INTRODUCTION

Approximately 70% of ACL injuries occur through noncontact mechanisms. Patients experience giving way of the knee when attempting to rapidly change direction. This involves deceleration, coupled with a cutting, pivoting, or sidestepping maneuver. The remainders of cases tend to occur through direct contact and often are associated with other ligament injury ***(Maguire & Cross, 2012).***

Surgical treatment and techniques for ligamentous injuries of the knee have improved significantly. Currently, arthroscopic reconstruction of the ACL with autogenous graft materials widely used for patients with anterior knee instability ***(Papakonstantinou et al., 2003).***

Imaging Studies includes Plain radiographs which are usually negative, Arthrograms which have generally been replaced by Magnetic resonance imaging (MRI) which has a sensitivity of 90-98% for ACL tears ***(Pittman, 2013)***.

Clinical evaluation and conventional radiography are used in routine follow-up after ACL reconstruction. However, as clinical manifestations of graft complications are often non specific, and plain radiographs cannot directly visualize the graft and the adjacent soft tissues, an important tool in the diagnosis of complications after ACL reconstruction has been magnetic resonance imaging which offers excellent soft tissue contrast and spatial resolution ***(Almekinders et al., 2008).***

The most commonly reconstructed ligament in the knee is the ACL. Clinical evaluation of ACL reconstructions can be difficult, and MR imaging plays an important role in evaluating the integrity of the ACL graft, as well as in diagnosing complications associated with ACL reconstruction ***(Recht and Kramer, 2012).***

AIM OF THE WORK

The aim of this work is to determine the value of magnetic resonance imaging in assessing instability after anterior cruciate ligament reconstructive surgery in males.

Chapter 1

ANATOMY

The knee, a hinge-type joint, is primarily composed of three articulating compartments: patellofemoral, medial femorotibial, and lateral femorotibial. A combination of muscles, tendons, ligaments, and extensions of the joint capsule collectively help to offer multidirectional stability to the knee. Numerous bursae about the knee allow for ease of motion of the stabilizing structures in relation to one another (fig.1) ***(Vohra et al., 2011)*.**

1- Compartments:

The medial femorotibial compartment is formed by the medial femoral condyle and medial tibial plateau articulation, and houses the medial meniscus and articular cartilage. Major medial stabilizers include the deep (coronary ligaments) and superficial portions of the medial collateral ligament (MCL), medial tendons (sartorius, gracilis, semitendinosus, and semimembranosus), and deep crural fascia of vastusmedialis, which helps to form the medial patellar retinaculum anteriorly. Posteriorly, the deep portion of the MCL, with contributing fibers from the semimembranosus tendon and synovial sheath, form the posterior oblique ligament, a major stabilizer of the posteromedial knee ***(De Smet, 2012).***

The lateral femorotibial compartment is formed by the lateral femoral condyle and lateral tibial plateau articulation, and houses the lateral meniscus and articular cartilage. The anterolateral joint is stabilized by the joint capsule and the iliotibial tract, which inserts on Gerdy's tubercle along the anterolateral tibia, and is a fascial extension of the tensor fascia lata ***(Vohra et al., 2011).***

The posterolateral corner is a complex anatomic area providing stabilization, achieved by several structures including the fibular (lateral) collateral ligament (FCL), biceps femoris tendon, popliteus muscle and tendon, popliteal fibular and popliteal meniscal ligaments, oblique popliteal, arcuate, and fabellofibular ligaments, and lateral gastrocnemius muscle ***(Vohra et al., 2011).***

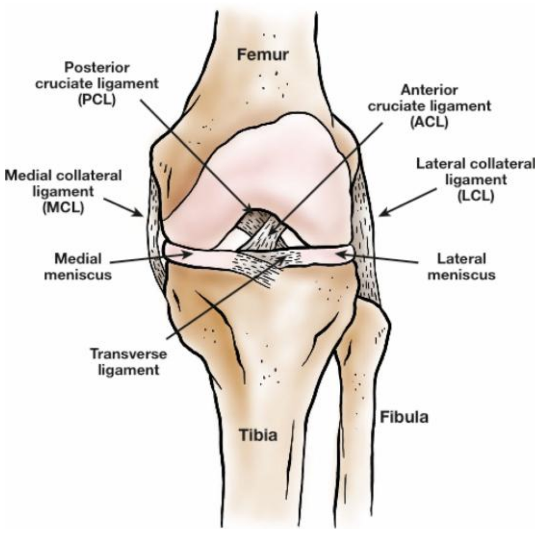

Figure (1): Anatomy of the knee joint anterior view: The knee meniscus is situated between the femur and the tibia. Crossing the meniscus are various ligaments, which aid in stabilizing the knee joint **Quoted fr*om* *(Vohra et al., 2011)*.**

2- Menisci:

The menisci are wedge-shaped in cross-section. They are attached to the joint capsule at their convex peripheral rims and to the tibia anteriorly and posteriorly by insertional ligaments. The medial meniscus covers around 60% of the articulating surface of the medial compartment and the lateral meniscus 80% of the lateral compartment (fig.2) ***(Getgood & Robertson, 2010).***

The main stabilizing ligaments are the medial collateral ligament, the transverse ligament, the meniscofemoral ligaments, and attachments at the anterior and posterior horns ***(Makris et al., 2011)*****.**

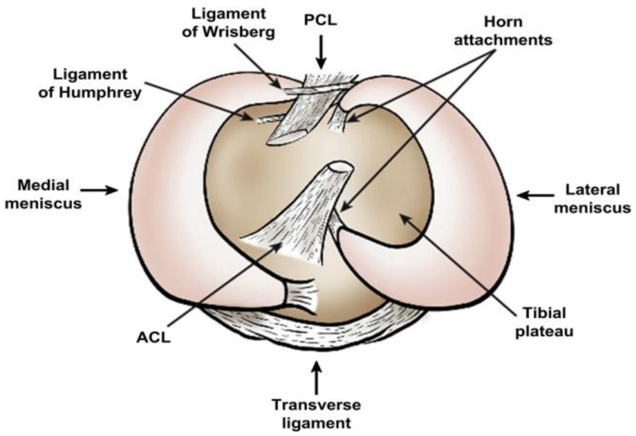

Figure (2): Anatomy of the menisci: superior view of the tibial plateau. This view of the tibial plateau highlights the ligaments of Humphrey and Wrisberg, which attach the meniscus to the femur. The menisci are attached to each other via the transverse ligament ***(Makris et al., 2011***).

A- Meniscal Ligaments:

Both menisci have firm attachments to the tibial surface at their anterior and posterior horns via the insertional ligaments. Anteriorly, the transverse meniscal ligament connects one meniscus to the other, posteriorly, the major attachments of the posterior horn of the lateral meniscus are the meniscofemoral ligaments with the Humphry ligament anterior to the posterior cruciate ligament (PCL) and the Wrisberg ligament posteriorly(fig3) ***(Makris et al., 2011).***

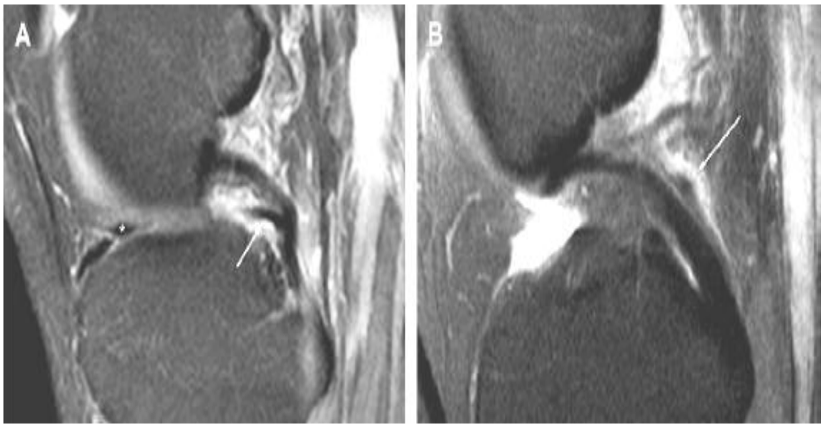

Figure (3): (A) Sagittal gradient echo image of the ligament of Humphrey located anterior to the PCL (arrow). Also noted is the anterior or transverse intermeniscal ligament (asterisk). (B) Sagittal fast spin-echo (FSE) fat-saturated proton density–weighted image of the ligament of Wrisberg, located posterior to the PCL (arrow) ***(Makris et al., 2011)***.

B- Meniscal Horns:

The meniscal roots, including the anterior horn of medial meniscus (AHMM), the posterior horn of medial meniscus (PHMM), the anterior horn of lateral meniscus (AHLM), and the posteriorhorn of lateral meniscus (PHLM), are defined anatomically as the portions of the menisci that attach to the central tibial plateau ***(Jones et al., 2010).***

3- Ligaments:

1- Anterior Cruciate Ligament:

The anterior cruciate ligament, an intracapsular extrasynovial structure with a synovial envelope, is the main stabilizer of the knee for pivotal activities. The intra articular length of the anterior cruciate ligament is between 28 and 31 mm **.**

The proximal attachment of the anterior cruciate ligament is at these micircular fossa on theposteromedial aspect of the lateralfemoral condoyle. At the distal attachment, theligament fans out under the intercondylar roof and the transverseligament to insert into the tibial spines between the lateral and medial menisci ***(Johnson, 2013).***

Normal appearance of ACL graft in MRI:

Graft Signal

An ACL graft varies in signal as it matures. Early postoperative imaging shows a hypointense graft on all pulse sequences. During the remodeling period, the graft undergoes revascularization and resynovialization, which results in increased signal intensity ***(fig.4) (Casagranda, 2014)***.

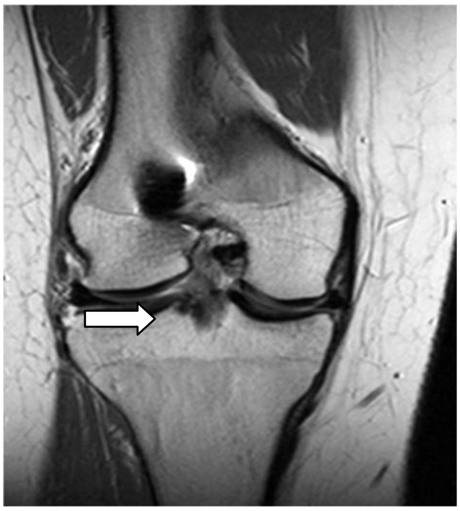

Figure (4): 13-year-old girl who presented for routine orthopedic follow-up 3 months after ACL reconstruction using BPTB graft using patellar tendon allograft. Coronal MR image shows continuity of graft fibers. There is high-signal-intensity edema in graft. This is a normal finding during remodeling phase, which occurs between 4 and 8months after surgery ***Quoted from (Casagranda 2014).***

Graft Integrity

Apart from incorrect tunnel placement, one of the most common causes of ACL reconstruction failure is a new injury. A new disruption of the reconstructed ligament appears on MRI as increased signal intensity in the T2 sequence within the graft body ***(Waltz et al., 2016).***

Tunnel Position

The correct positioning of the femoral and tibia tunnel represents a key technical step for the success of ACL reconstruction surgery. The MRI provides important information about those aspects, especially regarding the graft inclination.

Sagittal plane position (fig 5):

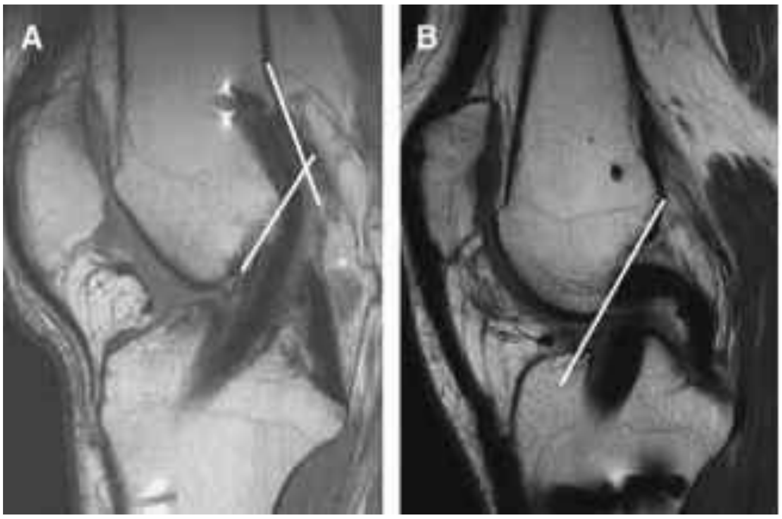

Figure (5): Sagittal proton density MR images (TR/TE, 2200/15) demonstrating the optimal positions for the femoral (A) and tibial (B) tunnels. The femoral tunnel is located at the intersection of the posterior femoral cortex and the roof of the intercondylar notch (A). The tibial tunnel lies completely posterior to Blumensaat's line (B) ***(Quoted from Ladvas et al., 2012).***

On the sagittal plane of the MRI the front border of the tibial tunnel should be localized behind a line that is tangential to the **Blumensaat line** (which is the line tangential to the intercondylar roof), without going beyond the midpoint of the proximal tibia with the knee in full extension.

If the tunnel is too forward, the risk of impingement of the graft with the intercondylar notch increases, possibly causing extension deficit or a Cyclops lesion, while a tunnel too posterior could lead to a vertical graft responsible of an incomplete control of knee antero-posterior and rotatory stability ***(Lee et al., 2012).***

A controversial matter of debate is the correct positioning of the femoral tunnel. Despite the fact that the most accurate evaluation is obtained through arthroscopy, MRI could be helpful to identify gross malpositioning. It is generally accepted that the femoral tunnel should be located at the intersection of the posterior femoral cortex and the lateral wall of the intercondylar notch ***(Tomczak et al., 2010*****).**

Coronal plane position (fig.6):

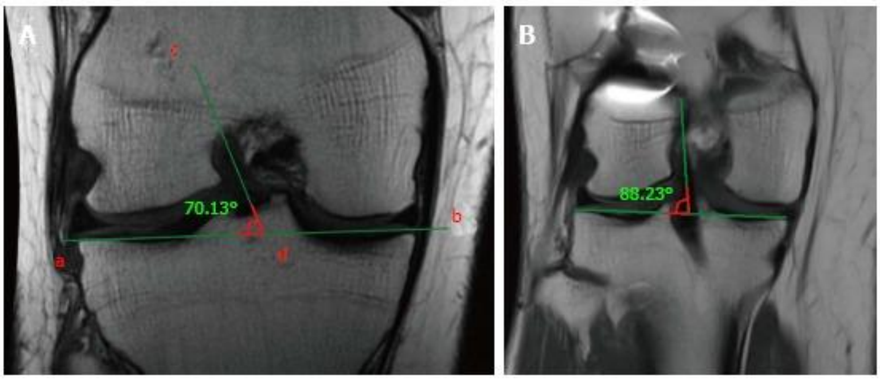

Figure (6): Coronal MRI images showing the correct position of both tibial and femoral tunnels of the ACL graft ***(Quoted from Ladvas et al., 2012).***

Similarly, on the coronal plane, the graft inclination should be less than 75°, as an excessively vertical graft sub-optimally controls rotatory laxity compared with a more horizontally placed graft **.**Usually, the coronal position of the tibial tunnel entrance does not represent an issue in the MRI evaluation after ACL reconstruction, as it is generally in the correct position under the femoral notch in the vast majority of the cases***(Tomczak et al., 2010*****)**.

2- Posterior Cruciate Ligament (Fig.7):

The PCL is larger and stronger than the ACL. The femoral attachment is along the medial side and medial roof of the intercondylar notch. The PCL can be divided into two functional bundles, the anterolateral bundle (ALB) and the posteromedial bundle (PMB).The bundles are named based on the location of their femoral attachments. The two bundles maintain their anterior and posterior locations during motion of the knee and do not rotate around each other as is seen with the bundles of the ACL.

On MRI with the knee in an extended position, the normal PCL is seen as a broad band of low T1- and T2-weighted signal, near the midline of the knee, extending from the femoral intercondylar notch to the posterior tibial plateau. On sagittal images with the knee extended, the PCL has a gently curved configuration. Although the PCL is slack in the fully extended position, the PMB is relatively taut, compared with the ALB ***(fig.7) (Carson et al., 2014).***

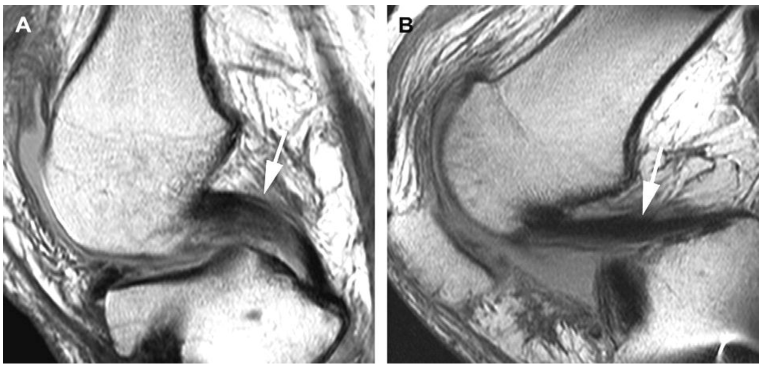

Figure (7): Normal PCL on sagittal proton density MR imaging in extension and flexion. (A) Extension. PCL (arrow) is bowed normally, reflecting its laxity as the posterolateral corner is taut. (B) Flexion (arrow). PCL is taut and provides most posterolateral rotatory stability when posterolateral corner structures are lax ***Quoted from (Carson et al., 2014)***.

3- Medial Collateral Ligament (Fig.8):

The MCL is part of a three-layer complex. Layer 1 is composed of the deep crural fascia, Layer 2 is the superficial part of the MCL, Layer 3 is the deep part of the MCL, which attaches just anterior and distal to the attachment of the superficial MCL **.**

The MCL also referred to as the tibial collateral ligament (TCL), is divided into two main components: the superficial MCL (sMCL) and deep MCL (dMCL) ***(Schein et al., 2012).***

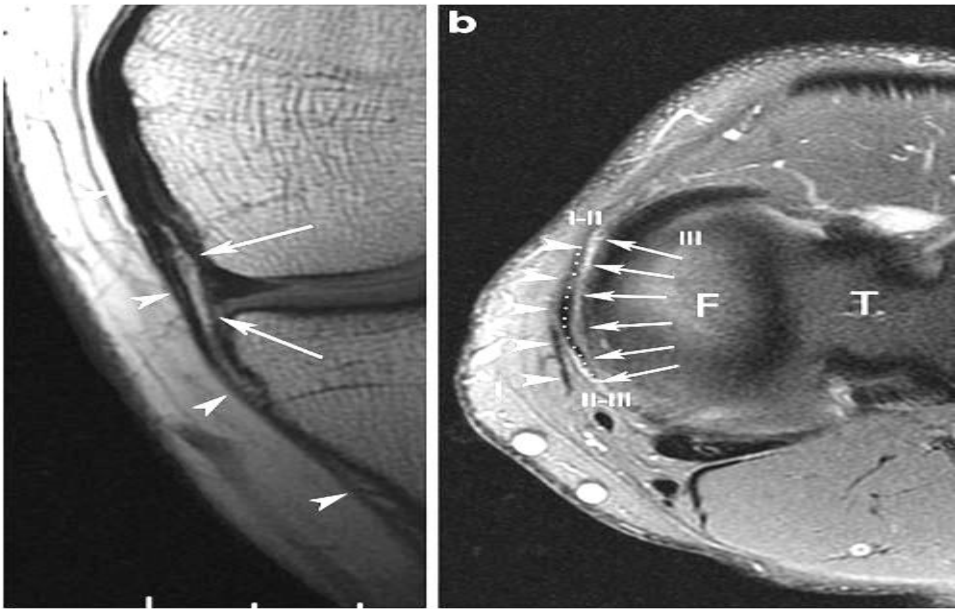

Figure (8): Normal MCL anatomy. a Coronal T1-weighted image. The sMCL courses from its femoral attachment at the medial epicondyle to its proximal and distal tibial attachments (arrowheads). The dMCL (arrows). b Axial proton density fat saturated image. the deep crural fascia (arrowheads), while (dotted line) contains the sMCL and (arrows) contains the dMCL ***(Schein et al., 2012)***.

4- Lateral Supporting Structures Including Lateral Collateral Ligament (LCL):

The LCL arises from the lateral condyle of the femur and attaches to the lateral side of the head of the fibula. Its deep surface has no attachment to the lateral meniscus (fig.9) ***(Dirim et al., 2008).***

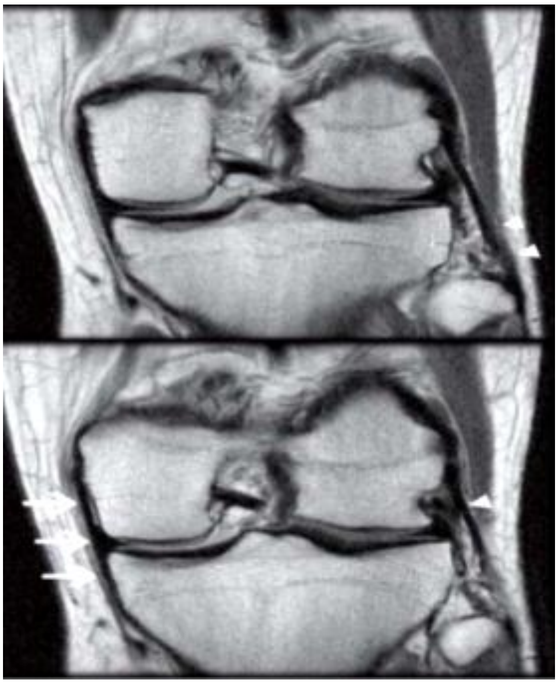

Figure (9): Coronal proton density images of the knee show a normal lateral collateral ligament (LCL) seen passing across successive images from the lateral femoral condyle to the head of the fibula (white arrowheads). The normal medial collateral ligament (MCL) (white arrows) ***Quoted from (Dirim et al., 2008).***

Tendons:

The quadriceps tendon is formed by the confluence of tendon from the 3 vastus muscles and the rectus femoris ***(Dirim et al., 2008).***

The infrapatellar tendon is a thickened band of fibrocartilaginous tissue arising from the anterior surface of the non-articulating inferior pole of the patella. It inserts proximally onto the anterior lip of the tibia and distally on the tibial tubercle (fig.10) ***(Peace et al., 2006).***

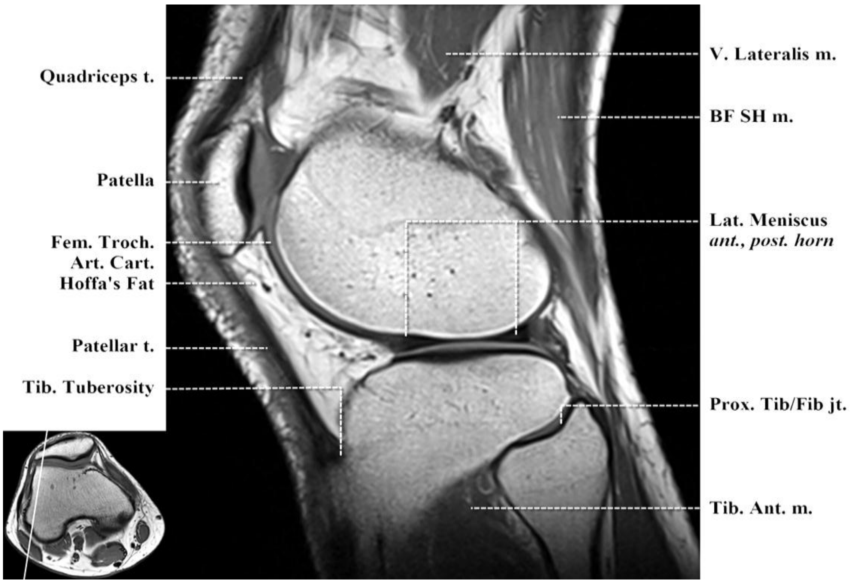

Figure (10): Sagittal T1-weighted image. Lateral femorotibial compartment. ant., anterior; Art.Cart., articular cartilage; BF SH, biceps femoris short head; Fem. Troch., femoral trochlear; m., muscle; Lat., lateral; post., posterior; Prox. Tib/Fib jt., proximal tibiofibular joint; Tib., tibia; Tib. Ant., tibialis anterior; t., tendon; V., vastus ***Quoted from (Vohra et al., 2011)***.