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Imaging for Cartilage injuries

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Abstract

Chondral injuries can occur in an isolated manner or, more commonly, in association with osseous or soft tissue injuries. Accurate pre-knowledge of the chondral injury and associated injuries helps the orthopaedic surgeon in planning appropriate treatment procedures. Advances in various treatment techniques for chondral defects places paramount importance on the identification, and quantification of these injuries. Through this article, we present a review of literature regarding Magnetic resonance imaging assessment of chondral injuries, also addressing the scan parameters used, advances in imaging for cartilage, role of Magnetic resonance imaging in post operative follow-up, comparison of accuracy of Magnetic resonance imaging with arthroscopy as well as the roles of ultrasonography and computed tomography in evaluation of articular cartilage.

Magnetic resonance imaging has an indispensable role in the pre-arthroscopic work-up and post-arthroscopic follow-up of chondral injuries. It gives an accurate knowledge of chondral defects/ injuries, staging of lesions, evaluating subchondral bone, assessing adjacent cartilage, identifying loose bodies in remote recesses likely to be missed on arthroscopy, and identifying other ligament/meniscal tears . It is also useful in assessing the donor and recipient sites in

The post-arthroscopic work up following cartilage repair. Ultrasound arthroscopy is a new quantitative intra-operative imaging modality, still not widely used. Computed tomography doesn't image the cartilage directly but plays an important ancillary role in evaluation of subchondral bone and identification of location and size of loose bodies.

Keywords: Chondral, injuries, MRI.

Introduction

Magnetic resonance imaging (MRI) has emerged as the modality of choice for evaluating the articular cartilage, as it allows good and accurate visualization of normal and abnormal cartilage. The recent increase in availability of treatment options for articular cartilage has pushed MRI into the forefront in preoperative evaluation of chondral injuries [1].

Objective and subjective assessment of the size and extent of chondral injury and the status of the adjacent cartilage is possible . Advances have led to development of MRI techniques capable of volume quantification of chondral injury and assessment of biochemical composition of the adjacent articular cartilage . This assumes increased significance for treatment planning and is useful in follow up monitoring of surgery , including postoperative complications.

Several reparative/ reconstructive surgical techniques are available for treating traumatic cartilaginous lesions such as microfracture and drilling, autologous chondrocyte implantation and osteochondral autologous transplantation (mosaicplasty). The decision of which modality to choose depends largely on the size of the chondral lesion . Follow up MRI scans with assessment of the chondral/osteochondral is possible by using the MOCART score, which is a standardized score available for the same [2,3]

In osteochondral injuries, it is possible to evaluate the size of the lesion, extent of bone involvement, and staging of the injury using MRI . MRI also detects the presence of loose bodies and their location , which is useful especially in locating loose bodies which may be entrapped in various recesses of the joint Chondral injuries are sometimes associated with ACL/PCL tears, meniscal tears and patellar dislocation and these can also be evaluated using MRI. The importance of this cannot be overemphasized as the surgeon then has a comprehensive pre operative knowledge of the extent of knee injury Through this article, we present a review of literature regarding MRI assessment of chondral injuries, also addressing the scan parameters used, advances in imaging for cartilage, role of MRI in post operative follow , and comparison of accuracy of MRI with arthroscopy. [4,6]

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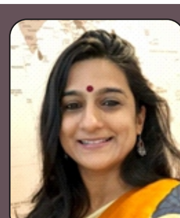

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Normal Anatomy Of Articular Cartilage

Hyaline cartilage is composed of 75-80 percent water and 20-25 percent of cellular substance, proteoglycans and collagen, which are essential to give firmness to the cartilage. When a joint is compressed, the water is

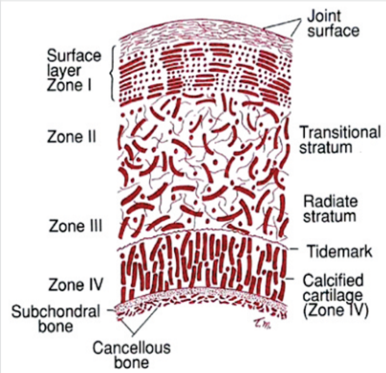

Fig 1: Histological layers of the articular cartilage.

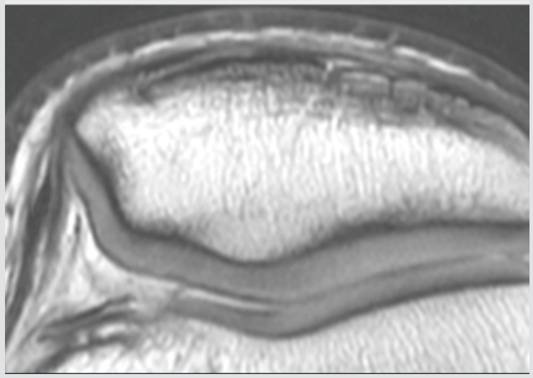

Fig 2: Trilaminar MRI appearance of articular cartilage: PD Axial image through the patello-femoral compartment: Thick mildly hyperintense intermediate zone with thin hypointense bands superficial and deep .

redistributed through the cartilage in order to absorb the compressive force but the overall volume of cartilage remains unchanged
Multiple layers exist in articular cartilage:
1] Superficial zone: No permeability for water and lower proteoglycan content. Collagen fibres are oriented in a horizontal fashion.
2] Transitional zone
3] Radial zone: Collagen fibres are oriented in a perpendicular fashion in the upper 2/3rds and curved obliquely in the lower 1/3rd.
4] Tidemark zone
5] Thin calcified zone where the collagen fibres anchor to the subchondral bone
6] Subchondral bone (Fig 1.)
MRI appearance of articular cartilage: Variation in T2 decay across the depth of the tissue produces a layered or laminar appearance. Longer T2 transitional layer separates the shorter T2 surface and deep layers
The merits of MRI are its superb spatial resolution and soft tissue contrast and the capability of imaging in multiple planes. On high resolution, high field strength MRI images, articular cartilage has a trilaminar appearance. There is a thick hyperintense intermediate zone, sandwiched between thin hypointense zones on either side. Mild signal variations may occur within the cartilage but it is possible to differentiate these from chondral disruptions which are abrupt. Also, articular cartilage over curved surfaces such as the femoral trochlea may show volume averaging [7,8] (Fig 2.)

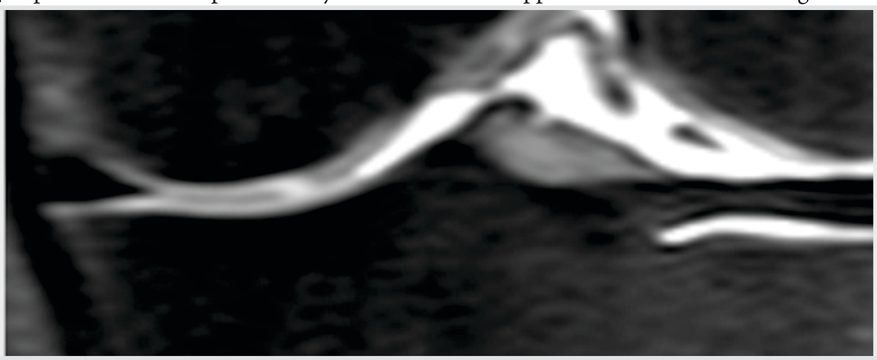

Fig 3: Thin [1.5 mm] PD coronal fat saturated: small full thickness chondral defect along inferior margin MFC

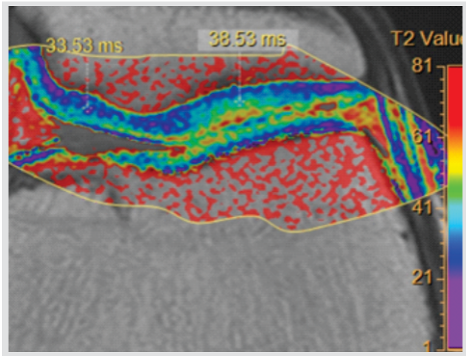

Fig 4: Cartilage map of the patello-femoral compartment

MRI Imaging Technical Parameters

3 Tesla scanner
Imaging in all 3 planes: axial, sagittal and coronal
Dedicated joint coil
Commonest sequences used are
1] 2D sequences:
2D fast spin-echo (FSE) PD and T2 images with and without fat suppression. T2 images provide excellent contrast between cartilage surfaces and joint fluid but the cartilage internal structure is poorly depicted .
PD images have better resolution of the internal structure of cartilage and also provide delineation at the cartilage-joint fluid

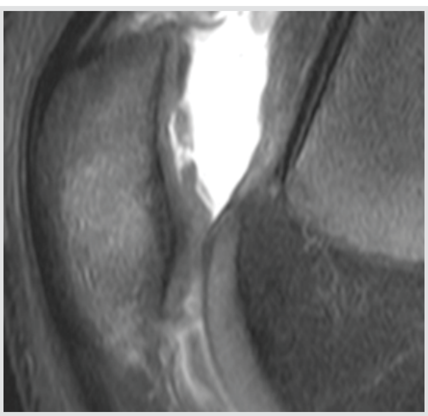

Fig 5: PD Fat saturated sagittal image: delamination in the mid patellar articular cartilage seen as a linear bright signal extending through the cartilage

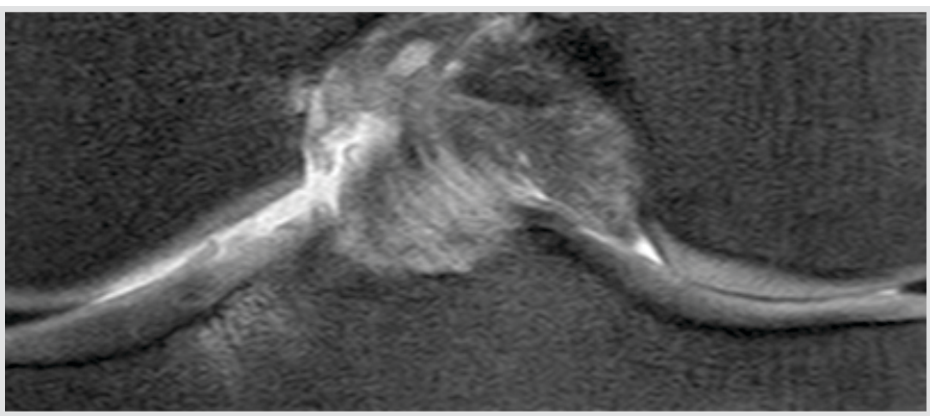

Fig 6: PD coronal image: surface flap in the cartilage along the superior margin medial tibial condyle seen as a T2 bright signal interrupting the normal surface continuity of the cartilage

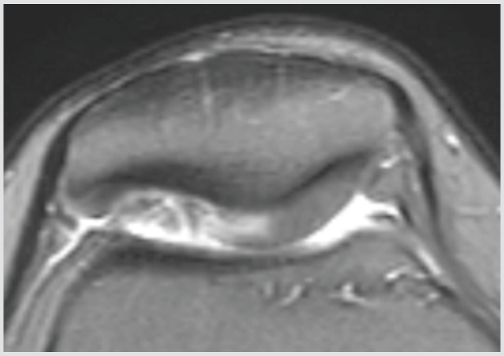

Fig 7: PD axial image: Full thickness chondral fissures in the patellar cartilage seen as bright signals extending vertically and obliquely through the thickness of the cartilage from the surface to the base

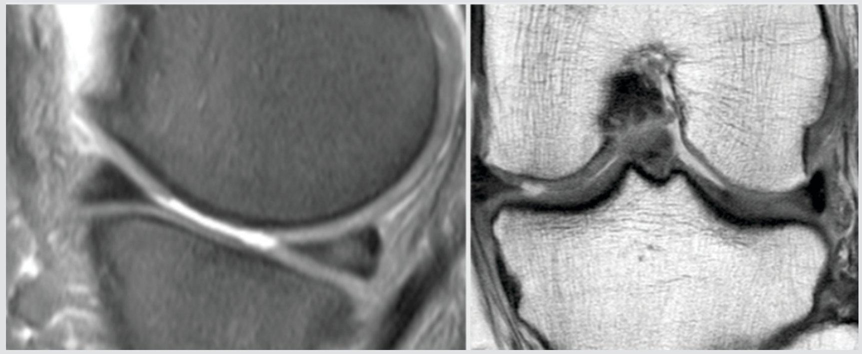

Fig 8, Fig 9. PD sagittal and coronal images: Near full thickness chondral defect along the inferior margin medial femoral condyle seen as a bright signal completely interrupting the full thickness of the cartilage

interface [7-10]

2] 3D sequences:

3D intermediate weighted FSE sequences provide good spatial resolution and allow for evaluation of subchondral bone.

Thin slices are possible thereby avoiding partial volume averaging artifacts.

Multiplanar reformation of the 3D images is possible [7-10] (Fig 3.)

3] New pulse sequences : Multiple new pulse sequences such as Steady state free precession (SSFP) , [fast imaging employing steady state acquisition (FIESTA)], True fast imaging with SSFP (true FISP), Balanced fast field echo and its variant, fluctuating equilibrium MRI (FEMR). Multiecho techniques such as dual excitation in the steady state [dual echo steady state (DESS)]; driven equilibrium techniques such as driven equilibrium Fourier transform (DEFT) and fast recovery fast spin echo; echoplanar techniques such as 3D echoplanar imaging with fat suppression and 3D DEFT; and 3D fast SE methods [7].

Cartilage Mapping /T2 Mapping

T2 of hyaline cartilage reflects interaction among water molecules and between water molecules and surrounding macromolecules and is highly sensitive to alterations of cartilage matrix. T2 is sensitive to changes in hydration and collagen concentration and to the normally anisotropic orientation of the collagen fibrils within the extracellular matrix [3].

T2 mapping provides objective data by generating a colour map representing the variations in T2 relaxation times within cartilage. Increased T2 correlates to chondral damage or degeneration. T2 maps can be used to assess the status of cartilage adjacent to chondral defects. T2 maps may be used to monitor the effectiveness of cartilage repair over time [longitudinal monitoring of changes in cartilage] [3]. (Fig 4.)

Chondral Defects

1] Delamination:

Delamination is the separation of the articular cartilage from the subchondral bone with a cleavage plane situated at the tidemark. Since delamination involves the base of the cartilage and not the surface, it may be difficult to detect on arthroscopy.

Delamination may also result in complete separation of the articular cartilage from the subchondral bone and its displacement from the parent bone

In young individuals with immature skeletons, there is paucity of calcified cartilage, so incidence of osteochondral fractures is much more than chondral delamination [11]. (Fig 5.)

2] Chondral flap

Extension of the chondral injury to the surface of the articular cartilage causes a chondral flap [5,11]. (Fig 6.)

3] Chondral fissuring (Fig 7.)

4] Chondral defect (Fig 8,9.)

5] OCD: Osteochondral lesion

Progressive separation of not just the articular cartilage, but also the underlying subchondral bone with the cleavage plane situated in the subchondral bone and involving full-thickness of the overlying articular cartilage.

Osteochondral lesions are classified as juvenile or adult depending on whether the skeleton is immature (open growth plates) or mature (closed growth plates) respectively. Juvenile osteochondral lesions are more often found to be stable and more amenable to conservative therapy. Adult osteochondral lesions are found to be more unstable.

MRI helps in diagnosing the lesion, staging it and showing the exact location [5].

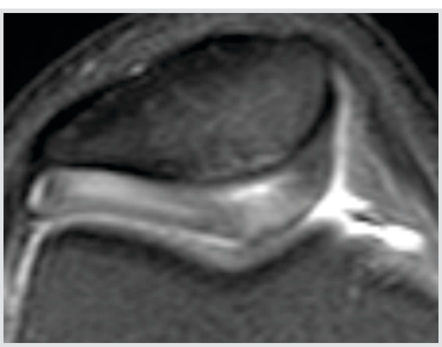

Fig 10: PD axial image: Stage I osteochondral lesion with overlying chondromalacia and intact surface

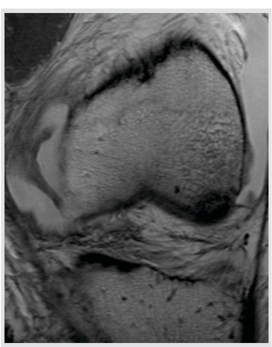

Fig 11: PDFS Sagittal and PD Coronal images depicting stage II osteochondral lesion.

Fig 12: PD fat saturated sagittal image : Stage III osteochondral lesion.

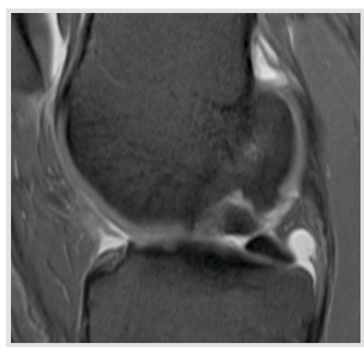

Fig 13: PD sagittal image: Stage IV osteochondral lesion

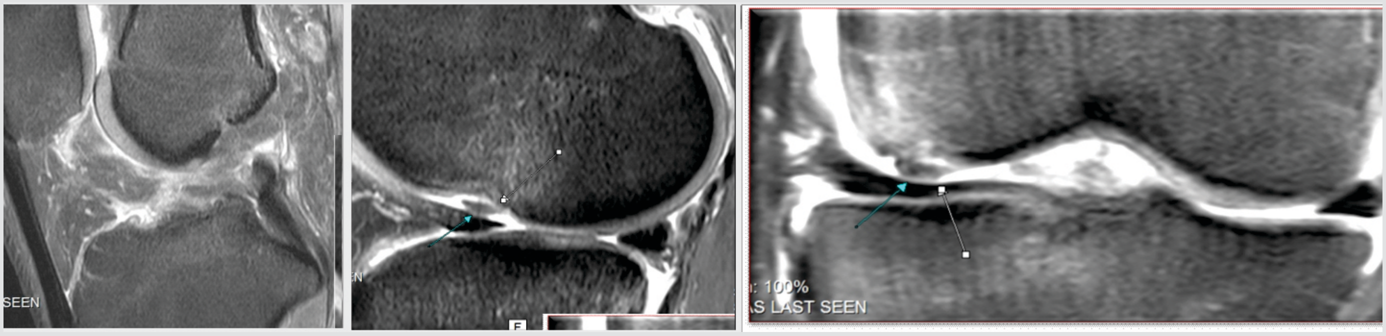

Fig 14: ACL tear along-with complete separation of chondral fragment along the anteroinferior aspect of the lateral femoral condyle

Stage I lesion:
Area of chondral softening covered by intact and smooth cartilage. No cleavage plane is visible. This is a stable lesion. This may be missed on arthroscopy [5,9]. (Fig. 10)

Stage II lesion:
T2 hyperintense cleavage plane causing partial discontinuity and cartilage fracture. This is visible as a fissure on arthroscopy. These lesions are further divided into type II A lesions [presence of marrow edema] and type II B lesions [absence of marrow oedema]. This is a stable lesion [9,12]. (Fig. 11)

Stage III lesion:
T2 hyperintense cleavage plane causing complete discontinuity of the fragment from the parent bone. The separated osteochondral fragment is however undisplaced. This is an unstable lesion [9]. (Fig. 12)

Stage IV lesion:
Complete separation of osteochondral fragment and dislocation of the fragment to form an osteochondral loose body within the joint [5,9]. (Fig.13)

Stage V: Subchondral cyst formation at the injury site and secondary osteoarthritis.

MRI instability criteria are:
High T2 signal rim around the osteochondral lesion
High T2 signal intensity fracture involving the full-thickness of the articular cartilage
Dislocated osteochondral fragment with a residual fluid-filled osteochondral defect.

Contrast MRI may have a role in that contrast enhancement of the osteochondral fragment indicates a probably viable fragment, while contrast enhancement of the interface between the fragment and parent bone suggests granulation tissue and a loose, potentially unstable, fragment [5,9].

Associations Of Osteochondral Lesions
1] ACL tear (Fig 14.)

2] Patellar dislocation (Fig 15.)

3T MRI Versus Arthroscopy
A 3T MRI gives a higher specificity and accuracy for diagnosing cartilage lesions as compared to a 1.5T MRI.
A high accuracy of 3T MRI is noted in diagnosing chondral/ osteochondral lesions in recent studies, with MRI seen to be diagnosing 96-100 % of the lesions seen on arthroscopy [13].
It is non-invasive, can assess the underlying bone and is reproducible multiple times in follow up evaluation
Limitations of MRI include underestimation of the lesion size , as compared to arthroscopy, especially in the femoro-tibial compartment [12,13].

Post Operative Evaluation Of Chondral Repair
1] Magnetic resonance observation of cartilage repair tissue (MOCART)
MR observation of cartilage repair tissue is a well established semi-quantitative scoring system for cartilage repair evaluation.
MOCART SCORE :
- Defect fill: percentage wise- 0%, 0-25%,25-50% and so on till 200%
- Cartilage interface: complete, demarcating border visible, defect visible<50%,defect visible>50%
- Bone interface: complete, partial delamination, complete delamination
- Surface: intact, surface damaged<50%, surface damaged>50%
- Structure: homogeneous, inhomogeneous/cleft formation
- Signal intensity: normal, nearly normal, abnormal
- Subchondral lamina: intact, not intact
- Chondral osteophytes: absent,<50 %repair tissue,>50%repair tissue

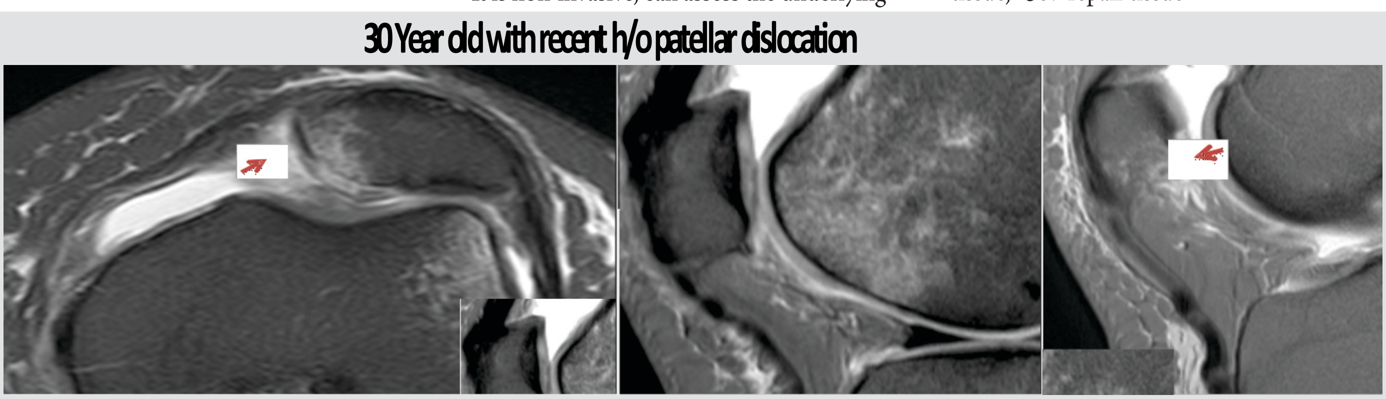

Fig 15: Lateral subluxation of the patella . Kissing contusions in the lateral trochlear facet and medial patellar facet with injury to the overlying patellar cartilage.

Fig 16: PD fat saturated sagittal image: Normal cartilage repair Osteochondral autograft transplantation surgery (OATS).

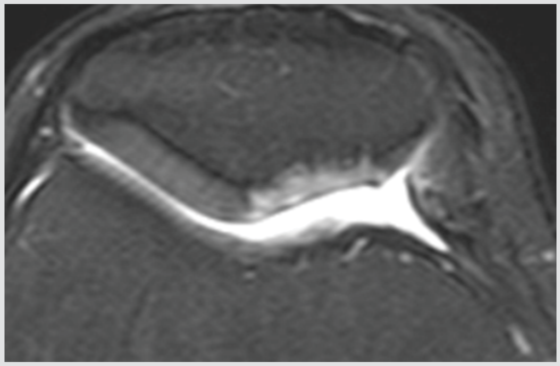

Fig 17: Normal Autologous chondrocyte implantation (ACI): PD fat saturated axial image through patello-femoral compartment

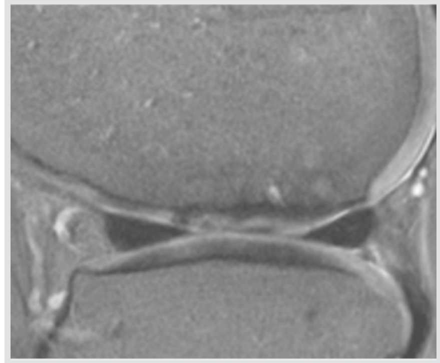

Fig 18: Microfracture: PD sagittal image: Slightly dark signal interspersed with normal appearing cartilage due to healing by fibrocartilage formation

• Bone marrow edema: absent, small <1cm, medium <2cm, large<4cm, diffuse
•Subchondral bone: intact, granulation tissue, cyst
• Effusion: absent, small, medium, large [10].

2] Cartilage repair osteoarthritis knee score (CROAKS)

Cartilage repair osteoarthritis knee score optimizes comprehensive morphologic assessment of the knee after cartilage repair [1]

3] Cartilage mapping

4] Delayed Gadolinium enhanced MRI of cartilage (D-GEMRIC), Sodium imaging and T1 Rho

These are quantitative compositional MR imaging measurements which help assess collagen content and orientation, water content and glycosaminogylcan/ proteoglycan content in the repair tissue [1].

Role Of USG

USG arthroscopy: A new quantitative imaging technique with ultrasound evaluation of the articular cartilage and subchondral bone done during arthroscopy, using a 9 Mhz flexible catheter inserted into the joint through conventional portals. Since the inter-observer and intra-observer reproducibilities of chondral lesions are poor to moderate, ultrasound arthroscopy was introduced for the dilemma. Advantages include comprehensive evaluation, quantitative cartilage measurements, accurate chondral and osteochondral lesion evaluation, radiation free and ability to carry out guided procedures like retrograde OCD drilling [6].

Role of CT

The size and exact location of osseous loose bodies sometimes requires additional CT evaluation along with an MRI scan. CT is limited by the lack of ability to image cartilage directly [12].

Conclusions & Keypoints

MR Imaging is a powerful noninvasive tool for the morphologic assessment of Chondral injuries, evaluation of exact size and location, status of adjacent articular cartilage, presence of intra-articular loose bodies and assessment of chondral repairs is possible with MRI. Other ligament and meniscal injuries can also be assessed simultaneously and a comprehensive pre-operative work up is possible

Cartilage mapping provides objective information at a glance and is also useful in post operative assessment of cartilage repair.

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