Research Article

Role of Magnetic Resonance Imaging in Evaluation of Anterior Cruciate ligament Graft

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Abstract
MR imaging plays an important role in evaluating the integrity of the ACL graft, as well as in diagnosing complications associated with ACL reconstruction. **Patient & Methods**: This study included 34 patients aged from 17 to 47 years (mean 29 years). MRI study assessed: pattern of the ACL graft (discontinuity, SI, orientation), presence or absence of graft impingement, ganglion cyst, arthrofibrosis, and hardware malposition. Associated knee injuries were also evaluated. **Results**: graft tear was the commonest finding (71%) in the included Cases. There was significant positive correlation between SI and orientation of the grafts with their tear. The MRI study revealed graft complications in 59% of cases: impingement in 12, Ganglion Cyst in 6, cyclops in 4, and hardware mal-position (loose femoral screw) in 2. Images of impingement cases showed increasing in the graft SI, lax orientation, and tear (partial or complete). Regarding ganglion cyst cases, all grafts had increased SI and most of them were lax and partially torn. Grafts in cyclops cases were normal SI, normal orientation, and intact. Graft discontinuity correlated with impingement positively, with ganglion cyst and cyclops negatively. **Conclusion**: MRI represents an important tool for assessment of the complication following ACL graft reconstruction. The most frequent complication was Graft tear followed by impingement. Graft SI and orientation is very helpful parameters in diagnosis of graft complications.
Keywords: MRI, ACL graft, complications

Introduction
Anterior cruciate ligament (ACL) reconstruction is currently one of the most common surgical procedures in sports medicine and has yielded promising clinical results for patients with ACL injuries. However, a substantial number of postoperative complications may occur after ACL reconstruction[(1)]**.** The causes of complications can be divided into three categories: technical, biologic, and external. Technical causes include: non-anatomic tunnel placement, improper tensioning and graft fixation, and insufficient graft material. Biologic causes include: failed ligamentization, infection, arthrofibrosis and infra-patellar contracture syndrome. External causes for failure include: traumatic rupture, secondary instability of the knee, and improper rehabilitation[(2)]**.**

Graft failure is defined as pathologic laxity of the reconstructed ACL. Early failures, those that occur within the first 6 months, often are secondary to poor surgical technique, failure of graft incorporation, or errors in rehabilitation. Late failures (>1 year after surgery) are likely related to new trauma and graft tearing. Other complications of ACL reconstruction include roof impingement, postoperative stiffness, tunnel widening due to cyst formation, and infection[(3)].

MRI can provide images with high contrast and spatial resolution, facilitating the recognition of anatomical planes as well as the identification of abnormalities. Also, it is important fact that MRI is a method free from ionizing radiation[(4)]**.** MRI is noninvasive and has multi-planar imaging capabilities that are useful for assessing tunnel positioning and other structures of the knee. It offers the added benefit of direct visualization of the graft with excellent soft tissue contrast[(5)]**.** This research aimed to study the role of MRI in the detection of ACL graft related complications.

Patients & Methods
This Prospective study included 34 patients; 32 males and 2 females who had a reconstructed ACL. This study was done in the period from

August 2018 to October 2019.The patients' age ranged from 17 to 47 years old. Cases were referred from the Orthopedic Department to Radiology Department in Minia university Hospital for MRI assessment. The time interval after the reconstruction will be ranged from 18 - 24 months, where the patients were supposed to finish the rehabilitation and restore their normal activity. Inclusion criteria included: the reconstruction done by arthroscopy or surgery. Knee complaint as: continued joint instability, stiffness, pain, and new injury. Preoperative evaluation for revision of clinically apparent failed ACL graft. Exclusion criteria included: PCL tear, contra-lateral knee injury, any contraindication to MRI examination.

MRI protocol

MRI was done for all patients using 1.5 T Gyroscan Intera (Philips Medical Systems, Netherlands) using knee coil. The examination was done using the following protocol: sagittal proton density–weighted fast spin-echo (FSE): TR/TE 2000–2300/14–18ms. to evaluate Cruciate Ligaments and menisci, coronal gradient-echo to evaluate collateral ligaments, axial T2-weightedspin-echo (SE) sequences: TR/TE 3500–4467/65–70ms. to evaluate patella-femoral space, and sagittal STIR: TR/TE 3600–4100/84–88ms. to detect signal of bone marrow edema or effusion. All sequences will be done by using a 4-mm slice thickness, 256–512x 192–256 matrix size, and 14 cm field of view.

MRI data analysis

I- ACL graft pattern:a- Graft discontinuity: the graft was considered completely torn when no intact fibers were seen and fluid signal was interposed between the torn ends. Partial tear was diagnosed when there was focal graft thinning compared to any detected segment of normal graft diameter[6]**. b- Graft signal intensity (SI):** it was graded on a scale[7]**: g**rade I (normal): similar to PCL intensity, grade II: >50% of the graft having a normal SI, grade III: <50% of the graft having a normal SI, and grade IV: 100% of the graft having an increased SI. **c- Graft orientation:** grafts orientation between femur and tibia were described as normal (taut and parallel), horizontal, or lax[8]**.**

II- ACL graft complications: a- Roof impingement of the graft: it was defined as contact of the graft with the antero-inferior margin of the intercondylar roof. It might be associated with posterior bowing and SI alteration of the graft[3]**. b- Ganglion Cyst**: it was a fluid collection around the graft, either within the femoral tunnel, or tibial tunnel[9]**. c- Arthrofibrosis**: it was defined as the presence of scar tissue in the knee joint. Localized anterior arthrofibrosis, or a cyclops lesion, appears as a well circumscribed nodule of intermediate to low signal intensity in the intercondylar notch just anterior to the tibial insertion of the graft and posterior to the infrapatellar pad of fat[10]**. d- Hardware malposition**

III- Secondary signs of ACL graft tear[11]**: a- Anterior tibial translation:** it was diagnosed when the posterior cortex of mid lateral tibia translated >7 mm anterior to the posterior cortex of the femur.**b- Uncovered posterior horn of lateral meniscus (LM). c- PCL buckling (**posterior concavity of PCL).

IV- Other pathological findings of the knee joint: a- Synovities: mild, moderate, or sever. **b-** Integrity of the following were evaluated and graded as normal, degenerated, or torn[8]: medial and lateral menisci, posterior cruciate ligament, medial and lateral collateral ligaments, quadriceps and patellar tendons.

Statistical analysis

All statistical calculations were done using SPSS version 20. Data were expressed as frequency (number- percent). Correlation analysis was performed using Spearman correlation test. $P < 0.05$ was considered significant.

Results

This study included 34 patients (32 males & 2 females) with their age ranged from 17 to 47 year (mean 29 year). Most cases were presented with knee pain, and besides it, other complaints were presented like history of trauma, instability, limited extension, or palpable mass.

MRI study assessed the following items: the pattern of the ACL graft, presence or absence of

graft impingement, ganglion cyst, arthro-fibrosis, and hardware malposition. Associated pathological findings of the knee were also evaluated.

I- ACL graft pattern

a- Graft tear

Graft tear was the commonest finding (71%) in the included Cases. There were 24 patients with graft tear; 10 had partial tear, 14 had complete tear. Four grafts from the completely torn grafts were not seen as they were resorbed **(table I)**.

Table I: number & percent of ACL graft discontinuity

Graft discontinuity		No. of cases		Percent	
Intact graft		10		29%	
Torn graft	Partial tear	24	10	71%	42%
	complete tear		10		42%
	Complete tear and resorbed		4		17%
		34		100%	

b- Graft SI

The signal of most studied grafts was hyperintense as shown in **table II**. Graft SI was normal or grade II in some cases of complete tear, but increased to grade III or IV in the other complete tear cases and in all partial tear cases.

c- Graft orientation

Regarding graft orientation, lax orientation was the highest detected feature. Normal graft orientation was detected in all intact grafts except in 2 cases where it was lax. Grafts were seen lax in all Partial tear cases, and in 60% of the seen complete torn grafts. Horizontal orientation occurred only when the grafts were completely torn (**Table III**).

Table II: ACL graft SI

Graft discontinuity		SI			
		Grade I	**II**	**III**	**IV**
Intact (10)		6 60%	4 40%		
Partial tear (10)				8 80%	2 20%
complete tear (14)	**Seen (10)**	2 20%	2 20%	6 60%	
	Resorbed (4)				
Total (34)		8	6	14	2

Table III: ACL graft orientation

Graft discontinuity		orientation		
		normal	**lax**	**horizontal**
Intact (10)		8 80%	2 20%	
Partial tear (10)			10 100%	
complete tear (14)	**Seen (10)**		6 60%	4 40%
	Resorbed (4)			
Total (34)		8	18	4

Correlation test between graft discontinuity and other graft patterns There were significant positive correlation between graft SI and discontinuity. Also, the correlation between graft orientation and discontinuity was positively significant **(table IV).**

Table IV: Correlation test between ACL grafts SI or orientation with graft discontinuity

Graft discontinuity	SI		Orientation	
	r	p	r	p
All grafts (intact or torn)	0.717	**0.000***	0.785	**0.000***
Torn grafts (partial or complete)	-.557	**0.011***	0.500	**0.025***

r= correlation coefficient *means significant = P<0.05

II- ACL graft complication:

The MRI study revealed graft complications in 20/34 patients (59%). Graft impingement in 12/34 patients; 10 patients showed anterior placement of tibial tunnel (partially or completely anterior to the slope of the intercondylar notch), while anterior placement of femoral tunnel was seen in 2 patients **(table V)**. Ganglion Cyst around the graft within the tibial tunnel was diagnosed in six of our patients (18%) who complained of pain or palpable masses. Focal Arthrofibrosis (Cyclops lesion) was also seen in four patients who complained of limited degrees of extension. Hardware malposition (loose femoral screw) was seen in 2/34 knees **(table V)**.

Table V: number & percent of ACL graft complication.

Findings	No. of cases	Percent
Impingement	8	24%
Ganglion cyst	2	6%
Impingement & Ganglion cyst	4	12%
Cyclops	4	12%
Hardware malposition	2	6%

The images of impingement or ganglion cyst cases showed increasing in the graft SI, while grafts in the Cyclops or hardware malposition cases showed normal SI **(table VI).** Normal orientation had never seen in impinged graft, but almost seen in cyclops cases. Most ganglion cyst cases associated with lax graft (**Table VII).**

Table VI: ACL graft SI in each graft complication

	Graft SI			
	Grade I	II	III	IV
Impingement (12)			10 (83%)	2 (17%)
Ganglion cyst (6)		2 (33%)	4 (67%)	
Cyclops (4)	4 (100%)			
Hardware malposition (2)	2 (100%)			

Table VII: ACL graft orientation in each complication

	Graft orientation		
	normal	**lax**	**horizontal**
Impingement (12)		10 (83%)	2 (17%)
Ganglion cyst (6)	2 (33%)	4 (67%)	
Cyclops (4)	4 (100%)		
Hardware malposition (2)		2 (100%)	

All impinged grafts were being torn whether partially or complete. Although some patients had intact grafts, they complained due to presence of ganglion cyst or cyclops. Hardware malposition cases had complete torn grafts (**Table VIII).**

Table VIII: ACL graft discontinuity in each graft complication

	Graft discontinuity		
	Intact graft	**Partial tear**	**complete tear**
Impingement (12)		8 (67%)	4 (33%
Ganglion cyst (6)	2 (33%)	4 (67%)	
Cyclops (4)	4 (100%)		
Hardware malposition (2)			2 (100%)

Correlation tests between graft discontinuity and complications

Regarding impingement, its correlation with graft discontinuity was significant: positively when all grafts data were used, and negatively when only torn grafts data were used. There was negative significant correlation between ganglion cyst and torn grafts. Cyclops was significantly and negatively correlated with all grafts discontinuity **(Table IX)**.

Table IX: Correlation test between ACL graft discontinuity & complications

Graft discontinuity	Impingement		Ganglion cyst		Cyclops		Hardware malposition	
	r	**p**	**r**	**p**	**r**	**p**	**r**	**p**
All grafts (Intact or torn)	0.48	0.004*	-0.04	0.82	-0.57	0.000*	0.16	0.36
Torn grafts (Partial or complete)	-0.51	0.01*	-0.53	0.008*			0.26	0.23

r= correlation coefficient ***means significant = P<0.05**

III- Secondary signs of ACL graft tear

The secondary signs of ACL graft tear as anterior tibial translation, uncovered posterior horn of LM, and PCL buckling, were present in some cases **(table X)**.

Table X: Number & percent of secondary signs of ACL graft tear

Findings	No. of cases	Percent
anterior tibial translation & uncovered posterior horn of LM	2	6%
PCL buckling	2	6%
anterior tibial translation & uncovered posterior horn of LM & PCL buckling	8	24%

IV-Other pathological findings of the knee joint:

Table XI: Number & percent of other knee pathological findings

Findings	No. of cases	Percent
Synovities	16	47%
Posterior horn of the MM tear	14	41%
Myxoid degeneration of MM and LM	2	6%
PCL tear	2	6%
MCL sprain	2	6%
Patellar tendonpathy	2	6%

Case presentation

Case No 1:

28 years old male. With History of ACL graft reconstruction 2 years ago, presented with Lt knee pain and instability without history of trauma.

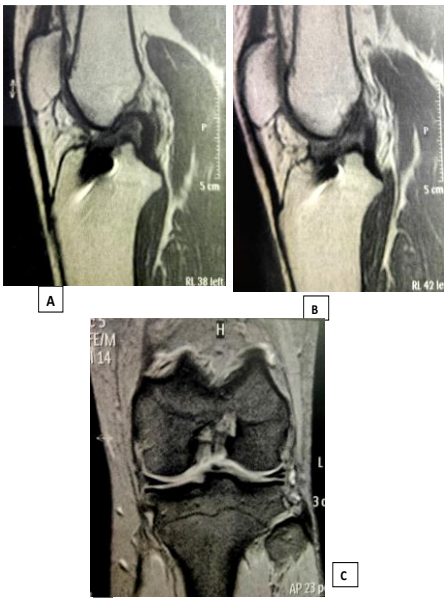

Fig.39: (a) (b) Sagittal PD (c) Coronal GRE MR images in a 28-year-old male show complete tear of ACL graft, with buckling of PCL

Case No 2:

32 years old male with History of ACL graft reconstruction 20 month ago, presented with Rt. knee pain and instability with history of trauma.
one day ago.

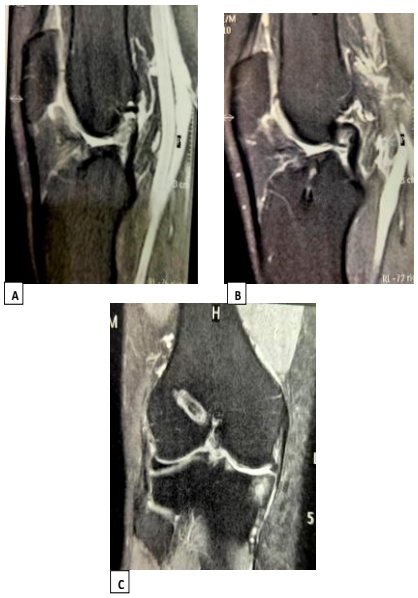

Fig.40: (a) (b) Sagittal PD (c) Coronal GRE MR images show complete tear of ACL graft, buckling of PCL, and moderate joint effusion

Case No 3:

22 years old male. With History of ACL graft reconstruction one year ago, presented with Lt knee pain since 2 weeks without history of trauma.

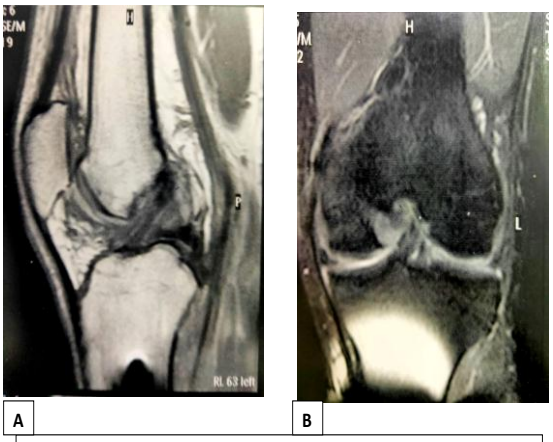

Fig. 41: a) Sagittal PD and (b) Coronal GRE MR images in a show partial disruption of ACL graft, increase SI within the graft

Case No 5:

39 years old male. With History of ACL graft reconstruction 2 years ago, presented with Rt knee pain and palpable mass instability without history of trauma.

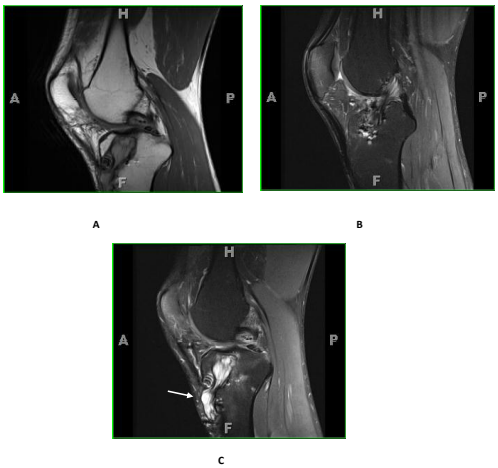

Fig. 43: (a) Sagittal PD (b) Sagittal PD with fat sat. (c) Sagittal STIR MR images show partial tear of ACL graft, ganglion cyst (white arrow)

Case No 6:

36 year old male with History of ACL graft reconstruction 3 years ago, presented with Rt. knee pain and limited extension without history of trauma.

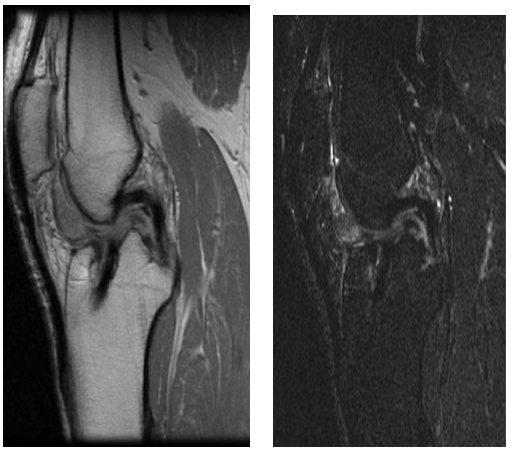

Fig. 44: (a) Sagittal PD (b) Sagittal STIR MR images show intact ACL graft, cyclops

Case No 7:

28 years old male. With History of ACL graft reconstruction 2 years ago, presented with Lt knee pain and and limited extension without history of trauma.

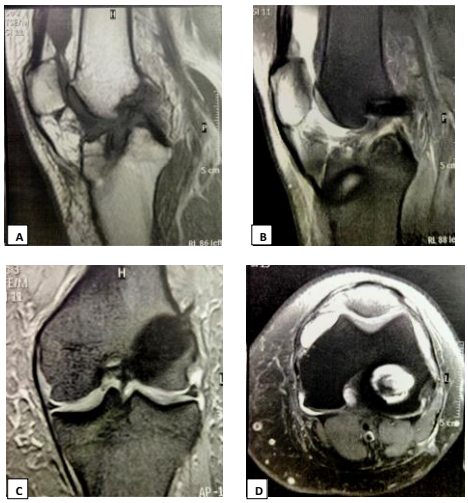

Fig. 45: (a) Sagittal PD (b)) Sagittal PD with fat sat (c) Coronal GRE and (D) axial STIR MR images show partial tear of impinged ACL graft, moderate effusion

Discussion

ACL reconstruction is one of the most common orthopedic surgeries. Although the quality of surgical techniques and fixation materials has improved, the failure after ACL reconstruction may occur[12]. The commonest indications for MR imaging after ACL reconstruction surgery include the inability of ACL graft to maintain the stability of the knee joint, postoperative re-injury to the knee and postoperative stiffness especially extension loss[9].

Jomha et al.,[13], reported that significant traumatic injury was found to be the most common cause of graft rupture and re-operation. In the current study, in spite of presence of graft tear in 24/34 cases by MRI, history of trauma was complained only in some cases of torn grafts (9/24). This may be explained as follow; the Egyptian patients experienced trauma only when it is major, or early aggressive rehabilitation may be a predisposing factor for graft failure. Collins et al.,[9] stated that graft failure manifested clinically as knee instability, as the present study detected.

As in agreement with Papakonstantinou et al.,[14] impingement was mostly resulting in loss of terminal knee extension. Patients with ganglion cyst complained of pain ± mild limitation of movement, and not associated with graft failure or knee instability.

With extension, painful impingement occurs between the cyclops and the intercondylar notch, blocking terminal extension[15]. This is consistent with our results, where our patients had presented with loss of terminal extension of the knee.

Regarding the MRI findings, we considered the graft to be disrupted completely when there was absence of intact fibers, or partially torn when some fibers remain intact in the thin section sagittal and coronal scans[5, 16]. Hyper-intensities within the graft on T2-weighted images that may be equal to the fluid with discontinuity of the fibers and graft thinning or thickening were considered as signs of graft tear either partial or full thickness tear[17]. Partial tears of an ACL graft may appear as areas of increased signal intensity within the graft tissue with some residual intact fibers on T2-weighted images[18]

Graft tear was the commonest finding in the included Cases, and the complete tear was more predominant than partial tear. These results are in accordance with El Adalany et al.,[17], Khedr et al.,[16] and Madeira et al.,[19]. Other researches as Galal et al.,[5], found that partial tear was more frequent than the complete one.

In chronic cases the fibers can be completely resorbed[20], as the detected 4 resorbed grafts in the current study. MR imaging signs of complete ACL disruption include a horizontal graft orientation or laxity and resorption of graft fibers[18].

There were significant positive correlation between graft SI and discontinuity in the present study. In contrary to these results, El Adalany et al.,[17]; Kamel & Darwish[21]; Khedr et al.,[16]; and Min et al.,[22] who stated that the increased signal intensity of the graft was considered as the least reliable sign in the discrimination between intact and torn grafts, or partially and completely torn grafts.

The increased signal intensity of the graft is due to many physiological factors as synovial reaction, edema of the graft, physiological ligamentization, and cellular infiltration and revascularization. These physiological changes might persist up to 18 months following the operation in an intact graft[7]. The time interval after the reconstruction would be ranged from 18 -24 months in our study.

El Adalany et al.,[17]; and Khedr et al.,[16] reported that horizontally oriented graft is considered as a reliable sign of discrimination between intact and torn graft, and also between complete and partial graft tear. ACL graft laxity had low sensitivity and specificity in discriminating graft tear from intact graft. These previous results are concordant with the current study as the horizontal orientation was detected only with complete graft tear, and lax orientation was detected with all grafts whether intact (2 cases because of posterior tibial tunnel malposition), partial torn, or complete torn.

The Grafts in this study were seen lax and hyperintense (grade III or IV) in all Partial tear cases. Partial tears are characterized by increased signal intensity and fiber laxity[20].

Graft impingement was the second cause of graft failure, and most of the impinged grafts showed anterior placement of tibial tunnel. This was in accordance with previous studies[17, 5]. The cause of graft impingement was mostly due to technical fault especially when the tibial tunnel was placed partially or completely anterior to the projected slope of the intercondylar roof[14, 23, 7].

Ganglion Cyst around the graft within the tibial tunnel was diagnosed in 18% of our patients, and this percent was nearly as tunnel cysts percent found by Khedr S. et al.,[16] and Madeira et al.,[19]. Formation of the tunnel cysts after ACL reconstruction has been attributed to several causes; incomplete incorporation of the allograft tissue within the bone tunnel and subsequent tissue necrosis may allow synovial fluid to flow through the tibial tunnel towards the pretibial subcutaneous tissue[16,19].
Hamstring autograft and fixation of the graft with endobuttons (soft tissue graft with insecure fixation) may predispose to cystic degeneration[5].

Cyclops lesion is a fibroproliferative scar nodule which was seen around grafts with normal SI. It develops after ACL reconstruction using all types of grafts. It can be caused by a residual ACL stump, residual bony or cartilage debris, and hypertrophy of graft fibers[24]. It is most commonly located anterolateral to the tibial Tunnel[10] anterior to the distal segment of the ACL graft above the tibial plateau[16].

El Adalany et al.,[17], Khedr et al.,[16], and Galal et al.,[5], found that the incidence of Cyclops was low, and this was approved in our research. In recent years the incidence of this complication is noted to be relatively low compared to the early days when ACL reconstruction was first performed, presumably due to the developed techniques and skills of the surgeons with less manipulations and invasiveness of the technique, and consequently less fibrous tissue and inflammatory reaction around the grafted ACL[10].

Increased signal intensity of the graft is considered as a highly sensitive sign in the detection of impingement[17]. This was in agreement with our research, as all impinged grafts had high SI. The intra-articular portion of the impinged graft showed abnormal morphology with increased signal intensity on T1 and T2 weighted images[5].

All impinged grafts were being torn whether partially or complete in this study, and these results are in accordance with Meyer et al.,[6]

who reported that the Partial tears may be seen in chronically impinged grafts. These previous results are against what El Adalany et al.,[17] found, as all impinged grafts were intact in their research. This controversy because of the anterior placement of tibial tunnels in most our cases. When the tibial tunnel was placed partially or completely anterior to the projected slope of the intercondylar roof in the extended knee, it caused the distal half of the roof to impinge the anterior surface of the graft during knee extension resulting in loss of terminal knee extension and a likehood of graft rupture[17].

There was negative significant correlation between ganglion cyst and torn grafts, and this is in agreement with Papakonstantinou et al.,[14]; Galal A. et al.,[5], who stated that on MRI the graft appeared intact with some fibers seen splayed apart around loculated fluid intensity (ganglion cyst) and significant tunnel enlargement was noted.

Secondary signs of ACL graft tear in this study showed that anterior tibial translation and uncovered posterior horn of LM were better signs than other secondary signs in discriminating not only torn from intact graft but also complete from partial torn graft. PCL buckling is insignificant in discriminating torn from intact grafts because of its presence with some intact grafts. These findings are concordant with Khedr S. et al.,[16], who suggested that anterior tibial translation and uncovered posterior horn of LM was helpful in predicting graft tear, while other secondary signs were of little values in diagnosis of ACL graft tear.

Limitation in this study included small number of cases and lack of clinical scoring. Correlation with arthroscopy could not be done as it was not indicated in most cases. Types of fixation or grafts and their relations to the incidence of graft complications were not mentioned, as the operation was done several months ago.

Lastly we concluded that MRI represents an important tool for assessment of the complication following ACL graft reconstruction. The most frequent complication was Graft tear, even without history of trauma. Increased graft SI and abnormal graft orientation is very helpful in diagnosis of graft tear. Horizontal orientation may be considered a reliable sign for diagnosing complete graft tear as it occurred only when the grafts were completely torn. Graft impingement is the second common complication, and it is mostly due to anterior placement of the tibial tunnel. Impingement is frequently associated with partial tear.

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