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The role of MRI in assessment of the post-operative knee

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Abstract:
Purpose:*To assess the role of MRI in evaluation of the post-operative knee joint and assessment of the post complications after ACL, meniscal and cartilage surgical repair procedures*
Patients and methods:*A prospective study recruited 50 patients, their ages ranged between 18 and 45 years after repair of ACL , menisci and cartilage. All patients were referred from the orthopedic department between January 2014 and June 2015 with symptoms and signs suspicious of complications. The patients were divided into three groups , group I after ACL repair included 26 patients , group II after meniscal repair and included 16 patients , group III after cartilage repair and included 8 patients.*
MRI knee was performed for all patients after meeting inclusion criteria.
Results:*(A) In group I Graft impingement was the most frequentlyencountered complication representing 6/26 (23%). Partial tear was encountered in 3/24 (11.5%). Complete tear was seen in two patients for each (7.69%). One patient had intact graft with bright signal (3.85%). One patient had cystic degeneration with ganglion cyst (3.85%). The remaining 13/26 (50 %) patients had negative MRI with intact graft. (B) In group II Retorn meniscus was the most frequently encountered complication representing 5/16 (31.25%). Effusion was encountered in 3/16 (18.75 %). One patient had osteonecrosis (6.25%). The remaining 7/16 (43.75 %) patients had negative MRI with intact meniscus. (C) In group III Delamination was the most frequently encountered complication representing 28 (25%). Intra-articular adhesions was encountered in 1/16 (12.5 %). Also One patient had hypertrophbic synovitis (12.5%). The remaining 4/8 (50 %) patients had negative MRI with intact repaired cartilage.*
Conclusion:*MRI proved as an accurate method for evaluation of the knee joint after ACL, meniscus and cartilage repair that can help predict post-operative complications.*

I. Introduction

The increased number of patients undergoing arthroscopy or surgery of the knee injuries lead to increased numbers of patients who require imaging after surgery because of failure to improve, recurrent symptoms, or new injury (1).

The most common procedures include partial meniscectomy & meniscal repair, anterior cruciate ligament (ACL) reconstruction, & cartilage repair procedures(1).

As in preoperative patients, magnetic resonance (MR) imaging is the most valuable imaging method for postoperative evaluation of the knee. Surgical changes increase the difficulty of diagnosis of abnormalities in the knee with MR imaging(2).

Specific findings of a retorn meniscus following meniscal repair or partial meniscectomy are increased signal intensity extending through the site of repair on T2- weighted images, displaced meniscal fragments, & abnormal signal intensity at a site distant from the repair(3).

Findings of ACL graft disruption on T2-weighted MR images include absence of intact graft fibers & increased signal intensity similar to that of fluid within the expected region of the graft(2).

Partial tears of the graft appear as areas of increased signal intensity affecting a portion of the graft with some intact fibers still present(2).

MR imaging has been shown to be accurate in the evaluation of cartilage repair tissue (4).

Recognition of the normal postoperative MR imaging appearance of the structures in the knee & of abnormalities is essential to accurate MR imaging evaluation of these patients(2).

II. Patients and method

This is a retrospective study carried out in Al Farwaniya and Al Razi Hospitals (Kuwait) from January 2014 to June 2015 for patients who have done MRI after knee surgery for assessment of surgery success and detect post-operative complications.

A total number of 50 postoperative knee patients were included in our study, 50 are male. The age of the patients ranged from 18 to 45 years.

Inclusion criteria were:
(A) ACL repair:
1. Full thickness ACL tear.
2. No evidence of arthritis.
3. Complaining of pain, decreased range of motion or laxity
(B) Meniscal repair:
1.Vertical full-thickness tear greater than 10mm in length
2. location of the tear less than 6mm from the meniscocapsular Junction
3. No evidence of arthritis.
4. Complaining of pain, decreased range of motion.
(C) Cartilage repair:
1. Full thickness cartilage loss.
2. No evidence of arthritis.
3. Complaining of pain and swelling.

Exclusion criteria were:
1.Previous inter-condylar notch plasty.
2.Chronic muscle disorders.
3.known active articular infection.
4.Metabolic bone disease and neoplastic disease.

III. Imaging

All patients recruited in our study were examined using MRI GE 1.5 tesla machine, with dedicated knee coil and 17 cm field of view. Imaging was done in supine position after routine patient preparation.
All patients were imaged in sagittal and coronal STIR (TR: 4080ms; TE: 30 ms; Slice thickness 4 mm), sagittal PD (TR: 2000ms; TE: 17 ms; Slice thickness 4 mm) Sagittal and axial T2 (TR: 3500 ms; TE: 90 ms, Slice thickness 4 mm).

IV. Image Analysis:

A- Interpretation of the MRI findings post ACL grafting / reconstructive surgery:
MR images were evaluated for graft thickness, shape, & signal intensity, as well as for femoral &tibial tunnel placement, arthrofibrosis, & associated injuries to the menisci, collateral ligaments & cartilage.

B-Interpretation of the MRI findings post meniscal surgery:
MR imaging criteriafor the diagnosis of primary meniscal tears include regionsof increased intra-meniscal signal intensity (on short echo timeimages) that reach an articular surface & abnormal meniscalmorphology. The findings of high-signal-intensityjoint fluid extending into a cleft within the meniscal fragmenton T2-weighted images or of a displaced meniscal fragmentare specific signs of a retorn meniscus.

C- Interpretation of the MRI findings post cartilage surgery: Through the assessment of the following:

1. Morphologic characteristics of reparative tissue
2. Presence or absence of delamination
3. Extent of peripheral integration (presence of fissures)
4. Autologous autograft transplantations
5. Degree of filling of defect by transplanted osteochondralplugs
6. Restoration of radial curvature of joint surface
7. Presence or absence of displacement
8. Peripheral integration of repair cartilage & osseous components.

V. Statistical analysis

Data entry was done by SPSS version 17 and analyzed by the same software.

VI. Results

We had three groups of patients in our study, and the results for each group were analyzed separately.

Groups		
	N	**%**
ACL repair	26	52.0
Meniscal repair	16	32.0
Cartilage repair	8	16.0
Total	50	100.0

Results for group I

As regards the indications 26 patients had abnormal findings in previous imaging, fifteen patients had pain (58 %) with the rest of the patients showing equivocal clinical findings (Table I).

Symptoms		
	N	%
Swelling	20	76.92
tenderness	17	65.38
limited extension	14	53.85
local tenderness	1	3.85

Table1: Symptoms of group I

Findings post ACL repair.

Out of 26 patients post ACL repair, 13 patients (50%) had Intact graft**(Fig 1)**, 6 patients (23%) had Graft impingement**(Fig 2)**, 3 patients (11%) had partial graft tear , 2 patients (8%) had complete graft tear**(Fig 3)**, 1 patient (4%) hadCystic degeneration of the graft (Ganglion cyst) and 1 patient (4%) hadIntact graft with bright signal. (Table 2)

Post-operative MRI Findings	N	%
Intact ACL Graft	13	50.00
Graft Impingement	6	23.08
Partial ACL graft Tear	3	11.54
Complete ACL graft tear	2	7.69
Intact graft with bright signal	1	3.85
Cystic degeneration with ganglion cyst	1	3.85

Table 2: post-operative MRI findings in group I

Associated meniscal and other MRI findings:

The patient population had the following associated MRI findings: 22 patients had PHMM tear , 4 patients had PHLM tear , 18 patients had joint effusion , 4 patients had diffuse arthrofibrosis, 3 patients had collateral ligament sprain, 3 patients had anterior tibial translation , 2 patients had uncovered PHLM, and 1 patient had Cyclops lesion**(Fig 4)**.**(Table 3)**.

Associated MRI findings		
	N	%
PHMM Tear	22	84.62
knee effusion	18	69.23
PHLM tear	4	15.38
Diffuse arthofibrosis	4	15.38
collateral sprain	3	11.54
Anterior translation	3	11.54
Uncovered PHLM	2	7.69
Cyclops lesion	1	3.85

Table 3: Associated MRI findings in group I

Results for group II

As regards the indications 16 patients had abnormal findings in previous imaging (11 torn medial meniscus , 5 torn lateral meniscus) , The patients had equivocal clinical findings as follows (Table 4):

Symptoms		
	N	%
Swelling	15	93.75
tenderness	11	68.75
limited extension	10	62.50
local tenderness	2	12.50

Table 4: Symptoms of group II

Post Operative MRI findings

Out of 16 patients in the post meniscal repair group, 7 patients (44%) had Intact meniscus**(Fig 5)**, 5 patients (31%) hadRetornmeniscus**(Fig 6)**, 3 patients (19%) had joint effusion , 1 patient (6%) had osteonecrosis. (Table 5)

Post-operative MRI		
	N	%
Intact meniscus	7	43.75
Retorn meniscus	5	31.25
Effusion	3	18.75
Osteonecrosis	1	6.25
Total	16	100.00

Table 5: Post-Operative MRI findings

Results for group III

As regards the indications 8 patients with abnormal findings in previous imaging, The patients had equivocal clinical findings as follows (Table 6):

Symptoms		
	N	%
Swelling	8	100.00
local tenderness	6	75.00
tenderness	2	25.00
limited extension	1	12.50

Table 6: Symptoms of group III

Post -operative MRI Findings:

Out of 8 patients in the post cartilage repair group, 4 patients (50%) had
Intact cartilage **(Fig 7)**, 2 patients (25%) had delamination , 1 patient (12.5%) had Intra-articular adhesions , 1 patient (12.5%) had Hypertrophic synovitis. (Table 7)

Post-operative MRI		
	N	%
Intact Cartilage	4	50.00
Delamination	2	25.00
Intra-articular adhesions	1	12.50
Hypertrophic synovitis	1	12.50
Total	8	100.00

Table 7: Post-operative findings in group III

VII. Discussion

The most commonly reconstructed ligament in the knee is the ACL. Its clinical evaluation can be difficult. Post operative ACL graft patients complaining of knee instability and loss of extension or pain are indicated for clinical and radiological examination aiming to diagnose ACL graft failure, ACL graft complication or other internal derangement (5).

The MR imaging plays an important role in the assessment of ACL graft and diagnosing complications associated with ACL reconstruction. Retrospective analysis of the primary MR imaging signs of ACL graft tear evaluated in this study revealed that evaluation for graft fiber continuity, complete graft discontinuity, and graft thickness are most valuable of graft failure and poor outcome(2).

Correct positioning and alignment of both femoral and tibial tunnels are crucial for graft stability and good clinical outcomes. In our study we found that graft fiber continuity and graft thickness are the most important for normal graft evaluation and this is in agreement with ***Horton et al, 2000*** who stated that a tear can be excluded if the full thickness of the graft is seen as intact on sagittal or coronal planes. Complete discontinuity of the graft on both coronal and sagittal planes was 100% specific for diagnosing tears.

In our study we had 26 patients coming for evaluation of ACL repair , all the included patients were males , there were 16 right knees and 10 left knees.

This study showed that 13 of our patients (50%) showed intact ACL graft Normal ACL graft should have low signal intensity on short-TE sequences and the full thickness of the graft is seen as intact on sagittal or coronal planes, this is in agreement with ***Horton et al, 2000***.

In our study 6 patients (23%) had graft impingement which was the commonest post-operative complication, the tibial tunnel was seen anterior to the intersection of the slope of the intercondylar roof with the proximal tibia in these patients where the graft was seen impinged on by the roof of the inter-condylar notch As the tibial tunnel should be oriented parallel to the Blumensaat line which is a line drawn along the intercondylar roof, its distal portion should start near the tibial tuberosity, and the intra articular opening of the tunnel should be completely posterior to this line. In some of these patients not only the tibial tunnel was mal-positioned also the femoral tunnel was also seen mal-positioned. This was concordant with ***Meyerset al, 2010***.

In this study we found that 3 patients(11 %) had partial graft tear and 2 patients (8 %) had complete ACL graft tear , in the former case there was partial discontinuity of the graft in the coronal and sagittal images with still remaining intact fibers this is in agreement with ***Horton et al, 2000***.

Complete ACL graft tear was found in 2 patients (8 %) where increased signal intensity was detected with complete discontinuity of the graft on both coronal and sagittal planes which was 100% specific for diagnosing tears together with abnormal Blumensaat line, this was associated with secondary signs, such as PCL buckling , anterior tibial translation and uncovering of the posterior horn of the lateral meniscus, this is in agreement with ***(Horton et al, 2000)***.

Cystic degeneration of the graft and ganglion cyst formation within the tibial tunnel were seen in one of our patients (3.85 %). The tibial tunnel appeared markedly widened and filled with fluid signal on all pulse sequences that extended into the joint space and distally to the tibial tubercle , ***White et al, 2005*** and others agreed with our findings and they stated that cystic degeneration of the graft may occur as a late complication of ACL reconstruction leading to marked widening of the tunnel and filling the tunnel with fluid signal.

In our study also 1 patient (3.85 %) intact graft with bright signal , the ACL graft is well stretched with normal Blumensaat line , this is in agreement with ***Meyers et al. (2010)***.

The patient population in our study for the ACL repair had the following associated MRI findings: 22 patients had posterior horn medial meniscus (PHMM) tear , 4 patients had posterior horn lateral meniscus (PHLM) tear , 18 patients had joint effusion , 4 patients had diffuse arthrofibrosis, 3 patients had medial collateral ligament sprain, 3 patients had anterior tibial translation , 2 patients had uncovered PHLM, and 1 patient had Cyclops lesion.

It is known that MRI is a non-invasive method to assess meniscal status and therefore easily accepted by patients. However, the evaluation of the meniscus after resection or repair is difficult to evaluate with MRI. Many authors proposed different, and not the classic MR criteria to differentiate repeat meniscal tears after meniscal resection(6).

This is because of the variable appearance of the meniscus after partial resection or repair, which is influenced by both location and degree of resection or repair(7).

According to the literature the appearance of the meniscus after meniscal repair has a grade three signal intensity on MRI scans postoperatively in the majority of cases in the healing meniscus , ***Farley et al , 2001*** suggested that the presence of grade three signal intensity within the postoperative meniscus was not an indicator of recurrent
meniscal tear.

Arnoczky et al , 2004 in an excellent study found that during the normal healing of a repaired meniscus there is a gap of 1–2mm between the repaired segments, which filled with a translucent tissue highly cellular and fibrovascular 3 months after repair. Six months postoperatively, the gap is gradually filled with the repair tissue showing evidence of fibrocartilagenous metaplasia, gradual filling of the gap, which is part of the normal course of meniscal healing, can be evaluated with conventional MRI. Our findings were in agreement with the above mentioned publications.

In our study we had 16 patients coming for evaluation of Meniscal repair , all the included patients were males , there were 8 right knees and 8 left knees.

This study showed that 7 of our patients (43.75 %) showed intact repaired meniscus which appeared as attenuated meniscus with either no abnormal signal within or with intra-meniscal signal intensity (IMSI) that showed reduction in size in the serial MRI follow up this is in agreement with ***Farley et al, 2001***. An limitation of our study is that our patients did not undergo second-look arthroscopy, which it is the standard of reference for evaluation of meniscal status. However, according to ***Morgan et al, 2001*** clinical examination seems to be a reliable method of evaluating the status of repaired menisci. In the above study, it was proved that clinical examination accurately predicted all failures in second look arthroscopy, with no false positives. In our study a repaired meniscus was considered healed if there was neither joint line tenderness, nor effusion or a positive McMurrey test, according to the strict clinical criteria of ***Barrett et al, 1998.***

Retorn meniscus was found in 5 of our patients (31.25 %) , The findings of abnormal meniscal morphology , high-signal-intensityjoint fluid extending into a cleft within the meniscal fragmenton T2-weighted images or reaching to articular surface as well as a displaced meniscal fragmentare specific and but less sensitive signs of a retorn meniscus , this is in agreement with ***Chung et al, 2005*** who stated that using of the stricter criterionof fluid signal intensity within a linear defect in the meniscuson T2-weighted images has been shown to provide highspecificity (88%–92%) but low sensitivity (41%–69%)for tears.

Joint effusion was observed in our study in 3 patients (18.75 %) and was associated with anoverall incremental increasein accuracy in the diagnosis of a recurrent meniscal tear , in accordance with ***Wood, et al, 2004.***

In our study 1 patient (6.25 %) showed Spontaneous osteonecrosisof the knee in MRI which presented as a well-demarcated focal region of subchondralbone marrow abnormality with more diffuse changes in signalintensity in surrounding bone marrow , these changes were described in a study by***Chung et al , 2011.*** These changesmost likely represent sequelae of mechanical changes relatedto the meniscectomy rather than a primary abnormality of bonemarrow.In the diagnosis of recurrent meniscal tears, conventional MRimaging had specificity of80%(12).

The ability of MR imaging to directly depict subchondral bone&bone marrow represents an advantage over arthroscopy. MR allows depiction of the depth & volume (percentage) Offilling of a cartilage defect(14).

The signal intensity of repair tissue is judged on the basis of GRE images. The signal in repair tissue may be isointense, hypointense, or hyperintensewhencompared with that in the native cartilage(14).

In our study we had 8patients coming for evaluation of the articular cartilage after repair , all the included patients were males , there were 5 right knees and 3 left knees.

Intact cartilage was found in 4 of our patients (50 %) , low signal intensity of thehealthy repair tissue was detected immediately after autologous chondrocyteimplantation , the initial signal intensity of the repair tissueincreased with time and, 6–9 months later, it resembled thatof the native cartilage , this is with agreement to a study made by ***Chow et al, 2004***.

Two of the patient's included in this study (25 %) showed signs of delamination in the post-operative MRI images , one showed partial delamination which appeared as a fissure between the repairtissue&underlying subchondral bone while the other showed complete delamination where the entire graft

was separate from the defect site &appearedas a loose body , these findings are in accordance with ***Brown et al, 2004***.

Intra-articular adhesions was detected in one patient (12.5 %) and appeared as areas of fibrosis with low to intermediate signalintensity on the cartilage surface in the infrapatellar fat pad & the suprapatellarpouch , this . Adhesions occur most frequently in patients who havehad extensive surgery , this is in agreement with ***Marlovits et al, 2006.***

Hypertrophic synovitis was detected in one patient (12.5 %) and appeared as proliferated synovial lining of the knee joint which enhanced with gadolinium and was associated with joint effusion , such findings were confirmed by a previous study by ***Tins et al , 2005***.

In conclusion our findings proved that MRI has high sensitivity and specificity regarding the assessment of the post-operative knee joint also all the above mentioned papers stressed that MRI imaging provides excellent anatomical and morphological assessment of the knee joint after surgical intervention in the field of ACL , meniscal and cartilage repair being time saving and non-invasive as well as being available on a broad spectrum.

A B C

Fig. 1:40 years old male patient with history of ACL reconstruction 9 months ago presented with knee pain. (A) Sagittal T2 showed intact graft fibers. (B) Sagittal STIR Intact graft. (C) Coronal STIR showed adequate location of the femoral tunnel with regular outline.

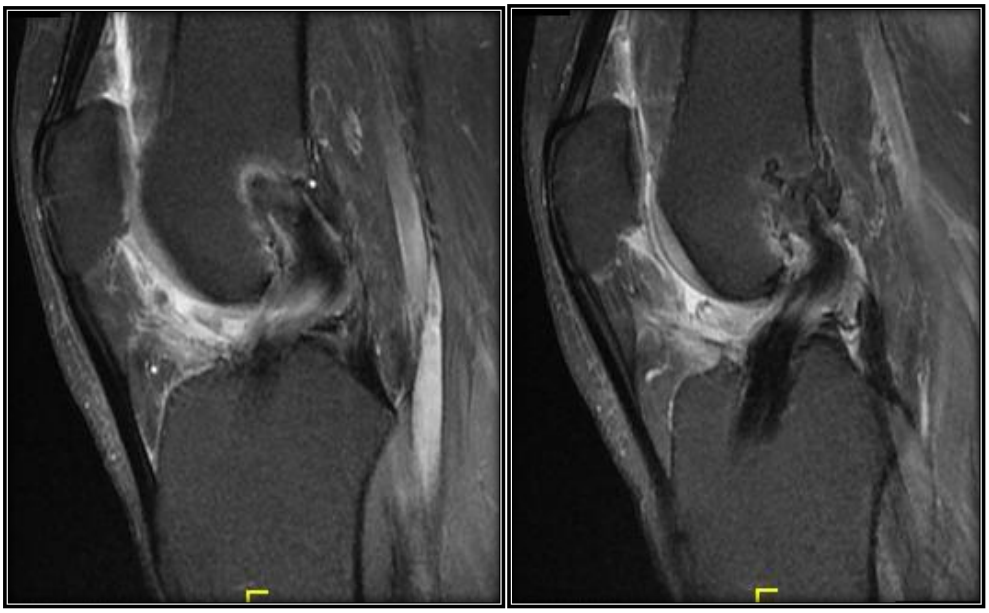
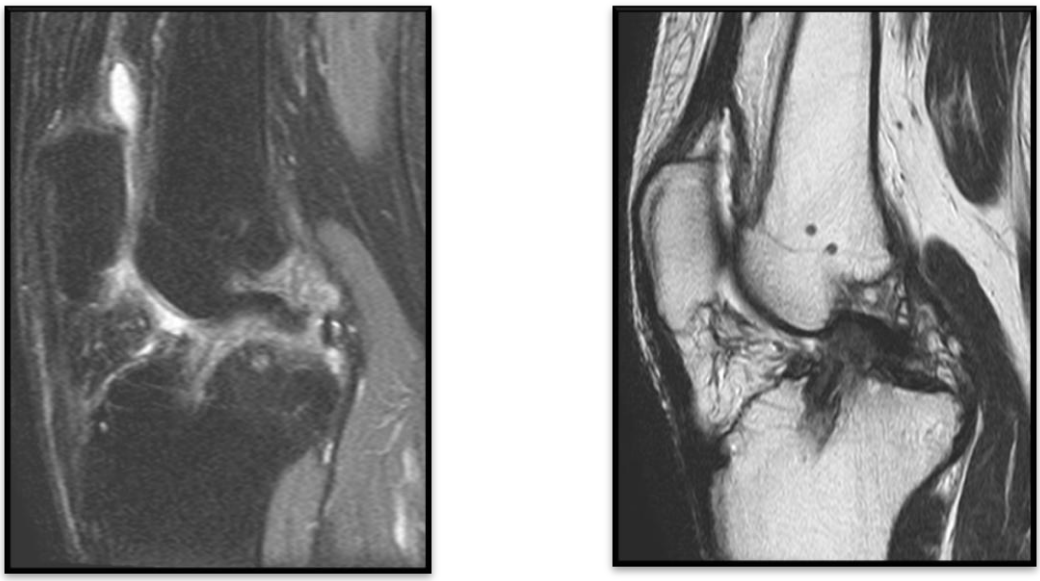
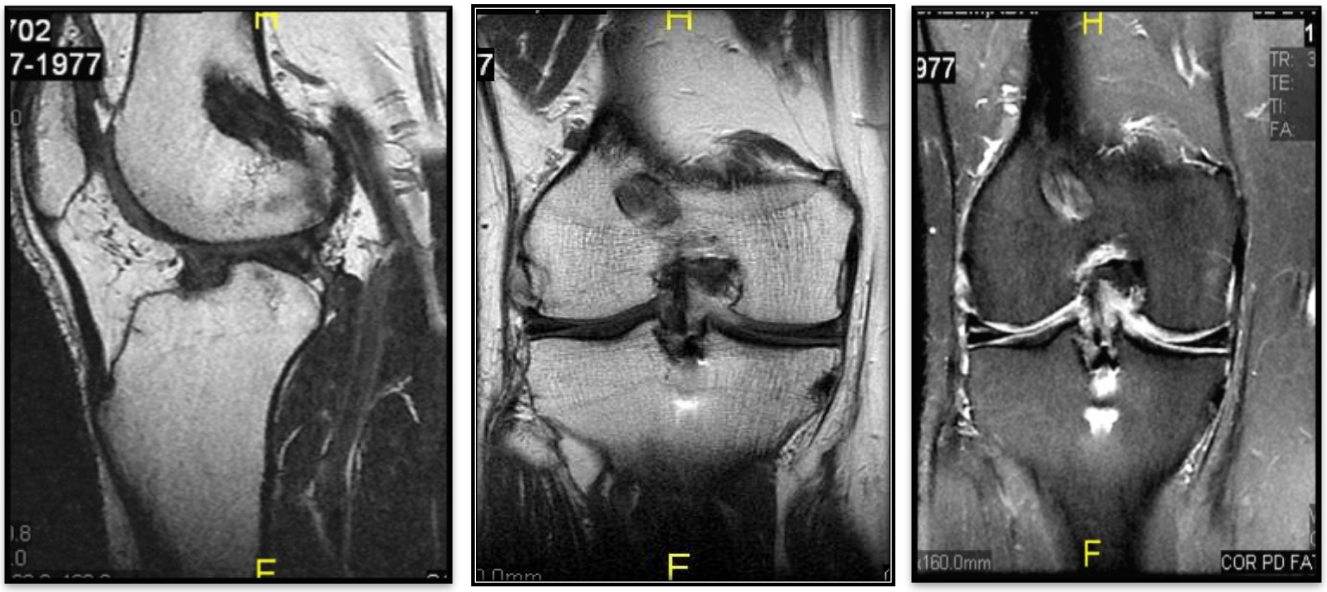


FIG2:42 years old male patient with history of ACL reconstruction one year ago presented with knee pain.Sagittal T2 PD Fat Sat showing thickened graft with intrasubstance bands of high signal denoting graft degeneration and intrasubstance tear due to chronic impingement against femoral inter-condylar notch.



AB

Fig. 3:37 years old male patient with history of ACL reconstruction 6 months ago presented with knee pain. (A) Sagittal STIR and (B) Sagittal T2 showed indistinct ACL graft fibers.



A B C

Fig. 4: 32 years old male patient with history of ACL reconstruction 10 months ago presented with knee pain. (A) Sagittal T2 showing a small focal lesion heterogeneous low signal intensity anterior to the distal half of the ACL graft (Cyclops)(B) Coronal T1 post contrastshowing small focal lesion of heterogeneous signal intensity and enhancing surrounding synovium anterior to the distal half of the ACL graft (Cyclops) (C) Coronal STIR showinga small focal lesion of heterogeneous signal intensity anterior to the ACL graft(Cyclops).

A **B**

Fig. 5: 28 years old male patient with history of lateral meniscus repair 7 months ago presented with knee pain. (A) Sagittal STIR T2 and (B) Coronal T2 STIR showing attenuated lateral meniscaus with no abnormal signal within denoting post-operative changes.

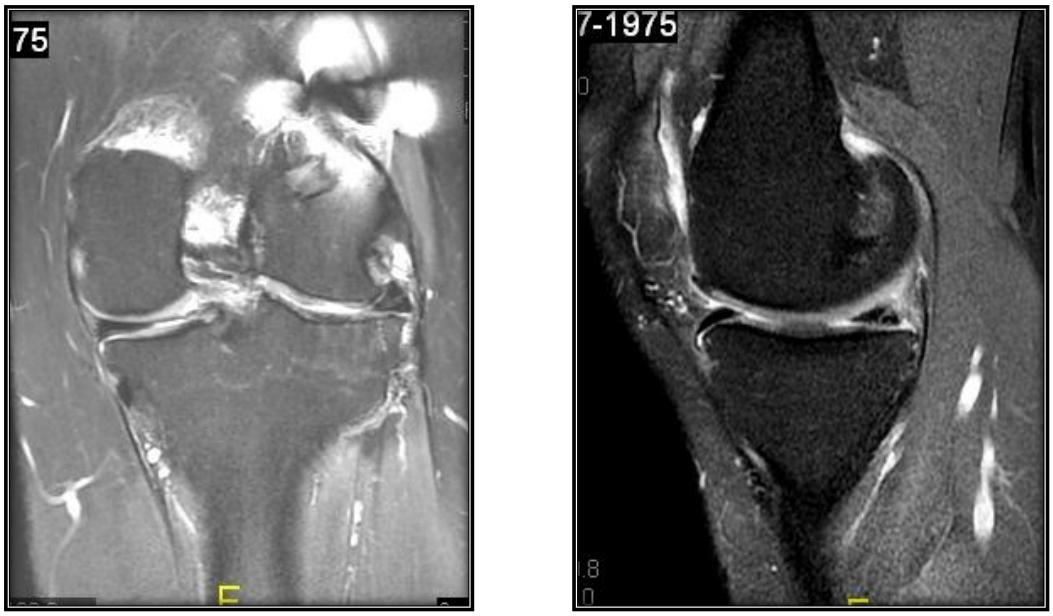


Fig. 6: 39 years old male patient with history of medial meniscus repair 6 months ago presented with knee pain. (A) Coronal STIR T2 and (B) Sagittal T2 STIR showing Branching high signal intensity interrupting the inferior articular surface and menisco-capsular attachment with meniscal extrusion in the coronal WIs suggestive of retear.

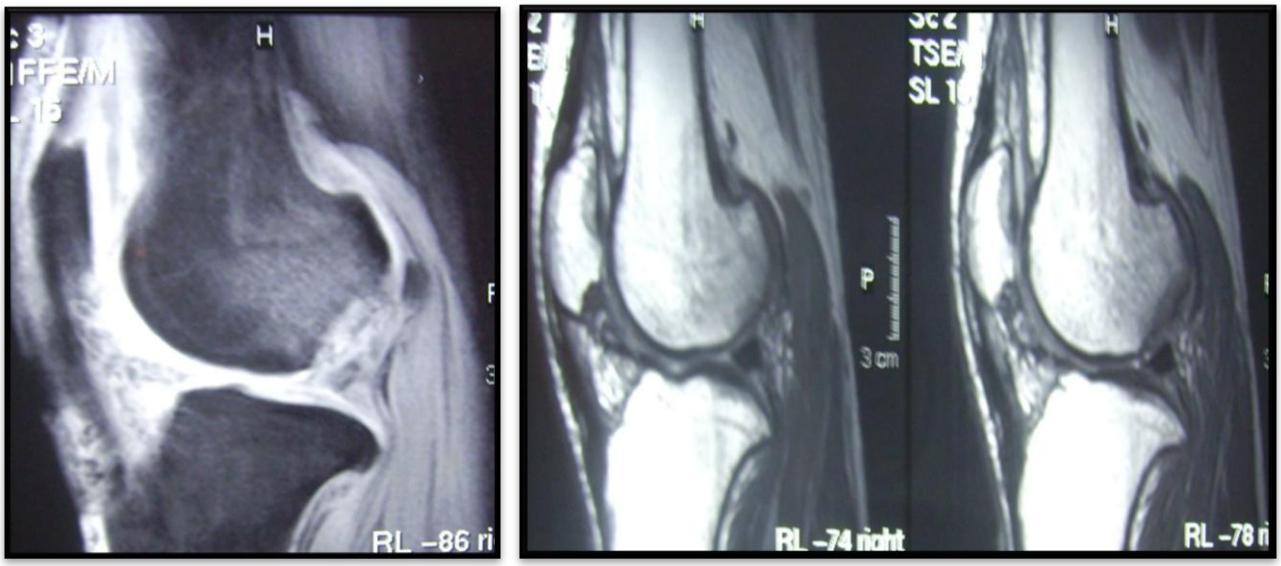


Fig. 7: 20 years old male patient underwent stem-cell implantation for articular cartilage defect from the lateral femoral condyle 9 month ago , coming for follow up (A) Sagittal PD (B) 3D SPIR SAGITTAL, showing good congruity between the artificial cartilage & native cartilage with no cartilaginous delamination.

VIII. Conclusion

MRI is highly accurate in diagnosing meniscal and ACL tears. It is the most appropriate screening tool for therapeutic arthroscopy. It is preferable to diagnostic arthroscopy in most patients because it is faster and avoids surgical risks.

Area of future research is the use of specific MRI sequences to identify problems in each of the various tissues in and around the knee (ligaments, menisci, tendons, articular surface and bone), while keeping the investigation within acceptable times and costs.

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