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ORIGINAL STUDY

Role of MRI in Evaluation of Postoperative Anterior Cruciate Ligament Reconstruction

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Abstract

Objectives: **This study aimed to spotlight on the diagnostic value of MRI in the assessment of anterior cruciate ligament (ACL) reconstruction graft and detection of its complications.**

Background: **ACL is the most frequently reported injured knee ligament that requires surgical reconstruction. MRI is the modality of choice for evaluation of ACL graft reconstruction surgery and assessment of its complication.**

Patients and methods: **This prospective study was conducted on 100 patients with postoperative knee reconstruction of the ACL. All patients were subjected to clinical history followed by MRI examination. MRI examination of the knee was performed in axial, coronal, and sagittal planes. Patients were positioned in the supine position with the knee placed in 10−15° of external rotation, and surface coil was applied. Different MRI sequences were obtained.**

Results: **According to our results, of the studied patients, 66 (66%) cases showed an intact ACL graft. The commonest post-ACL reconstruction complication was osteoarthritis, being noticed in 21 (21%) cases of the studied patients. The second most common complication was complete graft tear, where it was observed in 15 (15%) cases. The least common complications were the graft laxity and iliotibial band syndrome; each was seen in one case, representing only 1% for each.**

Conclusion: **We conclude that MRI is the gold standard method for evaluation of postoperative ACL reconstruction, as it plays an important role not only in the assessment of graft integrity but also in detection of the postoperative ACL reconstruction complications.**

Keywords: Anterior cruciate ligament, Complications, MRI, Reconstruction

1. Introduction

The anterior cruciate ligament (ACL) is the most frequently reported injured knee ligament that requires surgical reconstruction. ACL injuries most commonly occur in athletes playing multidirectional sports [1].

Owing to its importance in the biomechanical stability of the knee, it is one of the most commonly reconstructed ligaments in the human body. MRI is the modality of choice for the diagnosis of ACL injuries [2].

Clinical evaluation of ACL reconstructions can be difficult and MRI plays an important role in evaluating the integrity of the ACL graft, as well as in diagnosing complications associated with ACL reconstruction [3].

It is incumbent on radiologists to be familiar with the different surgeries performed for ACL reconstruction, the normal postoperative appearance, and complications that can be diagnosed with imaging [4].

Complications of ACL reconstruction manifest most often with nonspecific symptoms, necessitating imaging evaluation. Previous studies have emphasized the ability of MRI to allow detection of complications of ACL reconstruction [5].

MRI is the modality of choice for evaluation of failed ACL graft reconstruction surgery and ACL graft complications such as abnormal tunnel

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positioning, roof impingement, partial and complete graft tears, arthrofibrosis, tunnel synovial cysts, iliotibial band friction syndrome, hardware loosening, and infection [6].

The aim of this work was to assess the role of MRI in the evaluation of ACL reconstruction surgery and detection of its complications.

2. Patients and methods

This prospective study was conducted on 100 patients, comprising 94 males and six females, whose ages ranged from 17 to 55 years. The study was conducted between April 2018 and December 2021. All patients were subjected to ACL reconstruction surgery and were referred to the MRI units of Shebin El Koum Fever Hospital and other private radiology centers for postoperative evaluation.

Inclusion criteria included patients with a history of ACL reconstruction surgery. Exclusion criteria included recent ACL reconstruction surgery within 1 year and contraindications to MRI examination (implanted biological devices, for example, pacemakers, cochlear implants, CNS clips, history of claustrophobia or severe anxiety, and presence of metallic screws as they produce artifacts and affect tunnel position visualization).

2.1. Methodology

All patients were subjected to reporting their complaints, including knee pain, swelling, instability, loss of full knee extension or limited range of motion, past history of knee trauma, time of ACL reconstruction surgery, and the type of reconstruction graft used. MRI examination of the knee joint was done.

2.2. Technique

MRI examination of the knee was performed in axial, coronal, and sagittal planes. Patients were positioned in the supine position with the knee placed in 10–15° of external rotation, and surface coil was applied. An axial acquisition, through patellofemoral joint, was used as an initial localizer for subsequent sagittal and coronal plane images. Axial images were obtained from distal quadriceps tendon to insertion of patellar tendon on the tibial tuberosity. Sagittal images were obtained from medial to lateral femoral condyles, and coronal images were obtained with line parallel to femoral condyles.

2.3. MRI protocol

All patients underwent MRI examination by GE (8200 W Tower Ave Milwaukee, WI, 53223-3219 United States) 1.5 T machine.

The protocol of our examination included the sagittal T1, sagittal T2, sagittal proton density, sagittal T2 fat sat, sagittal proton density fat sat, coronal T2 fat sat, and axial T2.

The parameters of the knee MRI were as follows: TR/TE = 600/9 (sagittal T1), 2560/74 (sagittal T2), 2900/28 (sagittal proton density), 4770/74 (sagittal T2 fat sat), 1700/30 (sagittal proton density fat sat), 4763/74 (coronal T2 fat sat), 2560/74 (axial T2), a slice thickness of 3 mm, and FOV 16 cm.

The MRI were interpreted and the following findings: continuity and signal intensity of the ACL graft were better assessed in sagittal proton density (PD), sagittal T2WI, and coronal PD Fat Sat. Intact grafts appeared of low signal intensity on all MRI sequences. Partial ACL graft tear appeared as focal thinning of ACL graft with partial interruption of the graft fibers and increased signal intensity within the graft. Complete ACL graft tear appeared as a complete discontinuity of ACL graft fibers. The position of the femoral and tibial bone tunnels was assessed at sagittal and coronal MRI. ACL reconstruction complications, including mucoid degeneration, signs of impingement, signs of laxity, and osteoarthritic changes were observed in different MRI sequences. Signal intensity and amount of periligamentous tissue between and around the graft were observed for the, assessment of arthrofibrosis/cyclops development on sagittal T1WI, sagittal T2WI, sagittal PD and sagittal PD Fat Sat. Amount of fluid in the knee joint on sagittal PD Fat Sat and axial T2 images was graded as minor, moderate, or marked effusion. Artifacts from the metallic fixation devices were observed in some cases. Ancillary findings, including status of the collateral ligaments, menisci, patellar tendon, secondary signs of ACL graft tear, and osteoarthritic changes were assessed.

2.4. Statistical analysis

Data were collected, tabulated, and statistically analyzed using an IBM personal computer with Statistical Package for the Social Sciences (SPSS), version 20 (SPSS Inc., Chicago, Illinois, USA), where the following statistics were applied: descriptive statistics, in which quantitative data were presented in the form of mean, SD, and range, and qualitative data were presented in the form numbers and percentages.

3. Results

This study included 100 patients (94 males and six females), with a mean age of 31.9 ± 7.31 years and ranged from 17 to 55 years. They all had ACL reconstruction (Table 1).

Of the studied patients, 66 (66%) cases showed an intact ACL graft, 15 (15%) cases showed complete ACL graft tear, and 14 (14%) cases showed partial ACL graft tear. Mucoid degeneration of the graft was demonstrated in five (5%) cases. Graft impingement was found in six (6%) cases. Five (5%) cases had cyclops lesions, and two (2%) cases had arthrofibrosis. Only one (1%) case showed graft laxity. Two (2%) cases showed tunnel cysts. Only one (1%) case had iliotibial band syndrome. A total of 21 (21%) cases showed osteoarthritic changes (Table 2).

A total of 33 (33%) cases showed no ancillary findings, and 37 (37%) cases had joint effusion. Moreover, 17 (16%) cases had medial meniscectomy and four (4%) cases had lateral meniscectomy. Patellar tendinosis was found in three (3%) cases. Nine (9%) cases had medial meniscal tear, and seven (7%) cases had lateral meniscal tear. Medial meniscal degeneration was found in 10 (10%) cases, whereas lateral meniscal degeneration was found in four (4%) cases only. Anterior tibial translation was found in six (6%) cases, uncovered posterior horn lateral meniscus (PHLM) was found in four (4%) cases, and buckling of PCL was found in five (5%) cases (Table 3).

The primary and secondary signs of ACL graft tear were assessed in our study. Complete discontinuity of graft fibers was found in all cases of complete graft tear (100%), focal thinning of graft fibers was found in all cases of partial graft tear (100%), but increased signal intensity within the graft were detected in both complete graft tear (53.3%) and partial graft tear (78.5%).

Complete discontinuity and focal thinning of graft fibers were found to be valuable for differentiating between complete and partial graft tear, whereas increased graft signal intensity was found to be the least valuable sign for differentiating between them.

The secondary signs including anterior tibial translation, uncovered PHLM, and buckling of PCL were seen in both partial and complete tears, so they were considered nonspecific signs (Table 4).

Table 1. Sociodemographic data of the studied patients (N = 100).

Studied variables	Studied patients
Age (years)	
Mean ± SD	31.9 ± 7.31
Median	31.0
Range	17.0–55.0
Sex	n (%)
Male	94 (94.0)
Female	6 (6.00)

Table 2. Number and percentage distribution of MRI findings among the studied patients (N = 100).

Studied variables	Studied patients [*n* (%)]
Normal ACL graft	66 (66.0)
Complete ACL graft tear	15 (15.0)
Partial ACL graft tear	14 (14.0)
Mucoid degeneration	5 (5.00)
Graft impingement	6 (6.00)
Cyclops	5 (5.00)
Arthrofibrosis	2 (2.00)
Laxity	1 (1.00)
Tunnel cyst	2 (2.00)
Iliotibial band syndrome	1 (1.00)
Osteoarthritis	21 (21.0)

ACL, anterior cruciate ligament.

Case 1. a 24-year-old male patient underwent right knee ACL reconstruction surgery 3 years ago. He presented with right-side knee traumatic acute pain and showed complete tear of ACL graft (Fig. 1).

Case 2. a 32-year-old male underwent left knee ACL reconstruction surgery 2 years ago. He presented with decreased range of motion and showed graft impingement (Fig. 2).

Case 3. a 26-year-old female underwent left knee ACL reconstruction surgery 5 years ago. She presented with stiffness and limited ability to straighten the leg, showing arthrofibrosis (Fig. 3).

Table 3. The number and percentage distribution of ancillary MRI findings among the studied patients (N = 100).

Studied variables	Studied patients [*n* (%)]
No ancillary findings	33 (33.0)
Joint effusion	37 (37.0)
Medial meniscectomy	16 (16.0)
Lateral meniscectomy	4 (4.00)
Patellar tendinosis	3 (3.00)
Medial meniscal tear	9 (9.00)
Lateral meniscal tear	7 (7.00)
Medial meniscal degeneration	10 (10.00)
Lateral meniscal degeneration	4 (4.00)
Anterior tibial translation	6 (6.00)
Uncovered PHLM	4 (4.00)
Buckling of PCL	5 (5.00)

PCL, posterior cruciate ligament; PHLM, posterior horn lateral meniscus.

Table 4. The number and percentage distribution of primary and secondary signs of anterior cruciate ligament graft tear.

Studied variables	Complete tear (15) [*n* (%)]	Partial tear (14) [*n* (%)]
Complete discontinuity of graft fibers	15 (100)	0
Focal thinning of graft fibers	0	14 (100)
Increased graft signal intensity	8 (53.3)	11 (78.5)
Anterior tibial translation	4 (26.6)	2 (14.2)
Uncovered PHLM	2 (13)	2 (14.4)
Buckling of PCL	3 (20)	1 (7)

PCL, posterior cruciate ligament; PHLM, posterior horn lateral meniscus.

4. Discussion

ACL reconstruction is one of the most common orthopedic surgeries. Although the quality of surgical techniques and fixation materials has been improved, the failure after ACL reconstruction may occur [7].

Most patients who have undergone primary ACL reconstruction report good to excellent outcomes regarding stability and return to pre-injury activity level [8].

MRI plays a major role in the assessment of ACL graft integrity and bony tunnel placement, and also it has an important role in the assessment of the complications that are associated with ACL reconstruction surgery [8].

The indications for evaluating ACL reconstructions with MRI include failure of ACL reconstruction to stabilize the knee, postoperative re-injury to the knee, postoperative stiffness especially extension loss (flexion contracture), and preparation for revision of a failed ACL reconstruction, all of which aid the surgeon in preoperative planning [9].

Leathers et al. [10] observed a statistically significant male predominance of ACL reconstruction in their male-to-female incidence ratio of 2.03. Similar

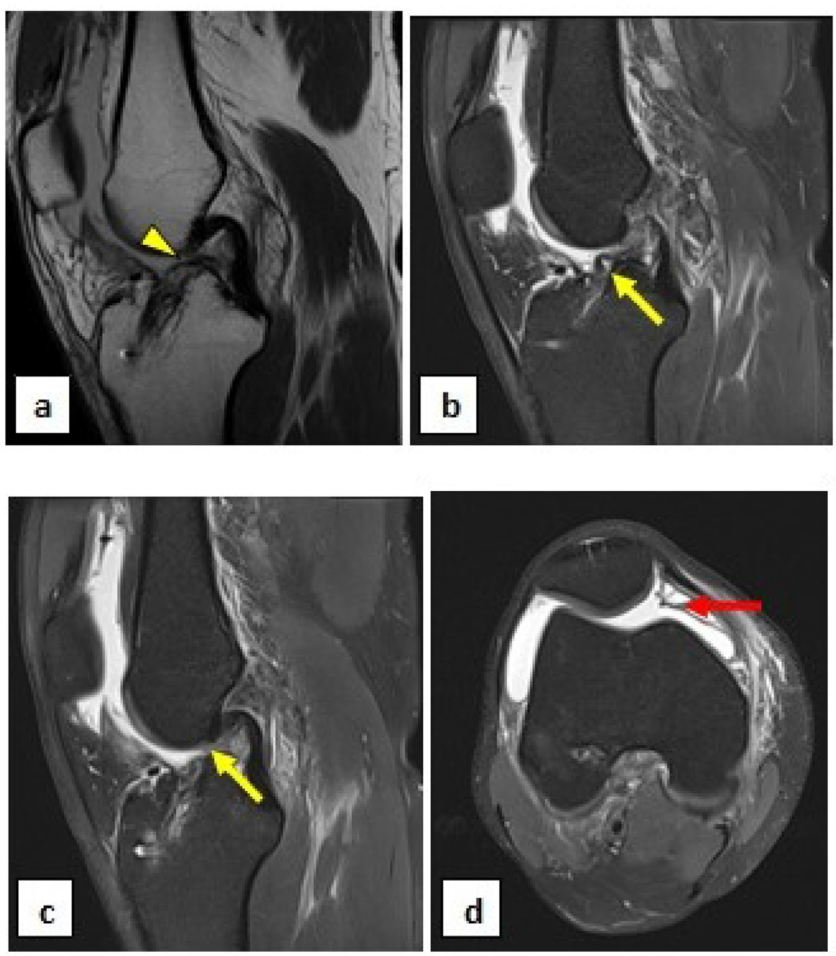

Fig. 1. A 24-year-old male patient underwent right knee ACL reconstruction surgery 3 years ago. He presented with right-side knee traumatic acute pain and showed complete tear of the ACL graft. Sagittal PD (a) and sagittal T2 FS (b, c) show complete discontinuity of ACL graft fibers (yellow arrows) with sagging of its fibers upon the tibial plateau (arrow head). Sagittal T2 FS (d) shows associated bone marrow contusion of the posterior lateral aspect of the tibial plateau (red arrow) and moderate joint effusion. ACL, anterior cruciate ligament.

Fig. 2. A 32-year-old male patient underwent left knee ACL reconstruction surgery 2 years ago. He presented with decreased range of motion and showed ACL graft impingement. Sagittal T2 FSE (a) shows too anterior position of tibial tunnel that ranges between 15 and 41% (normal up to 31 and 63% of the tibial plateau diameter). Sagittal PD Fat Sat (b) shows associated intermediate to high signal intensities seen within ACL graft fibers without interruption denoting graft impingement (arrow). Coronal PD Fat Sat (c) demonstrates diminution of the size of the anterior horn of the medial meniscus; sequela of previous partial medial meniscectomy (arrow head). ACL, anterior cruciate ligament.

results were also noted by Mall et al. [11], who observed a 1.4 male-to-female incidence ratio in their results.

Sayampanathan et al. [12] mentioned that the mean age of patients having ACL reconstruction surgeries in their study was 29.4 years. A study conducted by Nordenvall et al. [13] in Sweden revealed that the mean age of their study population of ACL reconstruction patients was 32.3 years (SD: 13.3).

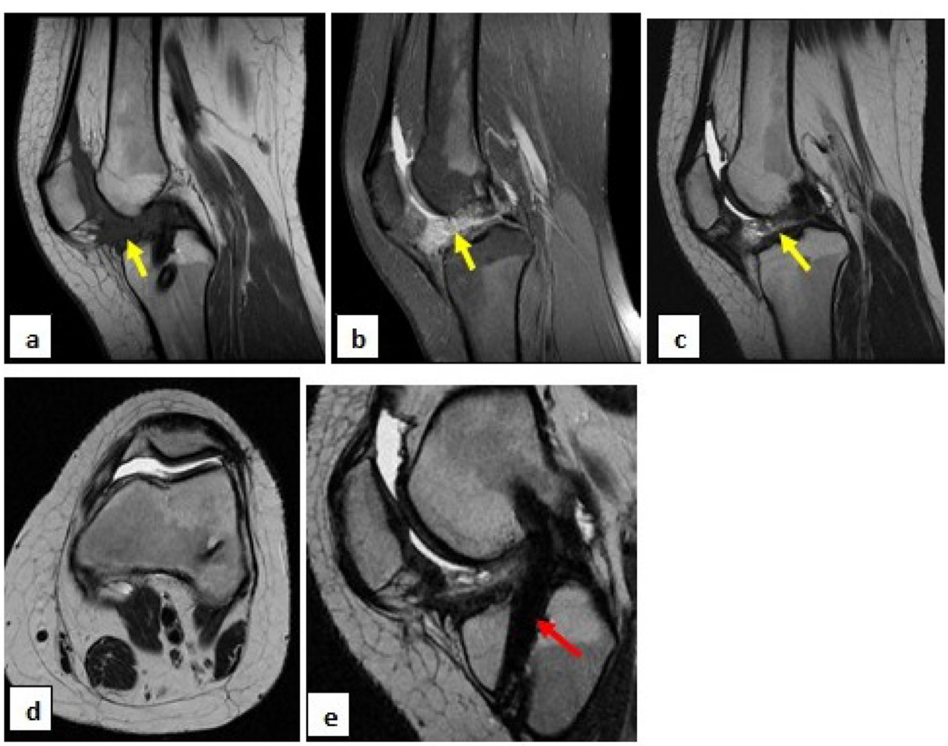

Fig. 3. A 26-year-old female patient underwent left knee ACL reconstruction surgery 5 years ago. She presented with stiffness and limited ability to straighten her leg and showed arthrofibrosis. Sagittal T1 (a), sagittal PD Fat Sat (b), and sagittal T2 FSE (c) show ill-defined intermediate signal intensity seen at intercondylar notch and anterior to the graft, eliciting low signal intensity in T1, iso to high signal in T2, and PD compatible with arthrofibrosis (yellow arrows). Axial T2 FSE (d) demonstrates mild joint effusion. Sagittal T2 FSE (e) shows normal orientation of ACL tunnel with intact ACL graft fibers (red arrow). ACL, anterior cruciate ligament.

Concordant results were found in our study, where there was a significant male predominance (94 males and six females), with an age range from 17 to 55 years and mean ± SD age of 31.9 ± 7.31 years.

Kamel and Darwish [9] believed that ACL graft discontinuity, focal thinning, and the presence of any intact ACL graft fibers were better assessed in the coronal plane than in the sagittal plane. They noticed that complete discontinuous graft on both sagittal and coronal planes increased specificity to 100% in the diagnosis of a full-thickness graft tear.

Kulczycka et al. [14] also showed that as compared with previous studies, complete ACL graft discontinuity was the most valuable primary sign in the diagnosis of full-thickness graft tear having high specificity (91%) in discriminating full-thickness graft tear from intact graft. They stated that focal thinning of ACL graft with the presence of any intact fibers was a more valuable sign in discriminating partial graft tear from intact graft.

This is in agreement with our study where the primary signs of ACL graft tear have been assessed. From these primary signs, complete discontinuity of the graft was found in all cases of complete tear (100%), so considered as a reliable sign for diagnosis of complete tear of the ACL graft. This is also in concordance with Saupe et al. [15], who stated that complete discontinuity of the ACL graft was considered the most valuable sign for the diagnosis of complete graft tear having specificity and positive predictive value (PPV) of 91 and 95%, respectively, in differentiation between complete graft tear and intact graft.

The second primary sign assessed in this study was focal thinning of the graft with the presence of any intact fibers. This sign was found in all cases of partial tear (100%), so considered to be the most valuable sign in discriminating between partial and complete graft tear.

Min et al. [16] and Khedr et al. [17] stated that increased signal intensity of the graft was considered as the least reliable sign in the discrimination between partial and complete graft tear as well as between torn and intact graft.

This is in agreement with our study, where increased signal intensity within the graft was detected in both complete (53.3%) and partial tear (78.5%); thus, this sign was found to be the least valuable sign for differentiating between them.

Bryan and Lee [18] and Kupczik et al. [19] suggested that the adequate positioning of the tibial tunnel is considered an important factor that prevents impingement of the ACL graft, and nonisotropic positioning of the bony tunnel causes the graft to be subjected to abnormal stress during the movement of the knee joint, thus spontaneous rupture may occur.

The previous results coincide with Hagino et al. [20], who found that when performing reconstruction of the ACL, the major and the most important complication is the malposition of the bony tunnels.

This agrees with our results, which showed that the main cause for graft impingement was the abnormal position of the tibial tunnel. Six (6%) patients who were diagnosed as graft impingement had an abnormal position of the tibial tunnel (anterior to the Blumensaat line); the impingement was noticed as an intermediate or high-signal-intensity on T2 and PD fat suppressed images. Another patient (1%) showed a posteriorly positioned tibial tunnel that was diagnosed as graft laxity.

Meyers et al. [4] and El Ameen et al. [21] also concluded that the abnormal position of the tibial tunnel causes the graft to be impinged against the roof of the intercondylar notch.

Bryan and Lee [18] and Carson et al. [22] stated that ACL graft failure is usually caused by either mechanical or technical factors, and the technical factors include abnormal placement of the femoral or tibial bony tunnels or inappropriate fixation of the graft. Meuffels et al. [23] and Saupe et al. [15] also reported that nonanatomic bone tunnel placement is the most common cause of a failed ACL reconstruction.

In our study, 25.7% of the cases associated with graft failure showed abnormal tibial tunnel position, 2.8% were found to have complete ACL graft tear, 5.7% had partial ACL graft tear, and 17.1% showed ACL graft impingement.

Hagino et al. [20] and Leathers et al. [10] have shown that 30–60% of primary ACL tears are associated with meniscal or chondral injury and that lateral meniscal tears are more common than medial meniscal tears. Injuries to the meniscal and chondral structures seen at the time of ACL reconstruction are common.

Lohmander et al. [24] stated that isolated ACL injuries are uncommon. Associated injuries to the menisci, other ligaments, joint cartilage, and subchondral or cancellous bone tend to occur when a patient sustains an ACL tear.

This explains the presence of the associated ancillary findings among our studied patients. A total of 19 (19%) patients showed medial meniscal lesions, nine (9%) patients had medial meniscal tears, and 10 (10%) patients with medial meniscal degeneration. Moreover, 11 (11%) patients showed lateral meniscal lesions, seven (7%) patients were lateral meniscal tears, and four (4%) patients were lateral meniscal degeneration. Anterior tibial translation was found in six (6%) patients, uncovered PHLM was found in four (4%) patients, and buckling of PCL was found in five (5%) patients; all were symptomatic patients.

According to Bolog et al. [25], the second common cause of impaired knee extension after the graft impingement was the presence of localized arthrofibrosis 'cyclops lesion.' It appeared in 1–10% of patients with ACL reconstruction and represented a focal fibrosis situated anterior to the distal portion of the ACL graft, often in the midline of the joint space.

Facchetti et al. [26] showed that the prevalence of cyclops lesions detected by MRI is observed in 25% of the patients with ACL reconstruction.

We detected seven (7%) patients with an arthrofibrosis/cyclops lesions in our study. These included two patients with diffuse arthrofibrosis. The other five patients of cyclops lesions showed heterogeneous but predominantly of low signal intensity nodule on the T2-weighted images, being well differentiated from high-signal-intensity joint fluid within the intercondylar notch.

Zappia et al. [27] stated that ACL reconstruction may in fact be a risk factor for osteoarthritis as a long-term complication 2–15 years after surgery. This is presumably owing to an alteration of normal biomechanics, leading to compression of articular cartilage, and the risk factors for developing osteoarthritis after ACL reconstruction include meniscal injury and age more than 25 years at the time of surgery.

Paschos [28] stated that ACL tear is associated with an increased risk for osteoarthritis development. This risk increases remarkably when an associated meniscal or chondral lesion is present, and although the ACL reconstruction potentially restores knee stability and appears to reduce the risk of osteoarthritis, it cannot fully eliminate the increased risk. The initial effect of injury at the time of ACL tear could explain the association between osteoarthritis and ACL tear.

According to our results, 21 (21%) patients showed osteoarthritic changes, which can be considered one of the most common associated findings of ACL reconstruction, and ACL reconstruction itself can be a risk factor for development of osteoarthritis.

According to our results, the commonest post-ACL reconstruction complication was the osteoarthritis being noticed in 21 (21%) patients. The second most common complication was complete graft tear, which was observed in 15 (15%) patients. This could be explained by the concomitant history of retrauma in these cases.

The least common complications were the graft laxity and iliotibial band syndrome, as each was seen in only one patient, representing 1% for each.

4.1. Conclusion

MRI is the gold standard method for evaluation of postoperative ACL reconstruction as it plays an important role not only in assessment of graft integrity but also in assessment of graft failure and detection of postoperative ACL reconstruction complications.

We can also conclude that assessment of tunnel position is very important for detection of graft failure. Moreover, increased signal intensity within the graft is a very specific sign in the detection of graft failure, although it is the least valuable sign in differentiating between complete and partial graft tear.

Ethical approval

We obtained the ethical approval of the study from the ethical committee of Faculty Medicine, Menoufia University.

Consent statement

A written informed consent was taken from the parents or caregivers after explaining the aim of the study.

Conflict of interest

There are no conflicts of interest.

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