The Egyptian Journal of Hospital Medicine (January 2018) Vol. 70 (9), Page 1552-1561

Role of MRI in Evaluation of Anterior Knee Pain

Hanan Mohammed Hanafi, Shaimaa El Metwally Eldiasty, Abdul Jabbar Amer Abbood
Department of Radiodiagnosis, Faculty of Medicine, Ain Shams University
Corresponding author: Abdul Jabbar Amer Abbood , E-mail:aldooryabod@gmail.com

ABSTRACT

Background: the knee joint is one of the most commonly injured joints in the body. Because of its complex structure, this joint is subjected to numerous pathologies and due to the recent increase in various sport activities; there has been a parallel increase in sport-induced internal derangements of the knee. **Objective:** the main objective of our work was to review several of the most common causes of AKP, with emphasis on their MRI findings with the goal of allowing more accurate diagnosis and grading of some of the most common pathologies, for understanding, better treatment and improvement of this common complaint. **Patients and Methods:** this study included 20 patients (13 females and 7 males). Their ages ranged between 10 - 70 years (average age 40.8 ± 5.83 years). All were presented by anterior knee pain and referred to Radiology Department of Ain Shams University Hospital or private centers for MRI examination after orthopedic consultation. **Results:** this study included 20 patients, with their ages ranged between 10-70 years, all of them were suffering from anterior knee pain. **Conclusion:** MRI is generally safe, accurate, and specific modality which has been proven to be the modality of choice in the diagnosis of different knee pathologies that cause anterior knee pain in different age groups

Keywords: magnetic resonance imaging, anterior knee pain**.**

INTRODUCTION

Anterior knee pain (AKP) is the most common knee complaint, usually occurring in adolescents and young adults [(1)]. It is more common in athletic individuals, with the incidence rate as high as 9% in young active adults and comprises up to a quarter of all knee problems treated at sports injury clinics [(2)].

AKP may cause chronic disability, limited sports participation and may affect quality of life. Despite its prevalence, AKP remains poorly understood, as it has not been well studied in the literature, making its treatment one of the most complex among the various pathologies affecting the knee [(3)]. Magnetic resonance imaging (MRI) in the recent decades has become the gold standard imaging modality for different knee pathologies as it is safe and RF pulses used in MRI do not cause ionization. [(3)].

With MRI, direct coronal and oblique image can obtained which is impossible with radiography and CT particularly useful for scanning and detection of abnormalities in soft tissue structures like the cartilage tissues, tendons and ligaments. MRI also can help determine which patients with knee injuries require surgery. MR imaging is recognized as a standard procedure and has replaced diagnostic arthroscopy as the primary diagnostic modality for many knee pathologies. Moreover, MR images can be used to assess anatomic variants that may contribute to chronic patellar instability [(4)].

AIM of the WORK

The main objective of our work was to review several of the most common causes of AKP and emphasis on their MRI findings with the goal of allowing more accurate diagnosis and grading of some of the most common pathologies, for understanding, better treatment and improvement of this common complaint.

PATIENTS and METHODS

This study included 20 patients (13 females and 7 males). Their ages ranged between 10 - 70 years (average age 40.8 ± 5.83 years). All presented by anterior knee pain and were referred to Radiology Department of Ain Shams University Hospital or private centers for MRI examination after orthopedic consultation.

Inclusion criteria: any patient complaining from anterior knee pain.

Exclusion criteria: any patient with absolute contraindications to MRI examination as cardiac pace maker, aneurysmal clipping, cochlear implants, hearing aids, intracranial aneurysmal clips, ferromagnetic surgical clips or staples, metalic foreign body in the eye, metal shrapnel or bullet and claustrophobia, patient who had surgeries to joints and early pregnant patient.

All patients were subjected to: history taking, plain X-ray of the affected knee joint (if clinically indicated) and MRI of the affected knee.

History taking (Personal history: it included age, sex and occupation. **Present history:** included analysis of patient complaint

Received: 14/11/2017 DOI: 10.12816/0044682
Accepted: 24/11/2017

(knee pain), site, onset, course, duration, and the relationship to posture, associated swelling, stiffness and deformity. **Past history:** previous trauma or operations.

MRI Examination: most patients had MR imaging of the affected knee joints on high field-strength scanners using (PHILIPS ACHIEVA) scanners (1.5 T). MRI was performed by phased array knee coil in all cases.

Patient's positioning: supine, feet first, knee coil (wraparound), place knee in the bottom half of the coil (slide the coil bottom along its base until you have the knee as possible as to iso-center), position comfort cushions at any pressure points with the opposite knee, attach the top half of the coil and lock it in place, do not pinch any skin between the coil halves, immobilize the knee by sliding the small and long cushions between the knee and coil. The need to restrict body movement during the scan time was explained to the patient.

RESULTS

Table 1: the descriptive statistics of the age of the patient's sample

	Minimum	Maximum	Average ± SD
(years)	10	70	40.8±5.83

Table 2: distribution of the sample according to sex

	No of patients	Percentage	Average(age)
Females	13	65%	28.09
Males	7	35%	30.55
No. of Patients	20	100%	

Table 3: percentages of the prevalence of different causes of AKP by sex.

	Patients	Female	Male
Patellar Causes	12	6	6
	60.0%	50.0%	50.0%
Hoffa disease	1	1	0
	5.0%	100.0%	0.0%
Miscellaneous	2	2	0
	10.0%	100.0%	0.0%
Quadriceps tendon causes	2	2	0
	10.0%	100.0%	0.0%
Patellar tendon causes	3	2	1
	15.0%	66.7%	33.3%

Table 4: demonstrates overlapping between patients who have more than one disease.

	Hoffa disease	Patellar instability	Cartilage Injury	Quadriceps tendinopathy	Patellar tendinopathy	Transient patellar dislocation	Sum
Chondromalacia Patella	5	1	1				7
Patellar instability	1		1	1			3
Anterior Meniscal Tear					1		1
bipartite patella						1	1
Osgood Schlatter disease						1	1
Sum	6	1	2	1	1	2	13

Table 5: demonstrates percentage of sex prevalence among the different diseases

	Female	Male	Sum
Chondromalacia Patella	3	1	4
	75.0%	25.0%	20.0%
Hoffa disease	1	0	1
	100.0%	0.0%	5.0%
Chronic Patellar instability	1	2	3
	33.3%	66.7%	15.0%
Sending-Larson-Johansen	0	1	1
	0.0%	100.0%	5.0%
Quadriceps tenondinopathy	2	0	2
	100.0%	0.0%	10.0%
Plica synovialis	0	1	1
	0.0%	100.0%	5.0%
Patellar tendinopathy	2	0	2
	100.0%	0.0%	10.0%
Osgood Schlatter disease	0	1	1
	0.0%	100.0%	5.0%
Cartilage injury	2	0	2
	100.0%	0.0%	10.0%
Bipartite patella	1	0	1
	100.0%	0.0%	5.0%
Bursitis	1	1	2
	50.0%	50.0%	10.0%

Table 6: demonstrates percentage of prevalence of different grades of chondromalacia patella

	Grade I	Grade II	Grade III	Grade IV	Grand Total
No. of Chondromalacia Patella patients	0	1	1	2	4
Percentages of chondromalacia Patella patients	0.0%	25.0%	25.0%	50.0%	100.0%

Table 7: demonstrates percentage of different grades of trochlear dysplasia among the patients with patellar instability

	Type A	Type B	Type C	Grand Total
No. of Trochlear dysplasia patients	1	1	1	3
Percentages of Trochlear dysplasia patients	33.33%	33.33%	33.33%	100.0%

Table 8: demonstrates percentage of patellar instability and transient patellar dislocation 66.7% and 33.3% respectively out of total number of patellar dislocation

		No. of patients	Percentage
Patellar Dislocation	Patellar instability	2	66.7%
	Transient patellar dislocation	1	33.3%
	Sum	3	100.0%

Table 9: demonstrates the statistically calculated minimum, maximum, median and mean values of trochlear groove depth by (mm), trochlear facet asymmetry by (%) and lateral inclination angle by (◦)

	D: Depth of trochlear groove by mm			T: Trochlear facet asymmetry by %			L: Lateral inclination angle by ◦		
	Type-A	**Type-B**	**Type-C**	**Type-A**	**Type-B**	**Type-C**	**Type-A**	**Type-B**	**Type-C**
Minimum	3.00	1.500	1.500	35.00	33.00	32.00	10.00	1.500	9.300
Maximum	6.00	4.000	2.000	50.00	60.00	50.00	23.00	20.00	23.00
Median	5.00	2.000	2.000	39.00	55.00	33.00	20.00	9.000	9.400
Mean	4.80	2.500	1.833	40.80	50.60	38.33	17.80	9.540	13.90
St dev.	1.15	1.000	0.289	6.221	10.45	10.11	5.586	8.032	7.881

CASE PRESENTATION

CASE 1

Clinical history: female patient of 24 years old with left anterior knee pain.
MRI Knee examination showed:

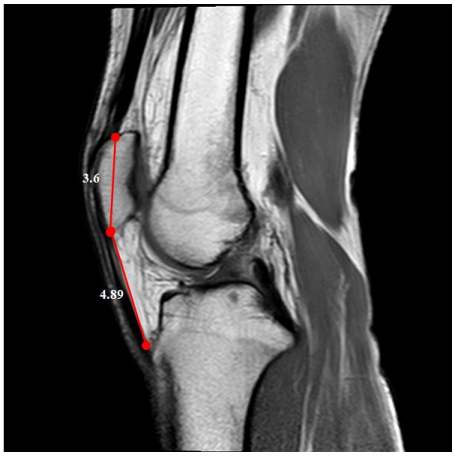
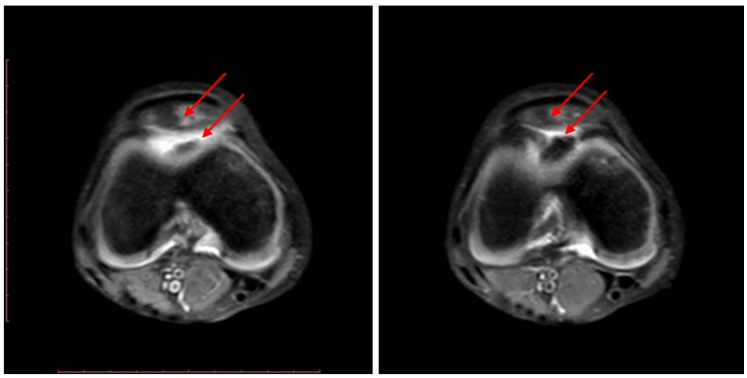


Figure 1: sagittal T1 demonstrates a high riding patella with patellar tendon/height ratio = 1.36 denoting patella Alta with minimal effusion is noted.
Diagnosis: patella Alta.

CASE 2

Clinical history: male patient of 13 years old presented with right anterior knee pain after knee trauma.

MRI Knee examination showed:



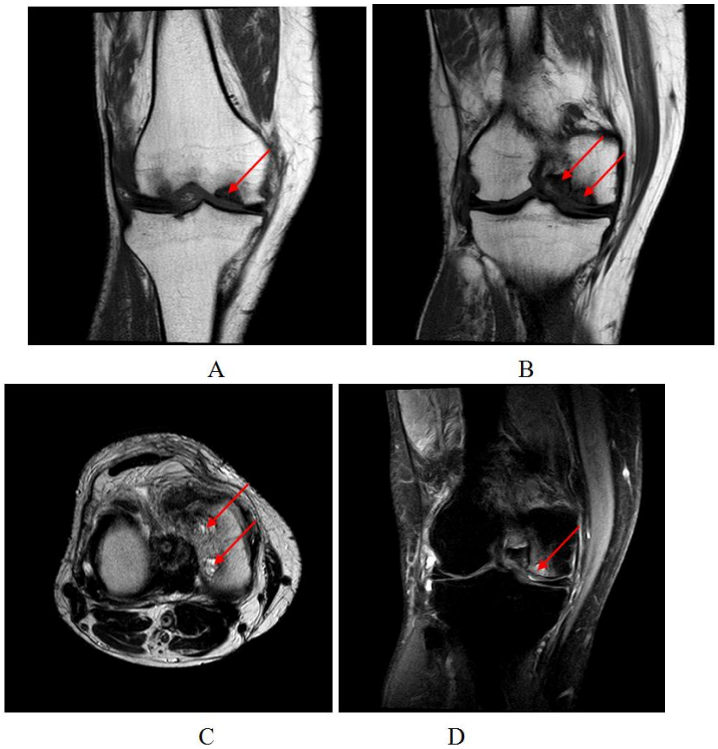
A B

C

Figure 2: A-Axial PD SPIR, B-Axial PD SPIR and C-Sagittal PD SPIR demonstrate the lower part of the patella and anterior part of the medial femoral condyle show BM edema/contusion displaying high signal in SPIR images with mild joint effusion.
Diagnosis: sending-Larson-Johansen disease.

CASE 3

Clinical history: female patient of 33 years old presented by right anterior knee pain with history of trauma since 6 months.
MRI Knee examination showed:



A B

C D

Figure 3: A-Coronal T1, B-Coronal T1, C-Axial T2 and D-Coronal STIR demonstrate an area of bone contusion noted in the lower lateral femoral condyle manifested by increased signal on STIR images.
Two well defined rounded subarticular low signal areas on T1WI and high signal on both STIR and T2WI are noted in the lower medial femoral condyle, still in place denoting osteochondritis dessicans. They are surrounded by a diffuse bone marrow oedema.

Diagnosis: osteochondritis dissecans.

CASE 4

Clinical history: female patient of 25 years old complaining from left anterior knee pain following trauma.

MRI Knee examination showed:

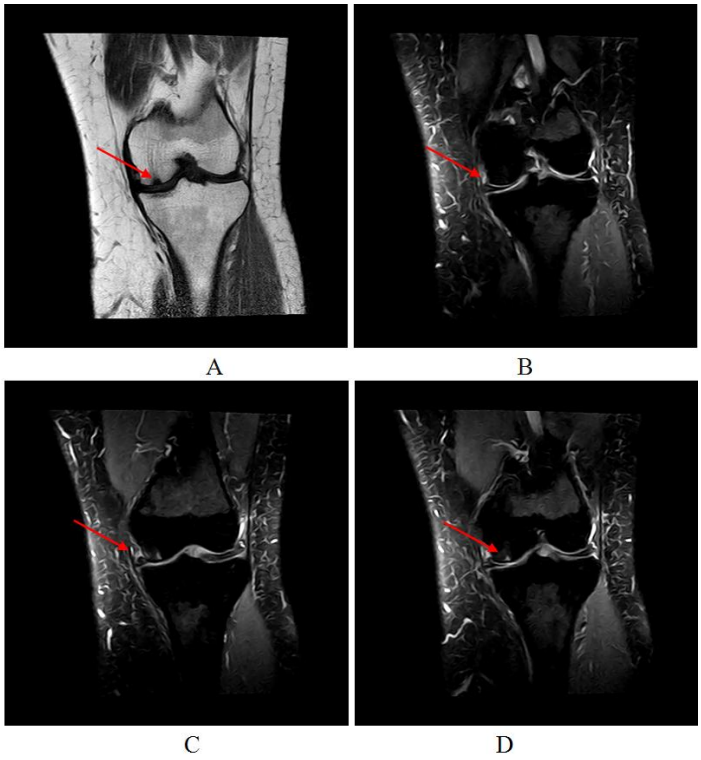


Figure 4: A- Coronal T1, B- Coronal proton density SPIR, C- Coronal proton density SPIR and D- Coronal proton density SPIR show small osteochondral defect seen in the medial femoral condyle with sprained MCL.

DIAGNOSIS: osteochondral defect seen in the medial femoral condyle.

DISCUSSION

MRI has the superiority over other radiological modalities in being able to detect different important etiologies and predisposing factors causing knee pain. Disorders of the knee are responsible for a major source of referrals to the musculoskeletal radiologist. Most cases have suspected abnormalities within the joint either following an acute injury or a more insidious development of symptoms. Anterior knee pain (AKP) is the most common knee complaint, usually occurring in adolescents and young adults [(1)]. The purpose of this study was to detect the accuracy of MR imaging as a diagnostic tool in the evaluation of different knee joint pathologies that cause anterior knee pain, with emphasis on some of their grades and types for better assessment.

This study included 20 patients, 13 were females and 7 were males, with their ages ranged between 10-70 years, all of them were suffering from anterior painful knee joint.

Diederichs *et al.* [(5)] reported that anterior knee pain (AKP) may affect up to one third of adolescents at any time. The majority of patients are female and the symptom most commonly occurs in the second and third decades of life.

In our results, 65% of the studied sample was female with their average age was 28.09 years and 35% were male with average age 30.55 years.

Our study results showed that there was a significant difference between the number of AKP in males and females patients.

In our study we divided the pathological process that causing the symptom of anterior knee pain in a fashion similar to that proposed by **McCauley and Disler** [(6)] to five categories according to location and anatomical structure affected as following:

(a) Patellar tendon disorders, (b) Quadriceps tendon disorders, (c) Patellar disorders (d) Hoffa's diseases and (e)

Miscellaneous causes including anterior meniscal tear and cartilage injuries.

In our study each category represented the following percentages:

(a) Patellar tendon disorders represent 15% of the sample size and they are including (Patellar Tendinopathy 10% and Osgood Schlatter disease 5%).

(b) Quadriceps tendon disorders represent 10% of the sample size and they are including (Quadriceps Tendinopathy 5% and Quadriceps tendon tear 5%).

(c) Patellar disorders represent 60% of the sample size and they are including (chondromalacia patella 20%, patellar instability 15%, transient patellar dislocation 10% and painful bipartite patella 5%).

(d) Hoffa's diseases represent 5% of the sample size and they are including (Hoffa impingement syndrome and Hoffa ganglion cyst), and finally;

(e) Miscellaneous causes that represent 10% of the sample size and including cartilage shear injury.

Patellar tendinitis (PT) or Jumper's knee is one of the most common tendon abnormalities in young active individuals. It is well established that the mechanism of the disease in PT is that of degenerative tendinopathy rather than an inflammatory tendinitis [(7)]**.** MR features of PT include focal thickening of the proximal one-third of the tendon, an AP diameter greater than 7 mm and focal T2 hyper-intensity within the proximal tendon, most commonly involving the medial one-third of the tendon [(8)]**.**

In our results**,** 15% of the patients presented with anterior knee pain showed MRI evidence of patellar tendinopathy (66% below the age of 30 years). In all cases the hyper-intense focal thickening was at the proximal third of the tendon, with the AP diameter of the patellar tendon greater than 8mm. This is concordant with the study of **Samim *et al.*** [(8)] as regard the MRI findings of patellar tendinitis.

Gottsegen *et al.* [(9)] defined Osgood Schlatter disease as an apophyseal traction injury of the tibial tubercle, caused by repetitive microtrauma. It is most common among adolescent male athletes.

Niitsu [(10)] also stated that if the tibial surface is not yet ossified, radiography may not reveal any abnormalities, so MRI is the best modality to detect early cases of OSD.

Aparicio *et al.* [(11)] stated that patella Alta (patellar height ratio of more than 1.3) (normal is 0.8 to 1.1) is one of the predisposing factors to OSD.

in our result 5% of the cases showed MRI evidence of patella Alta (Patellar height ratio equal 1.7) as a predisposing factor as shown in (**case number 1) .**

Quadriceps tendon rupture is an uncommon yet serious injury. It is the second most common injury to the extensor mechanism after patellar fracture. It is more common in older (>40 years) individuals. Tendon tears can be partial or full thickness. The quadriceps femoris consists of three layers, which if visible on sagittal images, are the rectus femoris, combined vastus lateralis and medialis, and vastus intermedius tendons [(10)].

In our results 5% had a quadriceps tendon rupture above the age of 40 years and experienced past history of trauma and none of them had a predisposing factor for spontaneous tendon rupture.

Pfirrmann *et al.* [(12)] stated that, altered biomechanics or chronic tensile forces to the quadriceps tendon may lead to chronic tendinosis of the tendon that clinically may present as anterior knee pain. MRI provides the characteristic diagnostic features of this form of chronic enthesopathy.

Grelsamer [(13)] had described chondromalacia patella as cartilage loss involving one or more portions of the patella that leads to patellofemoral pain and finding regions of slight surface depression and/or surface fraying by arthroscopic probing. The possible difference between chondromalacia patella and osteoarthritis of the patellofemoral compartment has not been clearly defined, with the later more common in the elderly population.

Grelsamer [(13)] also reported that chondromalacia patella is more common in female adolescents and young adults and this was matched with our study (75% female 35% male and 25years age average). Comparing to 0.05 level of significance, the P-value of Chi-Square-Test (0.03) showed that there was a significant difference between the prevalence of chondromalacia patella between males and females. Outerbridge grading system, divided chondromalacia patella arthroscopically into four types according to the extent of articular cartilage loss which was originally devised for arthroscopy but has become the foundation of modified MRI grading [(14)].

Chang *et al.* [(15)] stated that the International Cartilage Repair Society (ICRS)

Classification System has been found to have equal and good correlation with the Outerbridge classification system that is used arthroscopically. It also classifies articular cartilage injury into 4 grades. Grade1: focal areas of hyperintensity with normal contour. Grade2: Blister-like swelling/fraying of articular cartilage extending to surface with less than 50 % thickness cartilage loss. Grade3: severely abnormal (More than 50 % thickness cartilage loss with focal ulceration /defect down to bone). Grade4: severely abnormal (Full-thickness cartilage loss with underlying bone reactive changes). MR imaging is the imaging modality of choice in patients in whom patellar dislocation is suspected. MR imaging allows evaluation of typical injury patterns and can be used to diagnose anatomic variants contributing to the development of patellofemoral instability [(16)].

Holmes and Clancy [(17)] had suggested dividing patients suffering from anterior knee pain into three groups: patellofemoral instability i.e. subluxation or dislocation, patellofemoral pain with malalignment but no episodes of instability and patellofemoral pain without malalignment.

In study of **Kirsch *et al.*** [(18)] they concluded that the prevalence of patellar dislocation among 1450 patient was (2%). The most constant finding in all patients of the transient patellar subluxation was the presence of joint effusion (100%). Abnormalities in the medial patellar retinaculum was about 96%, an abnormal lateral patellar position in about 92%, contusions of the lateral femoral condyle and medial patellar facet in about 81%.

Dejour and Coultre [(19)] described trochlear dysplasia as one of the most important predisposing factors for patellar instability and recurrent patellar dislocation. They also classify trochlear dysplasia into four main types (type A, B, C and type D). In order to determine the severity of trochlear dysplasia according to the classification of Dejour, an axial MRI of the most proximal transverse MRI where the cartilage along the entire width of the trochlea was visible was performed.

Type A dysplasia: trochlear morphologic structures are preserved, but the sulcus was shallow. Type B dysplasia: flat, horizontally oriented trochlear joint surface. Type C dysplasia: flat, obliquely oriented trochlear joint surface with facet asymmetry. Type D dysplasia: same as type C, but with a prominent bone protrusion (cliff pattern) [(20)].

This classification is used in clinical practice and in the orthopedic literature to assess the severity of trochlear dysplasia [(20)]. On lateral radiographs, trochlear dysplasia can be diagnosed but a strict lateral view is necessary otherwise misinterpretation of the radiographs often occurs [(21)].

Because of X-ray difficulty and lack of accuracy, MRI with its multiplanner reformatting privilege has become the basic tool to assess trochlear dysplasia [(22)].

In our study we founded that 15% of the patients had patellofemoral pain with malalignment (i.e chronic patellar instability 33.3% females and 66.7% males) and showing MRI evidence of trochlear dysplasia. 25% categorized as type A, 25% as type B, and 25% as type C according to Dejour et al classification.

Carrillon *et al.* [(23)] ascertained the lateral trochlear inclination angle by MRI to estimate the severity of trochlear dysplasia. They found that a lateral trochlear inclination of 11◦ to be a threshold value to discriminate between patients with patellofemoral instability (trochlear dysplasia) and patients with non-specific knee pain.

Pfirrmann *et al.* [(24)] calculated the depth of the trochlear groove and trochlear facet asymmetry 3cm above the femerotibial joint. They found that trochlear groove depth less than 3mm and facet asymmetry of less than 40% are diagnostic value for trochlear dysplasia.

Diederichs *et al.* [(5)] stated that MR imaging has been shown to allow highly accurate and reproducible measurements of the femoral sulcus from both the subchondral bone and the articular cartilage, measurement from the articular cartilage may be more relevant than conventional radiography, because it constitutes the actual joint surface.

Nelitz *et al.* [(25)] did a study on 80 knees of 78 patients, aiming to evaluate whether specific measurements of the femoral trochlea can be assigned to the qualitative classification system of Dejour using the above mentioned measurements.

They concluded that by using a descriptive statistics using boxplot diagrams, none of the objective measurements of the femoral trochlea described in the literature could be assigned to the four-grade descriptive classification of trochlear dysplasia of Dejour as the median and average range of these measurements allow no discrimination between trochlear dysplasia type B, C and D. However,

threshold values to discriminate between low-grade (Dejour type A) and high grade dysplasia (Dejour type B-D) could be identified.

In our results, type B and C trochlear dysplasia showed nearly similar median and average values of both the trochlear groove depth and lateral inclination angle, (median value of trochlear groove depth for both B and C was 2mm and for A was 5mm, the median value of lateral inclination angle for both B and C were 9◦ and 9.4◦ respectively and for type A was 20◦). The median values of the trochlear facet asymmetry were different between different types of trochlear dysplasia (the median value for type A was 39%, for type B was 55% and for type C was 33%).

Fithian *et al.* [26] also reported that most patients with patellar dislocation are young and active individuals, with men in the 2nd decade of life having a high risk**.** In our study we found that 100% of the patients were male.

McCauley and Disler [6] also stated that there is a link between Patellar subluxation with both chondromalacia patella and patellar tendinopathy. In our result only 7% of the patients with patellar subluxation had MRI evidence of a chondromalacia patella and 7% had MRI evidence of patella Alta.

Bipartite patella represents failure of the fusion of the secondary ossification centers of the patella**. Samim *et al.*** [8] mentioned that there are three types of bipartite patella according to **Saupe *et al.*** [8] classification. The first type involved the inferior pole of the patella, the second type involves the lateral margin of the patella, and the third type, the most common type, involves the superolateral pole.

According to **Kavanagh *et al.*** [27]**,** bone marrow edema within the bipartite fragment was the sole finding in 49 % of the patients having this disease.

In our study, 5% of the patients with anterior knee pain had symptomatic bipartite patella of the third type (at the superolateral patellar pole) and had MRI evidence of bone marrow edema within their fragments.

Chung *et al.* [28] studied 50 patients with anterior knee pain and reported that 50% of the sample had Hoffa impingement syndrome with female predominance.

So, our study is concordant with results of **Chung *et al.*** [28] as regard the sex predominance, but differ in prevalence and this might be explained by the difference in the criteria of the selected sample between the two studies, as **Chung *et al.*** [28] excluded patients outside the ages of (14–50) years or those with a history of direct trauma to the knee, but in our study both were included.

McCauley and Disler [6] also mentioned that cartilage injuries and anterior meniscal tear as other main pathologies that are considered to be major causes of anterior knee pain.

MRI is the most powerful, accurate and non-invasive method for diagnosis of cartilage injury. It is more accurate than physical examination and has influenced patient care and clinical practice by eliminate unnecessary diagnostic arthroscopy or by identifying an alternative diagnosis whose clinical presentation mimic cartilage injury [6]**.**

Articular cartilage injuries in the knee are common, can clinically mimic meniscal tears, and have been associated with a less satisfactory clinical outcome following arthroscopy. Thus magnetic resonance imaging prior to surgical intervention is valuable to evaluate for isolated articular cartilage injuries, help to predict prognosis and identify patients who may benefit from cartilage replacement therapies [6]**.**

Acute or repetitive trauma can cause a variety of articular cartilage injuries, included fissures, chondral flaps or tears and loss of a segment of articular cartilage. These injuries may be isolated or more commonly associated with other intra articular injuries. In our results cartilage injuries were detected in 10% of the study sample, showing female predominance with average age 32 years. All have a past history of trauma also 25% of cartilage injury cases, were associated with anterior meniscal tear as shown in (case number 4).

CONCLUSION

MRI is generally safe, accurate, and specific modality which has been proven to be the modality of choice in the diagnosis of different knee pathologies that cause anterior knee pain in different age groups. Also it has a high specification in detecting the grades and types of some of these diseases or factors predispose to them as patella Alta and trochlear dysplasia.

The study was approved by the Ethics Board of Ain Shams University.

REFERENCES

1-Collado H and Fredericson M (2010): Patellofemoral pain syndrome. Clin. Sports Med., 29:379–398.

2- **Witvrouw E, Lysens R, Bellemans J, Cambier D and Vanderstraeten G (2000):** Intrinsic risk factors for the development of anterior knee pain in an athletic population. The American Journal of Sports Medicine, 28 (4):480-489.

3- **Biedert RM and Sanchis-Alfonso V (2002):** Sources of anterior knee pain. Clin. Sports Med., 21:335–347.

4- **Escala JS, Mellado JM, Olona M, Giné J, Saurí A and Neyret P (2006):** Objective patellar instability: MR-based quantitative assessment of potentially associated anatomical features. Knee Surgery, Sports Traumatology, Arthroscopy,14 (3):264-72.

5- **Diederichs G, Issever AS and Scheffler S (**2010): MR imaging of patellar instability: injury patterns and assessment of risk factors. Radiographics, 30:961–981.

6- **McCauley TR and Disler DG (2001):** Magnetic resonance imaging of articular cartilage of the knee. Journal of Am. Acad. Orthop. Surg., 9:28-35.

7- **Benjamin M, Toumi H, Ralphs JR, Bydder G, Best TM and Milz S (2006):** Where tendons and ligaments meet bone: attachment sites ('entheses') in relation to exercise and/or mechanical load. Journal of anatomy, 208(4):471-490.

8- **Samim M, Smitaman E, Lawrence D and Moukaddam H (2014):** MRI of anterior knee pain. Skeletal radiology, 43(7):875-93.

9- **Gottsegen CJ, Eyer BA, White EA, Learch TJ and Forrester D (2008):** Avulsion fractures of the knee: imaging findings and clinical significance. Radiographic, 28(6):1755-70.

10- **Niitsu M (2013):** Magnetic Resonance Imaging of the Knee.:Springer.Berlin.

11- **Aparicio G, Abril JC, Calvo E and Alvarez L** (1997): Radiologic study of patellar height in Osgood-Schlatter disease. Journal of Pediatric Orthopaedics,17(1):63-69.

12- **Pfirrmann C, Jost B, Pirkl C, Aitzetmüller G and Lajtai G (2008):** Quadriceps tendinosis and patellar tendinosis in professional beach volleyball players: sonographic findings in correlation with clinical symptoms. European radiology, 18(8):1703-9.

13- **Grelsamer RP (2005):** Patellar nomenclature: the Tower of Babel revisited. Clin Orthop Relat Res., 436:60–5.

14- **Recht MP, Piraino DW, Paletta GA, Schils JP and Belhobek GH (1996):** Accuracy of fat-suppressed three-dimensional spoiled gradient-echo FLASH MR imaging in the detection of patellofemoral articular cartilage abnormalities. Radiology, 198(1):209-12.

15- **Chang G, Horng A and Glaser C (2011):** A practical guide to imaging of cartilage repair with emphasis on bone marrow changes. Semin Musculoskeletal radiol., 15:221–237

16- **Toms AP, Cahir J, Swift L and Donell ST (2009):** Imaging the femoral sulcus with ultrasound, CT, and MRI: reliability and generalizability in patients with patellar instability. Skeletal Radiology, 38(4):329-38.

17- **Holmes SW and Clancy WG (1998):** Clinical classification of patellofemoral pain and dysfunction. J Orthop Sports PhysTher., 28:299–306.

18- **Kirsch MD, Fitzgerald SW, Friedman H and Rogers LF (1993):** Transient lateral patellar dislocation: diagnosis with MR imaging. AJR. American journal of roentgenology, 161(1):109-13.

19- **Dejour D and Le Coultre B (2007):** Osteotomies in Patello-femoral instabilities. Sports Med. Arthrosc., 15:39-46

20- **Balcarek P, Ammon J and Frosch S (2010):** Magnetic resonance imaging characteristics of the medial patellofemoral ligament lesion in acute lateral patellar dislocations considering trochlear dysplasia, patella alta and tibial tuberosity-trochlear groove distance. Arthroscopy, 26:926–935.

21- **Koeter S, Bongers EM, De Rooij J and van Kampen A (2006):** Minimal rotation aberrations cause radiographic misdiagnosis of trochlear dysplasia. Knee Surgery, Sports Traumatology, Arthroscopy, 14(8):713-7.

22- **Salzmann GM, Weber TS, Spang JT, Imhoff AB and Schöttle PB (2010):** Comparison of native axial radiographs with axial MR imaging for determination of the trochlear morphology in patients with trochlear dysplasia. Archives of orthopaedic and trauma surgery, 130(3):335-40.

23- **Carrillon Y, Abidi H, Dejour D, Fantino O, Moyen B and Tran-Minh VA (2002):** Patellar instability: assessment on MR images by measuring the lateral trochlear inclination—initial experience. Radiology, 216(2):582-5.

24- **Pfirrmann CW, Zanetti M, Romero J and Hodler J (2000):** Femoral trochlear dysplasia: MR findings. Radiology, 216(3):858-64.

25- **Nelitz M, Theile M, Dornacher D, Wölfle J, Reichel H and Lippacher S (2012):** Analysis of failed surgery for patellar instability in children with open growth plates. Knee Surgery, Sports Traumatology, Arthroscopy, 20(5):822-8.

26- **Fithian DC, Paxton EW, Stone ML, Silva P, Davis DK, Elias DA and White LM (2004):** Epidemiology and natural history of acute patellar dislocation. The American journal of sports medicine, 32(5):1114-21.

27- **Kavanagh EC, Zoga A, Omar I, Ford S, Schweitzer M and Eustace (2007):** MRI findings in bipartite patella. Skeletal Radiology, 36(3):209-14.

28- **Chung CB, Skaf A, Roger B, Campos J, Stump X and Resnick D (2010):** Patellar tendon-lateral femoral condyle friction syndrome: MR imaging in 42 patients. Skeletal Radiology, 30(12):694-7.