showing unstable OCD lesions.

TABLE 2
Summary of OCD Lesion Stability for All Patients[a]

Patient	Sex	Age at First MRI	Knee	MRI Examination							Stable Lesion Becoming Unstable	Unstable Lesion Becoming Stable Without Surgery
				1	2	3	4	5	6-8	9-10		
004	Male	14 y 5 mo	Left	S	S						No	No
010[b]	Male	10 y 10 mo	Right	U	U	U	S[c]				No	No
016[b]	Male	11 y 8 mo	Right	U	U	U					No	No
027	Male	9 y 2 mo	Right	S	S	S					No	No
031	Male	14 y 7 mo	Right	U	U						No	No
041	Male	11 y 7 mo	Left	S	U	U	S	S			Yes	Yes
047	Male	12 y 14 mo	Right	S	S	S					No	No
061R	Male	14 y 10 mo	Right	S	S						No	No
061L	Male	14 y 9 mo	Left	U	U	U					No	No
079	Male	9 y 2 mo	Right	S	S						No	No
080[b]	Male	10 y 11 mo	Left	U	U						No	No
081	Male	11 y 7 mo	Left	S	S						No	No
090	Female	12 y 4 mo	Left	U	S	S					No	Yes
092[b]	Female	9 y 10 mo	Left	S	S	U	U	U	U	S[c]	Yes	No
093	Male	8 y 3 mo	Right	S	S						No	No
097[b]	Male	12 y 5 mo	Left	S	S	S[c]					No	No
102	Male	13 y 9 mo	Right	U	S						No	Yes

[a]L, left; MRI, magnetic resonance imaging; OCD, osteochondritis dissecans; R, right; S, stable; U, unstable.
[b]Patient undergoing surgery.
[c]MRI after surgery.

Stable Lesions

The initial MRI lesion was graded as stable in 10 of the 17 knees (59%). Of those that were originally stable, 9 lesions were from male knees and 1 was from a female knee, with patients having a mean age of 10.9 ± 1.3 years. Seven lesions were found on the medial femoral condyle, while 3 were on the lateral femoral condyle. The mean MRI follow-up time for these patients was 6.4 ± 1.3 months. Seven (70%) were stable on MRI throughout the study period and did not require surgery. One of the 10 OCD lesions (patient 097) underwent surgical intervention with bioabsorbable implants despite continued documentation of stability on MRI. Indications for surgery were continued medial knee pain despite 18 months of activity modification in this previously active 13-year-old male elite soccer player. At 8.5 months postoperatively, the patient reported continued pain with athletic activity despite a follow-up MRI approximately 2 weeks later (in total, 9 months postoperatively) showing almost complete resolution of the OCD lesion with only 2 tiny cysts remaining (2 mm and 2.5 mm) (Table 3).

Of the initially stable 10 OCD lesions, 2 (20%) became unstable during the study period (patients 041 and 092) as per the Kijowski criteria. One of these 2 lesions (patient 092) underwent operative intervention with 4 bioabsorbable implants. Indications for surgery were continued medial pain for a number of years in this 13-year-old female patient, but she was still able to participate in her sport (soccer). MRI before surgery showed that the unstable lesion was not significantly different from the prior examination. She was noted to have some swelling and pain postoperatively, and there was concern of hardware failure on follow-up MRI. Four months after the initial surgery, repeat arthroscopic surgery was performed and revealed a stable lesion and no hardware complication. Debridement of scar tissue and prominent cartilage was performed. At the latest follow-up 2 years after the initial surgery, the patient continued to have some nonspecified knee pain, which was described as episodic in nature; however, MRI performed 4.5 months before this visit revealed further interval healing and remodeling of the OCD lesion (Table 3). Regarding the second patient (patient 041), subsequent MRI examinations showed stabilization with nonoperative management (Table 3).

Unstable Lesions

The initial MRI lesion was graded as unstable in 41% (7/17) of the knees. Of those that were originally unstable, 6 lesions were from male knees, and 1 was from a female knee, with patients having a mean age of 12.1 ± 1.1 years. Six lesions were found on the medial femoral condyle, while 1 was found on the lateral femoral condyle. The mean MRI follow-up time for these patients was 6.5 ± 2.6 months. Two of these 7 OCD lesions (29%) were unstable on MRI throughout the study period and had yet to be symptomatic enough to require surgical intervention (patients 031 and 061L). Two of the 7 OCD lesions (29%) progressed from an unstable to a stable lesion and did not require any surgical intervention (Figure 3).

Two OCD lesions remained unstable and underwent surgical intervention (Table 3). The indications for surgery in one, a 13-year-old male patient (patient 016), were continued pain and mechanical symptoms. The indications for surgery in the other, a 12-year-old male patient (patient 080), were pain while resting and pain with activity. A third patient with

TABLE 3
Summary of Age at MRI Examinations and Comparison of Intraoperative Abnormalities With MRI Stability[a]

Patient	Sex	Knee	Age at First MRI	Age at Surgery or Age at Last MRI Nonoperatively	Intraoperative Abnormality and Surgery Performed	MRI Stability Preoperatively
004	Male	Left	14 y 5 mo	14 y 6 mo	N/A	N/A
010	Male	Right	10 y 10 mo	11 y 6 mo	Debridement of medial plica and ligamentum mucosum; some softness but not ballotable; no fixation	Unstable
016	Male	Right	11 y 8 mo	13 y 10 mo	Debridement of plica; loose body removed; microfracture	Unstable
027	Male	Right	9 y 2 mo	10 y 1 mo	N/A	N/A
031	Male	Right	14 y 7 mo	14 y 10 mo	N/A	N/A
041	Male	Left	11 y 7 mo	13 y 5 mo	N/A	N/A
047	Male	Right	12 y 4 mo	13 y 4 mo	N/A	N/A
061R	Male	Right	14 y 10 mo	15 y 9 mo	N/A	N/A
061L	Male	Left	14 y 9 mo	16 y 3 mo	N/A	N/A
079	Male	Right	9 y 2 mo	9 y 11 mo	N/A	N/A
080	Male	Left	10 y 11 mo	12 y 7 mo	Debridement of medial plica and ligamentum mucosum; softening of cartilage overlying OCD; stabilized with 4 SmartNails[b]	Unstable
081	Male	Left	11 y 7 mo	12 y 8 mo	N/A	N/A
090	Female	Left	12 y 4 mo	13 y 6 mo	N/A	N/A
092	Female	Left	9 y 10 mo	First operation: age 13 y 8 mo for unstable OCD lesion and no other abnormalities; second operation: age 14 y 0 mo	First operation: lesion ballotable and stabilized with 4 SmartNails[b]; second operation: arthroscopic surgery of left knee and debridement of scar tissue	Unstable
093	Male	Right	8 y 3 mo	8 y 10 mo	N/A	N/A
097	Male	Left	12 y 5 mo	13 y 3 mo	Large, spongy, and palpable lesion; stabilized with 4 SmartNails[b]	Stable
102	Male	Right	13 y 9 mo	14 y 0 mo	N/A	N/A

[a]L, left; MRI, magnetic resonance imaging; N/A, not applicable; OCD, osteochondritis dissecans; R, right.
[b]Conmed Linvatec.

an unstable lesion underwent surgical intervention in which the lesion was not felt to require any treatment and only underwent plica and ligamentum mucosum debridement (patient 010). Indications for surgery were worsening pain in the lateral femoral condyle in this 11-year-old male patient. The patient noted worsening pain 11.5 months postoperatively, and subsequent MRI 7 days later revealed almost complete healing of the lesion with only a 4-mm residual subchondral bone irregularity remaining (Table 3).

Six-Point Instability Score

Table 4 shows the last MRI findings for unstable lesions before the lesion becoming stable with or without surgery. Those lesions requiring surgery had a mean instability score of 2.25 of 6, whereas those that stabilized without surgery had a mean score of 2.67 of 6, with no MRI score greater than 4. It is interesting to note that if the patient who developed a loose body is assessed separately, his stability score would have been one of the highest documented: 4 of 6 on MRI preceding the loose body (Table 5).

Surgical Outcome

Overall, 12 of 17 knees did not require surgery. Of these 12 knees, 11 lesions were from male knees, and 1 was from a female knee, with a mean age of 12.7 ± 2.1 years. Nine lesions were found on the medial femoral condyle, while 3 were on the lateral femoral condyle. The mean MRI follow-up time for these patients was 6.6 ± 3.4 months. Five of 17 knees underwent surgery. Four lesions were in male knees, and 1 was in a female knee, with patients having a mean age of 10.8 ± 1.2 months. Four lesions were found on the medial femoral condyle, while 1 was found on the lateral femoral condyle. The mean MRI follow-up time for these patients was 6.2 ± 1.9 months.

Table 3 summarizes the age at the first MRI examination for the patients who underwent both nonoperative and operative treatment as well as the intraoperative findings where applicable. Regarding the 5 patients who underwent surgery at some point during the follow-up period, 3 of the OCD lesions underwent repair with bioabsorbable implants, 1 underwent removal of a loose body and microfracture, and the last patient's lesion was not felt to require OCD surgery at the time of arthroscopic surgery.

DISCUSSION

The most important finding in this study was that MRI instability is a poor predictor of the necessity for surgery for JOCD lesions. During the study period, 4 patients had an unstable lesion that required surgery, with 1 patient

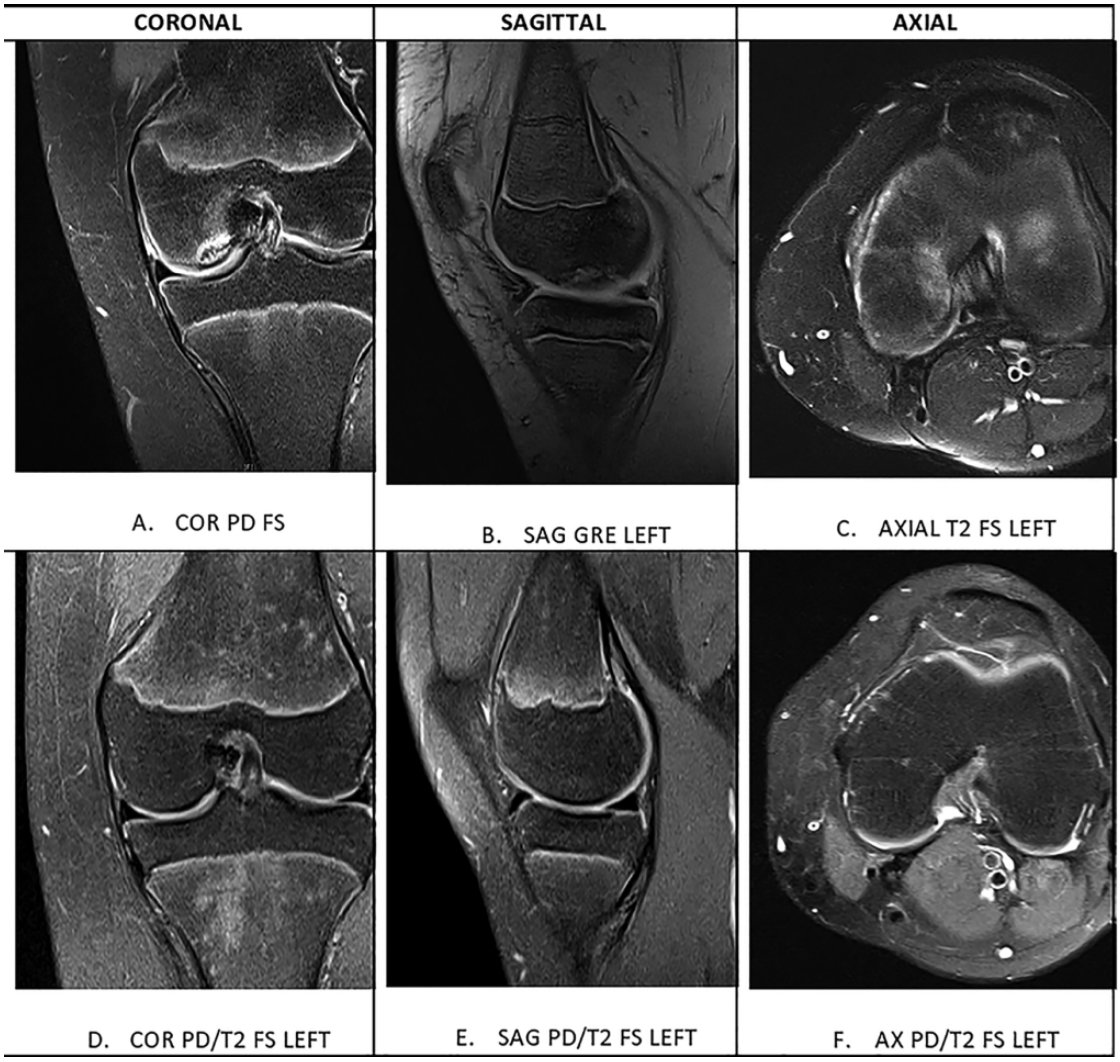

Figure 3. Unstable juvenile osteochondritis dissecans lesion that healed with nonoperative management. AX, axial; COR, coronal; FS, fat saturation; GRE, gradient echo; PD, proton density; SAG, sagittal.

suffering an irreparable loose body. However, an almost equal number of unstable lesions (n = 3) stabilized without surgery. Although patients' symptoms were a very important part of the management decision tree, surgery did not always correlate with symptom relief. These findings outline the fragile balance between treatments in these young patients being too aggressive and not aggressive enough.

With the advances in MRI technology to detect "truly" unstable lesions, there is potential to be more aggressive with surgery in JOCD. This study does not necessarily support this approach, as a number of the patients with an unstable lesion on the index MRI examination did not require surgery during the study period (57%). Furthermore, 44% (4/9) of the lesions that were unstable at some point during the study stabilized without operative intervention (includes patient 010, whose arthroscopic surgery did not reveal a lesion requiring treatment).

We are intrigued with the MRI findings for the patient who developed a loose body (patient 016). His MRI instability score before the loose body was very high (4/6). It is possible that the combination of potential MRI instability criteria along with other poor prognostic indicators may be important in determining lesions that may not heal without surgery. This would support the finding of Kijowski et al[16] that 3 of their criteria combined revealed an unequivocally unstable OCD lesion as confirmed at arthroscopic surgery. However, we were unable to replicate the findings of these authors that 3 secondary MRI findings had 100% sensitivity and 100% specificity for the detection of unstable JOCD lesions. This may be related to the delays between MRI and surgery in our study.

Despite Kijowski et al's[16] strong correlation between MRI findings and the gold standard of arthroscopic surgery, the literature has shown that MRI classification systems still do not always provide clear evidence of lesion instability. O'Connor et al[21] reported on the arthroscopic and MRI findings of 33 OCD lesions and found that 21 lesions were considered unstable using MRI while 10 of the 21 lesions were

TABLE 4
Last MRI Findings for Unstable Lesions Before the Lesion's Becoming Stable With or Without Surgery[a]

Patient	Age at Last Unstable MRI Lesion	Site of Lesion	Size of Lesion, cm × cm	High T2 Signal Intensity Rim	Multiple Breaks in Subchondral Plate	Second Outer Rim of Low T2 Signal Intensity	Cartilage Breach	Presence of Cysts and Size of Largest Cyst
Required surgery								
010	11 y 3 mo	LFC	1.0 AP × 0.5 ML	Yes	No	Yes	No	No
016	13 y 4 mo	MFC	1.6 AP × 0.6 ML	Yes	No	No	Yes, with loose body	No
080	11 y 6 mo	MFC	2.2 AP × 0.6 ML	Yes	No	No	No	Yes, multiple (0.055 cm)
092	13 y 6 mo	MFC	1.5 AP × 1.3 ML	Yes	No	Yes	No	No
Stabilized without surgery								
041	12 y 7 mo	MFC	3.0 AP × 1.5 ML	Yes	No	Yes	No	No
090	12 y 4 mo	MFC	2.1 AP × 1.1 ML	Yes	No	No	No	Yes (0.2 cm)
102	14 y 0 mo	MFC	1.7 AP × 1.3 ML	Yes	No	No	No	No

[a]AP, anterior-posterior; LFC, lateral femoral condyle; MFC, medial femoral condyle; ML, medial-lateral; MRI, magnetic resonance imaging.

TABLE 5
MRI Findings for the Patient Who Formed a Loose Body and Required Surgery[a]

Patient	Age at Last Unstable MRI Lesion	Site of Lesion	Size of Lesion, cm × cm	High T2 (or PD/T2) Signal Intensity Rim	Multiple Breaks in Subchondral Plate	Second Outer Rim of Low T2 Signal Intensity	Cartilage Breach	Presence of Cysts and Size of Largest Cyst
016: first MRI	11 y 5 mo	MFC	2.3 AP × 1.3 ML	No	Yes	No	No	Multiple
016: second MRI	12 y 2 mo	MFC	2.4 AP × 1 ML	Yes	Yes	No	No	Yes, many small cysts
016: last MRI before surgery	13 y 4 mo	MFC	1.6 AP × 0.6 ML	Yes	No	No	Yes	No

[a]AP, anterior-posterior; MFC, medial femoral condyle; ML, medial-lateral; MRI, magnetic resonance imaging; PD, proton density.

found to have overlying cartilage during arthroscopic surgery. Samora et al[24] analyzed 132 JOCD lesions that underwent arthroscopic treatment and found that the agreement between MRI and arthroscopic grading was only 62.1%. A high T2 signal was a reliable predictor for low-grade, stable lesions but less reliable for high-grade, unstable lesions.

Chen et al[5] devised a protocol combining 3-dimensional gradient echo (3D GRE) T1-weighted and routine MRI for the evaluation of OCD lesions. The presence of a high signal or cyst behind the lesion on T2 MRI generally indicates instability, but this high signal may also represent vascular granulation tissue in the healing response. To solve this, Chen et al found that 3D GRE T1-weighted MRI through routine sequences demonstrated excellent results in detecting unstable OCD lesions. 3D GRE T1-weighted MRI showed the articular cartilage as bright and the fluid as dark to intermediate. This distinction may help in the differentiation of fluid from granulation tissue and provide more accurate grading of JOCD.

Kramer et al[18] reported the use of magnetic resonance arthrography to improve the accuracy of the assessment of overlying articular cartilage. The contrast infiltrating into the interface clearly defined an unstable lesion. Conversely, the lack of contrast in the interface may indicate a stable lesion. However, the invasive procedure and coordinated fluoroscopy time limit the routine clinical use of magnetic resonance arthrography in the diagnosis of OCD.

Further confusion regarding JOCD knee lesions exists because of the normal growth variants seen in the pediatric knee. Gebarski and Hernandez[13] retrospectively reviewed MRIs of the knees of 38 children to look for features that might separate normal variants of ossification from stage 1 OCD lesions. The inclusion of normal variants in the stage 1 OCD category might explain the noticeable difference in published outcomes between juvenile and adult OCD. Ossification defects in the posterior femoral condyle with intact overlying articular cartilage, accessory ossification centers, spiculation, residual cartilaginous modeling, and lack of bone marrow edema are features of developmental variants rather than OCD.

Although surgery for these lesions is minimally invasive, with reported high success rates,[23] the risk/benefit

ratio of surgery must always be considered. One of the patients in this study abandoned their first surgery because of bronchospasm. While the patient did not suffer any complications related to this, the result could have been more serious. Considering the absence of a sensitive physical examination test for these lesions,[7] the lack of a diagnostic test that clearly identifies the degree of lesion instability that prevents the lesion from being able to heal spontaneously, and the lack of sufficient long-term follow-up documenting issues that may arise from surgical techniques that damage the articular cartilage, the decision to operate on these lesions must be made carefully. It can be very difficult to determine if JOCD is in fact the cause of the patient's complaint, as may have been the case with the continued pain despite surgical intervention in some of the patients in the current study.

There are a number of limitations with this study. The number of OCD lesions was small; however, the sample size is comparable to or larger than many of the published studies of this relatively uncommon condition.[23] The retrospective nature of the study is not as reliable as a prospective review because of incomplete data, such as the nonoperative treatment prescribed and patient compliance. One of the major weaknesses of the study was considering lesions as unstable according to the use of independent MRI findings and not all 3 of the Kijowski criteria combined. We felt that using these secondary criteria was a reasonable compromise, as most lesions in this study did not meet all 3 criteria, even those that were noted to be unstable at arthroscopic surgery. Furthermore, many surgeons become concerned when these independent MRI findings by themselves are present. Also, not all of the patients were observed until healing of the OCD lesion, and a longer term follow-up may be necessary to understand the true role of MRI in this patient population. Information on objective physical examination measures of the patients was not documented and thus could not be correlated to MRI findings in any meaningful or statistical way. Some of the MRI examinations were performed at outside centers and were not always performed with the ideal protocol for imaging OCD lesions in pediatric patients, although duplicate independent reviews using standardized criteria occurred to minimize the effects of this. In addition, in the adolescent population, biological age does not always correlate with developmental age, and so we were unable to assess whether biological age alone is a predictor of lesion healing. Finally, the OCD lesions were not always classified clearly during arthroscopic surgery, making a correlation with the MRI classification difficult and possibly introducing a selection/spectrum bias.

Future areas of research should focus on a longer term follow-up of patients with OCD lesions treated both operatively and nonoperatively to better elucidate the optimal time to try nonoperative therapy before proceeding with surgery. Because of the small numbers of patients frequently found in these studies, larger multicenter prospective cohort trials are necessary. Efforts on developing a standardized scoring system that incorporates patient clinical history/physical examination findings with radiographic features of lesion stability and poor prognostic indicators are warranted to better ascertain which features of the lesion radiographically are more likely to resolve with continued nonoperative measures versus those that will likely only improve with surgical intervention. A standardized arthroscopic classification system for these lesions would be beneficial in comparing the results of different trials. The ROCK (Research in OsteoChondritis of the Knee) study group has already published such a classification system that could be adopted for future studies after surgical intervention.[4]

CONCLUSION

MRI by itself was not sufficient to determine which patients would eventually require operative intervention to stabilize unstable JOCD lesions. Unstable lesions on MRI did not appear to correlate with patient symptoms necessitating surgical intervention. The severity and duration of patients' symptoms, their functional limitations, and a careful clinical examination are important ancillary information before the decision to operate is made.

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