(iii) Anterior cruciate ligament reconstruction — evolution and current concepts

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Abstract

Since the early 20th century, the considerable evolution of anterior cruciate ligament reconstruction has been an essential impetus for our understanding of knee anatomy and biomechanics, and their relation to function, injury and rehabilitation. Traditional use of non-anatomic intra- and extra-articular reconstructions has moved to an emphasis on restoring anatomy and native knee kinematics whilst preserving biology. With new evidence and technology, old concepts such as ACL repair and lateral procedures are being revisited with a fresh perspective in an attempt to restore normal knee function. Every aspect of the technique is a source of constant innovation with new concepts and controversy. This review describes the key milestones of this evolution then provides an appraisal overview of current concepts and the rationale for variations in technique.

Keywords anatomic; anterior; cruciate; fixation; graft

Introduction

Anterior cruciate ligament (ACL) injuries are one of the most common knee injuries, with an annual incidence of 100 000 –200 000 in the US.[1] Non-surgical management of this injury may be appropriate in certain instances; however, it is widely accepted that for symptomatic instability an ACL reconstruction is critical for the prevention of secondary injury and long-term morbidity.

The goals of ACL reconstruction (ACLR) are to stabilize the knee joint, restore normal kinematics and prevent early onset degenerative arthrosis. Unfortunately, despite extensive anatomical, biomechanical and clinical research, this has not yet enabled us to fully restore normal knee function. However, this has led to constant improvements in our understanding with regards to ACLR over the last 30 years, which in turn has yielded significant improvements in the clinical outcomes following ACL injury. ACLR continues to dominate both the literature and clinical forums in the field of soft-tissue knee surgery. A recent PubMed search for ‘anterior’ ‘cruciate’ ‘ligament’ revealed over 14 000 results, with 1050 in 2013 alone. However, a recent meta-analysis concluded that the majority of the evidence is below Level II and must be considered carefully.[2]

Advances have come largely from a better understanding of ACL anatomy; in particular, the anteromedial (AM) and posterolateral (PL) bundles, their inherent anisometry, the morphology of their bony insertions and how these relate to surrounding structures.[3–5] Historically, reconstructions placed a bone-patellar tendon-bone (BPTB) graft in a non-anatomic, isometric position, high and deep in the notch outside of the femoral footprint. Biomechanical and clinical studies observed a lack of rotational control and persistent pivot-shift, leading surgeons to re-examine the anatomy and the unaddressed role of the PL bundle. This prompted the advent of anatomic double-bundle (DB) and mid-bundle ACLR.[6]

More recently, the importance of the lateral side of the knee has also been revisited, with the possibility of an anatomic reconstruction of the ‘anterolateral’ ligament replacing traditional tenodesis procedures. The biological and mechanical advantages of ACL remnant preservation have also been highlighted in the context of complete and partial rupture.[7]

Here, we present an overview of the current concepts in ACLR, focussing on anatomy, graft selection, tunnel position, fixation and control of rotational stability.

Evolution

At the dawn of the 20th century, operative treatment of ACL rupture focused on direct repair. The first ACL reconstruction used tensor fascia lata autograft and was performed in 1912 by Giertz. In 1917, Hey-Groves attempted to reconstitute the anatomy of the ACL, drilling inside-out in an open procedure. In 1938, Palmer proposed the idea of double-bundle reconstruction in his thesis on the ACL, but this was widely unaccepted at the time.[6]

Up until the mid-1970s, the diagnosis of ACL injury was difficult to elicit and relied on discernable laxity at 90° of flexion with the foot in varying degrees of rotation. Naturally, this did not identify isolated ACL injuries and only tended to be positive when other ligamentous or meniscal structures were damaged. Classic studies, such as those of Girgis et al.,[3] described the relationship between knee laxity and flexion angle as well as identifying the ACL’s role in controlling tibial rotation. Such

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biomechanical awareness led to descriptions of the 'pivot shift' (Galway et al. 1972) and later the 'Lachman Test' (Torg et al. 1976). The need to control rotation and the difficulty of intra-articular reconstruction led to a series of extra-articular lateral procedures being described. Pioneered by Strickler (1937) initially, then by Lemaire (1960) and MacIntosh (1970s), these used a lateral tenodesis to control anterolateral tibial subluxation. However, these procedures in isolation resulted in residual instability and subsequent early degenerative change.[8] This failure directed attention towards intra-articular reconstruction of the ACL.

The 1980s saw the uptake of arthroscopy as both a diagnostic tool and an adjunct to open ACLR. Transtibial drilling of tunnels/sockets was the 'gold-standard' throughout the 1980s and 1990s. This technique produced a reconstruction that resisted anterior tibial displacement relatively well but with only limited rotational stability.[9] Initial wire fixation of the bone plugs was replaced with interference screws.

In the early 21st century, studies noted that up to 25% of patients had a persistent pivot shift following transtibial ACLR, going on to develop secondary meniscal and chondral injuries which are likely to propagate to degenerative arthrosis.[10] Up until now, a 'non-anatomic' isometric position was sought after on the femur, as one graft had to resist tibial translation at all flexion angles. This leads to the function of the PL bundle being considered and the concept of anatomical DB-ACLR being defined by Yasuda et al., 2004.[11] This technique has gained popularity over the last decade, due to a perceived improvement in reproduction of anatomy and rotational stability when compared to traditional ACLR.[6,12,13] However, 'anatomic' placement of single bundle (SB) ACLR in a more oblique position, 'down the clock face' and within the femoral footprint, has been more widely accepted. There is a general consensus in the literature that both of these 'anatomic' techniques more closely restore normal knee kinematics than the traditional 'over the top' technique. However, given the complexity of DB reconstruction, 'anatomic' SB — ACLR is now considered the new gold standard by many.[6]

At present, no ACLR technique restores normal anatomy, kinematics and function to the knee. Whilst there is consensus on the indications for ACLR, controversy persists surrounding the optimal reconstructive technique; tunnel placement, graft selection and fixation method.

Anatomy

The ACL is an intra-articular but extra-synovial structure with a blood supply predominantly from the middle genicular artery, arising from the poplitaeal artery. A functional native ACL provides proprioceptive feedback that is protective to the knee but which is lost, at least in the short term, following reconstruction. The ACL has a mean length of 31—38 mm and width of 11 mm. It is a strong structure with a mean tensile strength of 2150 N and stiffness of 242 Nmm^{-2}.[3]

The ACL originates from the medial border of the lateral femoral condyle and inserts in proximity to the tibial spines. It does not function as a simple tube of fibres with a constant tension, but rather consists of fibre groups that are subjected to episodes of lengthening and slackening throughout the range of motion; i.e. it is anisometric. This has advocated the functional subdivision of the ACL into an AM and a PL bundle, named according to their relative insertions on the tibia. The AM bundle is tighter with the knee in flexion and the PL tighter in extension (Figure 1). However, the description of two bundles may be somewhat of an oversimplification, and current anatomical studies suggest a ribbon-like structure that inserts as a 'C'-shape onto the tibia.[14] This 'ribbon' is not separated into two distinct bundles in the proximal half of the ACL.[15]

In addition to the ACL, it is now evident that other structures provide significant rotational stability. This concept has recently been revisited by Claes et al[16] describing a well-defined ligamentous structure clearly distinguishable from the anterolateral capsule and the iliotibial band: the anterolateral ligament (ALL).

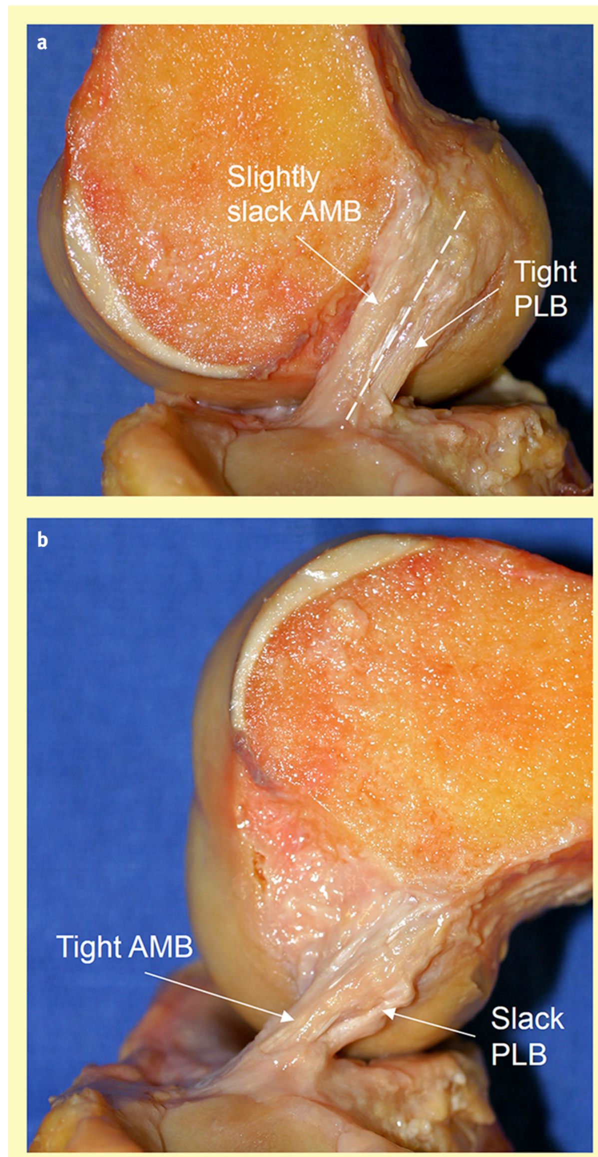

Figure 1 Lateral view of the native ACL depicting the nominally divided anteromedial (AMB) and posterolateral (PLB) bundles. (**a**) The PLB is tight whilst the AMB is slightly slack in extension. (**b**) The AMB is tight whilst the PLB is slack during flexion. *Images courtesy of Dr Charles Brown, Abu Dhabi Knee & Sports Medicine Centre*.