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Original Research Article

The evaluation of MRI findings in symptomatic knees by means of 0.2 T low field-strength open MR scanning; A research study comprising literature comparison with high field-strength scanners

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Abstract

Magnetic Resonance Imaging (MRI) is a superb modality in the examination and evaluation of the musculoskeletal system, and in particular, the knee joint. The superiority of MRI in knee joint imaging is due to its certain advantages over other imaging modalitites. First of all MRI is a noninvasive modality. It also can obtain direct multiplanar visualization, and has overwhelming superiority in assessing soft tissue contrast. In this study, the imaging data from knee joint imaging done by a 0.2 T low field-strength open MR scanner was evaluated and compared with the literatuıre data obtained from 1.5 T high field-strength MR imaging, and it was seen that the two groups of data were similar and in congruence. This finding led us to the conclusion that low field-strength MR imaging is as effective as 1.5 T high-field MR imaging in the evaluation of the knee joint, and it can well be utilized especially in patients who suffer clostrophobia and other restrictive conditions which prohibit them from getting into a closed-bore system.

Keywords: Knee, MRI, Low field-strength MRI, Open MRI, Permanent magnet MRI

INTRODUCTION

The knee joint has a complex structure which comprises the femoral and tibial condyles, together with the patella, ligaments, menisci, interlocated bursae, and the joint capsule (Figures 1 and 2). Pathological conditions of the knee may arise from any one or more of these structures (Ustun, 2003; Kean et al., 1983; Beltran et al., 1990; Li et al., 1986).

The first step in the detection of knee joint pathologies is obtaining a detailed clinical history and performing a thorough physical examination. The next step is imaging. Imaging is performed by different modalities, which are conventional radiography, computed tomography (CT), ultrasonography (US), arthrography, and MRI. Arthrography is an invasive imaging modality. Therefore, imaging modalities such as CT and MRI are somewhat more valuable in the imaging of the knee noninvasively. But all of these modalities possess certain limitations of their own (Ustun, 2003; Miller et al., 2002; Kean et al., 1983; Beltran et al., 1990; Li et al., 1986; Khan et al., 2014).

Conventional radiography is the basic means of imaging the knee. In routine practice, orthogonal views are obtained, which demonstrate the knee region both on the anteroposterior and lateral projections. Optional views

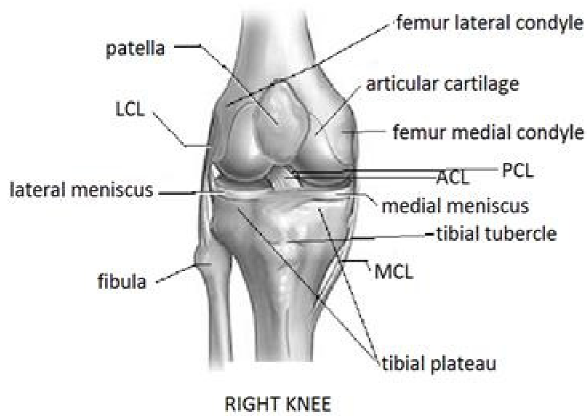

Figure 1. A schematic view of the knee joint and its components in the coronal plane

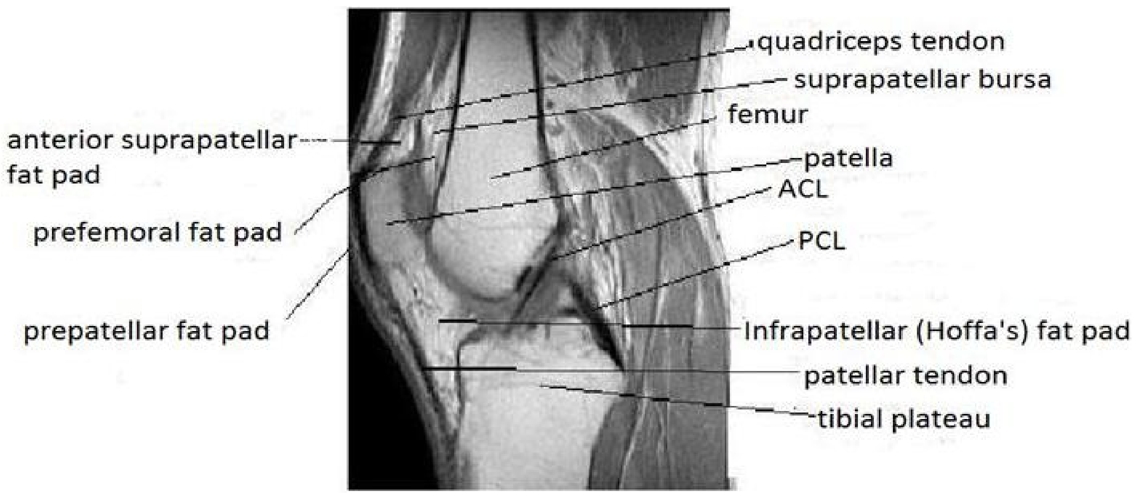

Figure 2. This **s**agittal T1W image of the knee joint demonstrates the components of the joint in full detail.

too, may be obtained, which image the knee region in varying angles and positions (Ustun, 2003; Tuncel 2002; Cherney et al., 1989).

On the other hand, CT has an important place in the evaluation of the knee joint, especially its bony components. CT helps determine the degenerative and osteoporotic changes that take place in the bones of the knee joint. It is also very useful in the diagnosis of tumoral growths of the bone, together with the demonstration of tumor growth both in and out of the tumoral area. CT is also very effective in the imaging of new bone formations and calcifications. On the other hand, tumor regression following therapy can also be monitored by means of CT imaging (Ustun, 2003; Ghelman, 1985; Mosher et al., 2013). High-resolution CT imaging can also be helpful in visualizing meniscal pathologies. The drawbacks of CT imaging are that it utilizes ionizing radiation, its tissue contrast is not as good as MRI, and it cannot provide direct multiplanar imaging.

High-resolution US is utilized for the evaluation of the soft tissue components of extremities. It is technically desirable that the transducers used for this purpose have an optimum operational frequency of 10 MHz or more. Linear transducers are utlized for this purpose, because it is more favorable that the sound beam comes perpendicular to the region of interest and the examination site is as wide as possible. US is rather insufficient in the visualization of bony pathologies and intraarticular soft tissue components. US performed with high-frequency superficial transducers is helpful in the detection of cystic and vascular pathologies in the near vicinity of the knee joint. The extensor tendons of the knee, which are the quadriceps and patellar tendons, may be visualized by US, especially when the knee is flexed. The collateral ligaments on the other hand, usually cannot be discriminated properly due to the presence of neighboring fat tissue and articular capsule. The cruciate ligaments and menisci, on the other hand, cannot be visualized by US. In some studies, the

Figure 3. The 0.2 T low field-strength open MRI scanner used in our study

posterior cruciate ligament (PCL) and its injuries have been investigated and visualized by means of US, and certain positive findings have been observed, such as ligament thickening and focal discontinuity (Miller et al., 2002). But MR is the modality of choice in this regard (Stoller et al., 1987; De Smet et al., 1994; Kaplan et al., 1991; Reinig et al., 1991; Mosher et al., 2013; Griffin et al., 2008).

Arthrography used to be utilized with single or double contrast, in the pre-CT and pre-MR era. But it is an invasive procedure and may provide satisfactory results only when performed with skilled hands. Arthrography is abandoned in today's modern imaging era (Ustun, 2003; Wilson et al., 1990; Ferris et al., 1981).

Arthroscopy on the other hand, is an invasive clinical modality and when performed by skilled hands, it may provide satisfactory diagnostic, as well as therapeutic, results. Today, arthroscopy is mainly a therapeutical operational procedure, and diagnostically it has limited applications such as a problem-solving function in cases whose conditions cannot be clearly evaluated by MRI (Wilson et al., 1990; Ferris et al., 1981; Cannon et al., 1994; Rosenberg et al., 1993).

Magnetic resonance (MR), as a raw technique, was first described by two researchers, Bloch and Purcell, who had been working on the same issue separately. The two researches won the Nobel prize in 1946. Lauterberg was the first scientist to use MR as an imaging modality in the 1980s. He won the Nobel prize for this great achievement in 2003.

MR imaging of the knee was first described by Kean et al in 1983. MRI demonstrated a very fast development thanks to technical achievements and became the gold standard in the visualization and evaluation of the knee joint (Kean et al., 1983; Tuncel, 2002; Lee et al., 2000; Carpenter et al., 1990; Vahey et al., 1990; Khan et al., 2014; Mosher et al., 2013; Griffin et al., 2008). MRI has many advantages which make it a superior modality in diagnostic radiology. First of all, MRI is a noninvaisve imaging modality which does not utilize ionizing radiation. Secondly, it provides direct multiplanar imaging. MRI can differentiate different tissue types such as fat, water, and blood, according to the proton properties of these structures. MRI also has superb contrast resolution, and it provides excellent anatomical detail. MRI is a radiologic modality whose sensitivity is very high, while its specificity is rather low. Therefore, a thorough clinical history is mandatory for a proper MR evaluation. MRI provides reliable diagnosis in a rather short period of time (Ustun, 2003; Tuncel, 2002; Katz et al., 2001; Mosher et al., 2013; Griffin et al., 2008).

The purpose of this research study was to image and evaluate the MRI findings of symptomatic knees by means of a 0.2 T low field-strength open MR scanner, and then to compare these findings with the literature data obtained from studies conducted by 1.5 T high-field MR scanners.

MATERIALS AND METHODS

214 knees which belonged to patients who had applied to the Orthopedics Department of the Numune Teaching and Research Hospital, Adana, Turkey, with various complaints concerning the knee joint, were included in this study. The study was conducted in accordance with the Helsinki Declaration. All patients were given thorough explanations about the study prior to the procedures.

Table 1. (n = 214) The frequency and percentages of the clinical findings

Clinical Finding	Frequency	Percentage
Meniscopathy	56	26,2
Medial meniscus tear	71	33,2
Knee trauma	7	3,3
Discopathy	1	0,5
ACL tear	9	4,2
Lateral meniscus tear	10	4,7
Knee pain	46	21,5
Whole body arthralgia	4	1,9
Synovitis	3	1,4
Swelling of knee	4	1,9
Knee clicking	1	0,5
Deep vein thrombosis (DVT)	1	0,5
Knee instability	1	0,5
Sum	214	100

Patients gave their full-informed consents before the study took place.

Conventional orthogonal X-rays of the knees were obtained prior to the MRI examinations. The initial clinical diagnoses of the patients were achieved by means of evaluating the physical findings and conventional radiograms.

The clinical initial diagnoses, and their frequencies and percentages are given in Table 1. The patient group which was recruited for the study mainly comprised those with medial meniscal tears and other meniscopathies, and those who presented with the complaint of knee pain. The most frequent of these entities was medial meniscus tear, which presented a ratio of 33.2 %.

MRI examinations were performed in a 0.2 T low field-strength open MRI scanner (Hitachi Airis Mate, Hitachi Corp., Japan) (Figure 3). The kness were placed properly in the special receiver coils.

Initially, localizer axial GRE images were obtained. The best one of these slices was used as a baseline for sagittal and coronal studies. The sagittal cuts were obtained first, over the initial axial slices. Spin Echo T1-Weighted (SE T1W), Proton Density Weighted (PDA), and Fast SE T2-Weighted (Fast SE T2W) slices were obtained on the sagittal plane. Following the sagittal work-up, coronal imaging was performed. SE T1W, SE PDW, and FSE T2W sequences were utilized. Besides, sagittal GRE slices were obtained in addition to axial ones. The STIR sequence was not routinely performed. But this sequence was performed when needed.

The parameters utilised in T1W imaging were as follows: TR = 400 ms, TE = 27 ms, slice thickness = 4 mm, interval = 1 mm, FOV = 16 cm, NSA = 2 (1), matrix = 280 x 260, sagittal scan time = 3 min 28 s, coronal scan time = 3 min 22 s, overall scan time = 6 min 50 s.

The parameters utilized in FSE T2W imaging were as follows: TR = 4000 ms, TE = 100 ms, slice thickness = 4 mm, interval = 1 mm, NSA = 2 (1), matrix = 256 x 168, FOV = 16 cm, sagittal scan time = 5 min 4 s, coronal scan time = 5 min 36 s, overall scan time = 10 min 40 s.

The parameters utilized in PDA imaging were as follows: TR = 4000 ms, TE = 20 ms, slice thickness = 4 mm, interval = 1 mm, NSA = 2 (1), matrix = 256 x168, FOV = 16 cm, sagittal scan time = 5 min 36 s, coronal scan time = 4 min 16 s, overall scan time = 9 min 52 s.

The parameters utilized in GRE imaging were as follows: TR = 500 ms, TE = 17 ms, Flip Angle = 30°, slice thickness = 4 mm, interval = 1 mm, NSA = 2 (1), matrix = 224 x204, FOV = 16 cm, sagittal scan time = 5 min 4 s, axial scan time = 3 min 24 s, overall scan time = 8 min 28 s.

Average MR examination time for a knee was about 30-35 minutes. No complications were experienced during the scans.

In the MRI examinations, the menisci, anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial and lateral collateral ligaments (MCL and LCL), joint cartilage, and peripheral soft tissues were examined and evaluated. The staging system invented by Stoller et al was used in the evaluation of meniscal degenerations and tears (Stoller et al., 1987). According to this staging model, globoid signal increase in the meniscus was defined as Grade 1, whereas linear signal increase not abutting the joint surface was defined as Grade 2, while a signal increase in the meniscal tissue abutting one or more joint surfaces was determined as Grade 3. Grade 1 and 2 signal increases were categorized as degeneration, and Grade 3 signal increase was classified as meniscal tear. The menisci were also evaluated for any structural anomaly such as discoid meniscus.

Any distortions in the anatomical unity of the ligaments, together with signal increases within the ligaments, or contour irregularities and ondulations, were investigated. Besides, periligamentous signal increases and any deviations from the normal configurations, were also studied. In the light of these findings, it was decided

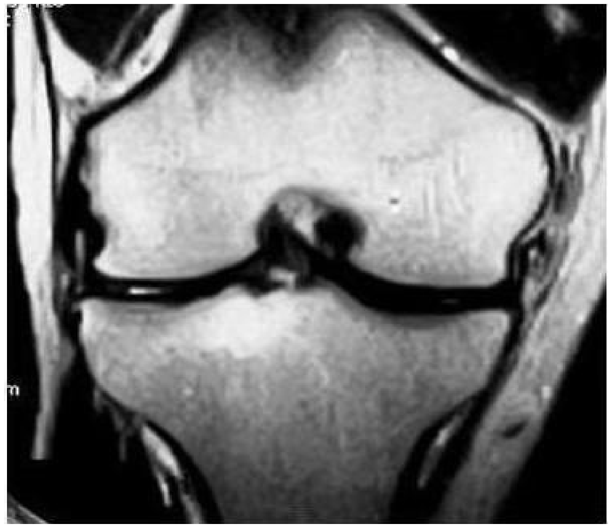

Figure 4. This T2W coronal image depicts medullary edema at the intercondylar notch of the tibial plateau as a hyperintense zone.

Table 2. (n = 214) The frequency and percentage of discoid meniscus in the lateral and Medial menisci

Discoid meniscus	Frequency	Percentage
Lateral discoid meniscus	1	0,5
Medial discoid meniscus	0	0

Table 3. (n = 214) The frequency and percentage of ACL pathologies

ACL pathologies	Frequency	Percentage
Injury sequela	23	10.7
Partial tear	8	3.7
Complete tear	9	4.2
Sum	40	18.7

whether there was an injury sequela, or a partial or complete tear, in the meniscus. The presence of effusions and hematomas were evaluated by means of T2W imaging. Synovial structures were evaluated by the utilization of both the T1 and T2W sequences.

Both the T1 and T2W sequences were utilized for the evaluation of the bony structures. Contusions which took place in the medullary bone following trauma were visualized as a signal decrease in T1W, and signal increase in T2W, sequences (Figure 4). Any alteration in the joint space, be it narrowing or widening, was evaluated in both the sagittal and coronal planes. The presence of patellar lateralization or medialization was assessed on the axial views. Joint cartilage was evaluated especially by the GRE sequence. Other various soft tissue planes were assessed by both T1W and T2W sequences.

RESULTS

A sum of 214 knee joints were evaluated in this study. Each knee was accepted as an individual case. Of these knees, 107 belonged to male, and the other 107 belonged to female, patients. The ages of the patients varied between 13 and 75 years. The results are summoned below: (Table 2)

Meniscus discoid configuration was encountered only in the lateral meniscus. No discoid meniscus formation was found in the medial meniscus. (Table 3)

The sum of overall pathological conditions of the ACL is 18.7 %, injury sequela of the ACL being the most frequent of all, with a rate of 10.7 %. The second in frequency is the complete tear of the ACL, with a frequencu of 4.2 %. (Table 4)

The frequency of overall pathogical conditions of the PCL is 1.9 %, and all are injury sequelae. No partial or

Table 4. (n = 214) The frequency and percentage of PCL pathologies

PCL pathologies	Frequency	Percentage
Injury sequela	4	1,9
Partial tear	0	0
Complete tear	0	0
Sum	4	1,9

Figure 5. PCL tear as seen on sagittal T2W sequence.

Table 5 (n = 214) The frequency and percentage of MCL pathologies

MCL pathologies	Frequency	Percentage
Injury sequela	7	3,3
Partial tear	1	0,5
Complete tear	0	0
Sum	8	3,8

complete tear of the PCL was encountered. (Figure 5)

The study revealed that ACL pathologies had a frequency which was 10-fold more than that of PCL pathologies. The reason for this is that PCL is anatomically stronger and more durable than ACL. The most frequent pathological condition for both of these ligaments was injury sequela. Partial and complete tears were encountered only in ACL. (Table 5)

The frequency of overall pathological conditions of the MCL was 3.8 %. Of all of these pathological conditions, injury sequela was the most frequent, with a ratio of 3.3 %. (Table 6)

The frequency of overall pathological conditions of the LCL was found to be 8.9 %, and among these, injury sequela was the most frequent one, with a rate of 8.4 %. The results of our study showed that the LCL was affected by injury two times more frequently than MCL. (Table 7)

Fluid accumulation was encountered with a percentage of 61.2 %, in the suprapatellar bursa. This ratio was 15 % for plica formation, and 2.3 % for synovial hypertrophy, respectively. Fluid accumulation was found to be the most frequent pathological condition of the suprapatellar bursa. (Table 8)

In the infrapatellar bursa too, just like the suprapatellar bursa, the most prominent pathological condition was fluid accumulation. But plica formation and syn-ovial hypertrophy were not present within the infrapatellar

Table 6. (n = 214) The frequency and percentage of LCL pathologies

LCL pathologies	Frequency	Percentage
Injury sequela	18	8,4
Partial tear	1	0,5
Complete tear	0	0
Sum	19	8,9

Table 7. (n = 214) The frequency and percentage of suprapatellar bursa pathologies

Suprapatellar bursa pathologies	Frequency	Percentage
Fluid accumulation	131	61,2
Plica formation	31	15
Sinoviyal hypertrophy	5	2,3

Table 8. (n = 214) The frequency and percentage of infrapatellar bursa pathologies

Infrapatellar bursa pathologies	Frequency	Percentage
Fluid accumulation	36	16,8
Plica formation	0	0
Synoviyal hypertrophy	0	0

Table 9. (n = 214) The frequency and percentage of prepatellar edema

	Frequency	Percentage
Prepatellar edema	3	1.4

Prepatellar soft tissue edema was encountered in 1.4 % of the knees.

Table 10. (n = 214) The frequency and percentage of Baker cysts

	Frequency	Percentage
Baker cyst	17	7,9

Baker cysts had a frequency of 7.9 %, in our study.

Table 11. (n = 214) The frequency and percentage of fluid accumulation in the knee joint

	Frequency	Percentage
Fluid accumulation in the joint space	50	23,4

bursa. Instead, synovial plica formation and hypertrophy were findings of the suprapatellar bursa. (Table 9-11)

In 23.4 % of the knees studied, fluid accumulation in the knee joint was detected. In other words, 50 of the 214

Table 12. (n = 214) The frequency and percentage of degenerative joint disease in the knee joint

	Frequency	Percentage
Degenerative joint disease	66	30,8

Table 13. (n = 214) The frequency and percentage of osteochondral bony lesions in bones constituting the knee joint

Osteochondral lesion	Frequency	Percentage
Osteochondral lesion at distal femur	8	3.7
Osteochondral lesion at proximal tibia	7	3.3
Osteochondral lesion at patella	2	0.9
Osteochondral lesions in sum	17	7.9

Table 14. (n = 214) The frequency and percentage of patellar chondromalacia

	Frequency	Percentage
Patellar chondromalacia	7	3.3

Patellar chondromalaica was found in 3.3 % of the knees studied in our study

Table 15. (n = 214) The frequencies and percentages of patellar lateralization and medialization

	Frequency	Percentage
Patellar lateralization	27	12.6
Patellar medialization	0	0

Patellar lateralization was found in 27 of the 214 knees studied (12.6 %). No patellar medialization was noted in the study.

Table 16. (n = 214) The frequencies and percentages of degeneration and tear in the anterior horn of the lateral meniscus

Anterior horn of lateral meniscus	Frequency	Percentage
Normal	205	95.8
Grade 1 dejeneration	5	2.3
Grade 2 dejeneration	3	1.4
Grade 3 dejeneration (tear)	1	0.5
Sum	214	100

knees in the study group demonstrated an increase in knee joint fluid. (Table 12)

The ratio of degenerative joint disease in the knees studied in our study group was found to be 30.8 %. In other words, 66 of the 214 knees studied demonstrated findings consistent with degenerative joint disease. (Table 13)

In 17 of the 214 knees, an osteochondral erosive lesion was detected (7.9 %). Most of these lesions were encountered at the distal femur. The other sites were the proximal tibia and patella. (Table 14-16)

The ratio of pathological conditions detected at the anterior horn of the lateral meniscus was found to be 5 %. The most abundant of these was Grade 1 degeneration, constituting 50 % of the cases. (Table 17)

The ratio of pathological conditions of the posterior horn of the lateral meniscus was found to be 20 %. These were degenerations and tears. The majority of these pathological conditions were Grade 1 degenerations which constituted two-thirds of the sum. The second in line were Grade 3 degenerations (tears). (Table 18)

The ratio of pathological conditions encountered in the anterior horn of the medial meniscus was 6%. These were degenerations and tears, and the majority were

Table 17. (n = 214) The frequencies and percentages of degenerations and tears encountered in the posterior horn of the lateral meniscus

Posterior horn of lateral meniscus	Frequency	Percentage
Normal	171	79.9
Grade 1 dejenerataion	31	14.5
Grade 2 dejeneration	4	1.9
Grade 3 dejeneration (tear)	8	3.7
Sum	214	100

Table 18. (n = 214) The frequencies and percentages of degenerations and tears in the anterior horn of the medial meniscus

Anterior horn of the medial meniscus	Frequency	Percentage
Normal	201	93,9
Grade 1 dejeneration	4	1,9
Grade 2 dejeneration	2	0,9
Grade 3 dejeneration	7	3,3
SUM	214	10

Table 19. (n = 214) The frequencies and percentages of degenerations and tears encountered in the posterior horn of the medial meniscus

Posterior horn of the medial meniscus	Frequency	Percentage
Normal	51	23.8
Grade 1 dejeneration	96	44.9
Grade 2 dejeneration	32	15
Grade 3 dejeneration	35	16.4
Sum	214	100

Figure 6. This sagittal T1W image clearly demonstrates a Grade 3 degeneration (tear) in the posterior horn of the medial meniscus.

Grade 3 degenerations (tears). (Table 19)

The posterior horn of the medial meniscus is the most frequently affected one of all the menisci, by various pathological conditions. The ratio of pathological conditions encountered in the posterior horn of the medial meniscus was found to be 76 %, in our study. These comprised degenerations and tears. The most frequent one of these were Grade 1 degenerations. Tears were the second in line. (Figure 6)

In overall estimation, pathological conditions of the anterior horn of the lateral meniscus were found in 5 % of the knees studied. The most abundant one of these pathologies was Grade 1 degeneration. In 20 % of the cases, the posterior horn of the lateral meniscus was evaluated as pathological. In the posterior horn of the lateral meniscus, too, the most frequently encountered pathological condition was Grade 1 degeneration. As a result, it is obvious that the most frequent pathological condition of the lateral meniscus is Grade 1 degeneration. Degeneration and tear are more frequent in the posterior, rather than the anterior, horn of the lateral meniscus.

In 75 % of the knees, a pathological condition in the posterior horn of the medial meniscus was detected. The most frequent one of these was Grade 1 degeneration. The posterior horn of the medial meniscus demonstrated a higher frequency of degenerations and tears in comparison to the anterior horn. In overall evaluation, it must be emphasized that the medial meniscus, and its posterior horn in particular, is more prone to degeneration and tear.

Our study showed that medial meniscopathy is more frequent than lateral meniscopathy. In both of the menisci, the posterior horns were more affected by pathology than the anterior horns. Meniscus tear was most frequently encountered in the posterior horn of the medial meniscus, with a rate of 16.4 %.

In addition to the general findings stated in the article, there were certain additional accessory findings not mentioned in the text, and these concerned the bony structures constituting the knee joint. These pathological alterations can be summarized as follows: medullary edema and contusion in 10 (4.7 %) patients; sclerosis and cyst formation in 4 (2 %) patients; multiple calcifications in 1 (0.5 %) patient.

DISCUSSION

Until 1985, the visualization of the pathological conditions of the knee joint was made by means of imaging modalities such as conventional radiography, US, CT, and arthrography. All of these modalities possess certain limitations. After it was introduced into the imaging efforts of the knee in the 1980s, MR became the most valuable modality of choice in the imaging of the knee joint. As MR technology evolved and MR became more widely used in the world, the gold standard in the imaging of the knee became MR imaging (Marti-Bonmati et al., 2000; Cotten et al., 2000; Colman et al., 2004; Mosher et al., 2013; Griffin et al., 2008).

MR imaging has certain advantages over other imaging modalities in that it does not utilize ionizing radiation, it makes possible direct multiplanar imaging, it has a superb soft tissue contrast resolution, and it is also very efficient in bone imaging.

Various sequences may be utilized in MR imaging. For the imaging of the knee, for example, the most widely used sequences are the SE and GRE based T1 and T2 weighted sequences. Literature data show that some other sequences too, like the (3 dimensional Fourier transformation) 3DFT sequence, have been used in knee MR imaging, but these accessory sequences have been shown not to be superior to the routinely used SE and GRE sequences. SE and GRE sequences are usually used together in combination in knee imaging. These sequences are somewhat complementary to each other (Adam et al., 1989; Haggar et al., 1988).Tayfun et al., 1993).

Some authors prefer to use the proton density (PD) and T1 weighted sequences for MR imaging of the knee, while others rely on the T1 and T2 weighted sequences because they say these are complementary sequences which work together well and in harmony (Tayfun et al., 1993; Adam et al., 1989). In our department, we have utilized all these three sequences together.

The generally accepted way of starting an MR examination of the knee joint is obtaining an initial axial T1-weighted sequence. This is the pilot sequence, and other routine sequences are obtained over this axial initial sequence. We utilized the GRE sequence in order to achieve this goal and obtain a baseline pilot series. Then we obtained T1, T2, and PDA weighted sagittal and coronal images by appointing the best slice of the initial series as the pilot view. Visualization of the collateral ligaments and bucket handle tears is best possible only on the coronal images. In case an allegedly pathological condition is present in the patellofemoral joint, axial imaging too, is very effective. The ACL is viewed best on the sagittal images. Sometimes, oblique sagittal images are added to the menu in order to image a disrupted ACL. The transverse ligament, geniculate artery, popliteus tendon, meniscofemoral ligament, and partial volume effect, are all among the factors that may lead to false positive signals on MR imaging (Beltran et al., 1990; Li et al., 1986; Singh et al., 2014). Coronal imaging is mandatory in order to avoid such misleadings. It was shown in a study that some of the lesions reported as Grade 2 degeneration on MR were proven to be tears instead, by arthroscopy. This ratio was found to be 17 % in a study (Ferris et al., 1981).

ACL tears are tears that can be more readily and easily diagnosed clinically. But still MR imaging is more sensitive and specific than clinical examination in the demonstration of the pathological conditions of the ACL and other components of the knee joint. In case of an ACL tear, irregularities of the contours of the ligament, together with a signal increase in the ligament and its periphery, are seen. In addition, the anatomical integrity of the ligament is disrupted. During the acute phase of the injury, it is possible to diagnose ACL tears clinically, but the same is not true for associating meniscal injuries (Lee et al., 1988; Barry et al., 1991; Mosher et al., 2013). In such situations, MR provides an incompatibly efficient solution to the problem.

MR visualization of the ACL must be performed with the knee in 15° - 20° external rotation. This position makes possible to obtain excellent in-axis slices of the obliquely lying ACL. The T2 weighted sequence has been shown to be more effective in the demonstration of ACL injuries. The sensitivity of T2 weighted imaging is more than that of T1 weighted imaging (Kohn et al., 1995; Griffin et al., 2008).

In our study, pathological conditions of the medial and lateral collateral ligaments and the ACl and PCL have been defined in three categories, these being injury sequelae, partial tears, and complete tears. Meniscal pathologies on the other hand, have been classified as Grade1, Grade 2, Grade 3 degenerations, and discoid configuration. The presence of fluid, synovial plicae, and hypertrophy, in the joint and bursae, have been included in the evaluation process. Baker’s cysts have been reported in the popliteal fossa. The presence of chondromalacia has been reported. The localization of osteochondral erosive lesions has been defined as being either the distal aspect of the femur, the proximal aspect of the tibia, or the patella itself. The presence and signs of degenerative joint disease (DJD) on the other hand, have been assessed by the use of conventional radiography and MR, in combination. Besides all of these, certain other pathological conditions such as patellar subluxations and bone contusions, have been included in the database of our study. All of the results have been processed and evaluated in order to achieve statistical conclusions. MR imaging was performed with a 0.2 T low field-strength open MR scanner (Figure 3). It was seen at the end of our study, that the results obtained from our study about the detection of pathological conditions of the knee joint by means of low field-strength MR imaging were consistent with those drawn from the literature and obtained from 1.5 T high field-strength MR imaging (Kreitner et al., 1999; Fisher et al., 1991; Cotten et al., 2000).

Only receiver coils are used in MR imaging of the knee. Because the structures to be examined in the knee are rather small, it is vital to reach a maximum spatial resolution in order to visualize these structures properly by MR. One of the factors which affect spatial resolution is the signal-to-noise ratio (SNR). Surface coils are utilized in MR imaging of the knee with the purpose of obtaining a better SNR by means of increasing the signal from the knee region. The use of surface coils may decrease the sensitivity to deeper tissues, but this does not create a big problem in MR imaging of the knee joint. High field-strength magnets usually provide higher signal broadcast, and thus, a higher SNR. Fischer et al have declared at the end of their study that 1.5 T high field-strength MR imaging was superior to 0.5 T mid-field MR imaging in the evaluation of the medial meniscus, but there was no difference between the two field strengths when it came to the lateral meniscus (Fisher et al., 1991).

Image quality in low field-strength MR scanners like the one we utilized in our study can be bettered by means of increasing the number of excitations, but this has a payoff of extending the examination time (Fisher et al., 1991).

As an overall conclusion, the patients who were recruited for our study were referred to our department from the Orthopedics department, with various complaints concerning their knees. The patients first undertook an X-ray examination and their knees were imaged by conventional radiograms.The majority of clinical diagnoses concerning the patients were meniscopathy and knee pain. The study group comprised 214 knees, of which 107 belonged to male, and the other 107 to female, patients. All knees were examined by our 0.2 T low field-strength MR scanner. All findings were recorded in forms prepared for this purpose. Data concerning the names, ages, genders, clinical diagnoses, imaging findings, and other clinical data, were recorded in these forms. The menisci, lateral and cruciate ligaments, joint space, and bursae, together with bone, cartilage and soft tissues, were all evaluated.

The most frequent meniscopathy was the one seen in the posterior horn of the medial meniscus, with a ratio of 76.2 %. The posterior horns of the medial and lateral menisci were found to be more prone to the development of pathology than the anterior horns. Discoid configuration was most frequently encountered in the lateral meniscus. These data were found to be generally consistent with that from the literature (Schonholtz et al., 1993; Barnes et al., 1988; Silverman et al., 1989; Auge et al., 1994; Fuji et al., 1992).

The cruciate ligament which was most affected by injury was the ACL, with a ratio of 18.7 %. The PCL is more durable and resistant to injury than the ACL, due to its stronger anatomophysiological structure.

The results of our study showed that of the two collateral ligaments, it was the LCL which was affected by injury the most, and not the MCL. This data was in discordance with that from the literature (Mink et al., 1987; Herman et al., 1988; Mesgarzadeh et al., 1993).

Synovial hypertrophy and plica formation were most frequently seen in the suprapatellar bursa. Fluid accumulation in the joint space and suprapatellar bursa were encountered in 60 % of the knees studied.

Baker cysts were detected in 8 % of the knees. Literature data point to a higher ratio in symptomatic knees (Mink et al., 1987; Herman et al., 1988; Mesgarzadeh et al., 1993; Cao et al., 2014).

Osteochondral lesions were seen in 8 % of the knees. 50 % of these were detected at the femoral condyles.

These data are consistent with that from the literature (Mink et al., 1987; Herman et al., 1988; Mesgarzadeh et al., 1993).

Patellar subluxation was seen only as patellar lateralization. No patellar medialization was noted. Patellar chondromalacia had a ratio of 3.3 %. By evaluating conventional radiograms and MR examinations in combination, findings of DJD were found in approximately one-thirds of the knees.

MR technology is evolving, and one fascinating development was the introduction of open MR scanners. Open scanners usually are low field-strength machines. The one we used in our study had a field strength of 0.2 T. Despite some disadvantages of these machines in comparison to high field-strength ones, these scanners also present certain superiorities. For example, these machines do not require chillers, their magnets are permanent so they do not possess electromagnetic type magnets and thus do not reqire helium consumption. These scanners are also very economic, due to the reasons stated above. These magnets also have very long-lasting permanent homogeneities.

When examining the knee with MR, it is very important to evaluate the ligaments and tendons as a whole and image these structures in unity and continuity. The magic angle phenomenon, which may impair the evaluation process considerably, takes place in high field-strength MR scanners. On the other hand, low field-strength open scanners are not affected by this drawback, because the magic angle phenomenon does not happen with these machines, basically due to the vertically-positioned z-axis in these machines. Another advantage of low field-strength machines is that no intensity chaos happens when fat and water are present in the same site. This is good because these machines do not face the disadvantages of the chemical shift artifact (Rothschild et al., 2000; Cotten et al., 2000; Singh et al., 2014; Strach et al., 2010).

Clostrophobia is an important problem concerning MR. People with clostrophobia sometimes cannot tolerate lying in the closed bore of a magnet. Sometimes they need to be sedatized in order to conduct the examination, and sometimes they even have to be given general anesthesia (Rothschild et al., 2000; Cotten et al., 2000; Colman et al., 2003). On the other hand, another drawback is the situation with children. It is impossible to place kids in closed bar magnets. They are very scared to go in these machines. Concerning all of these difficulties with the closed bar magnets, open MR scanners come out with a very big advantage of overcoming all these problems. These machines, including the one we used for this study, are ideal for examining children and patients with clostrophobia. They are good for the elderly, too. Because patients do not feel deserted and lonely in these machines. These scanners do not have a closed bar, instead, they have a very large space with nearly completely open sides. The one we used for this study had a 270° open side. Relatives of the elderly and mothers of the kids may well stay in the scanning room, hold their patients' hands, and talk to them, while scanning is on (Rothschild et al., 2000; Singh et al., 2014; Strach et al., 2010).

Anyhow, there are some drawbacks too, with the low field-strength scanners. For example, because their magnetic fields are weak, the number of excitations must be increased. This in turn, extends the examination time (Fisher et al., 1991; Singh et al., 2014; Strach et al., 2010). Again, because of the weak field strengths of these machines , the amount of contrast media to be used must be increased in order to achieve adequate image contrast.

MR is the most superior modality invented up to date, in the examination and visualization of soft tissues. Thus, it is a perfect modality for the imaging of the knee joint and its components, including the menisci and ligaments. Its multiplanar imaging capability, together with its superb soft tissue contrast, makes MR the gold standard of knee imaging.

In our study, the results of MR evaluation of the knees by means of a low field-strength scanner came out to be similar to those obtained from the literature and achieved by high field-strength scanners. Our study, and many other previous studies, have shown that MR is the gold standard in the imaging of the knee joint. One of the most important achievements in MR technology has been the low field-strength open scanners. Even though open scanners have a lower field strength than high-field ones, they achieve results as good as and similar to those obtained from high field-strength scanners. These machines have many advantages over high field-strength closed bar systems, in terms of patient comfort.

MR is a noninvasive, nonionizing, and superb modality, with multiplanar imaging capability and very high soft tissue contrast. Because of all these factors, it has a unique place in the imaging of the knee joint. Open MR scanners have proved to be as effective as high field-strength ones, in terms of knee joint imaging, as also proven by our study. Technologies in development will surely lead to the production of more efficient open MR scanners, which will provide excellent whole body imaging together with very high patient comfort.

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