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Anterior cruciate ligament fixation devices: Expected imaging appearance and common complications

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ABSTRACT

Anterior cruciate ligament reconstruction is a commonly performed orthopaedic procedure which has increased in frequency over the past decade. There are a variety of fixation devices used to secure grafts within the femoral and tibial tunnels during the reconstruction procedure. An understanding of the expected appearance of the varied hardware utilized for reconstruction graft fixation, and their potential complications is important in the review of post-operative imaging. We describe the most common anterior cruciate ligament reconstruction fixation devices and illustrate their more frequently documented abnormalities.

1. Introduction

Disruption of the anterior cruciate ligament (ACL) is one of the most common injuries resulting in surgical intervention [1]. The rate of surgical reconstruction for ACL disruption is on the rise. Buller et al. estimated a 37% increase in ACL reconstructions performed annually when comparing data from 1994 (87,000 procedures) with 2006 (134,000 procedures) [1]. As the frequency of ACL reconstruction has increased, so has the varied available surgical fixation devices to secure the graft [2].

Clinically, ACL graft reconstruction failure is defined as continued pain, stiffness, or instability following placement and can be related to multiple underlying causes [3]. The failure load of an ACL reconstruction is the force in Newtons the bone-graft-fixation device complex can endure without pulling out [3]. Stiffness refers to the force in Newtons per millimeter required to displace or stretch the complex [4]. Both failure load and stiffness are influenced by the ACL fixation devices utilized during reconstruction, with the fixation site considered the weakest link of the ACL reconstruction in the immediate post-operative period [5].

There are a wide range of graft fixation devices which the radiologist will likely encounter, each with a unique relationship to the graft and native bone. An understanding of these devices, their expected imaging appearance, and their complications is necessary for evaluation of the knee following ACL graft reconstruction.

2. Anterior cruciate ligament reconstruction procedure

The native ACL is composed of two bundles named for their tibial attachments – anteromedial and posterolateral – both of which contribute to rotary and anterior knee stability [6–8]. The anteromedial bundle is taut throughout the range of flexion, while the posterolateral bundle is taut with full extension [6,8] (Fig. 1). A healthy ACL requires over 2100 N of force to rupture, with most activities of daily living falling below 454 N [9,10].

Although a double bundle reconstruction more closely simulates the native anatomy of the ACL when compared to a single bundle procedure, clinical outcomes appear similar [2,8]. As such, ACL reconstruction is most commonly performed today using a single bundle technique, requiring only a single femoral and tibial tunnel [8,11]. The graft is composed of either autologous (from the patient) or allograft (cadaveric) tissue [2,12,13]. Autografts are preferred for initial reconstruction, when available and accessible, as studies have demonstrated superior outcome versus allografts [13,14]. The graft is typically harvested as either a bone-patellar tendon-bone graft (BTB), with a component of the patellar tendon flanked by patellar and tibial bone

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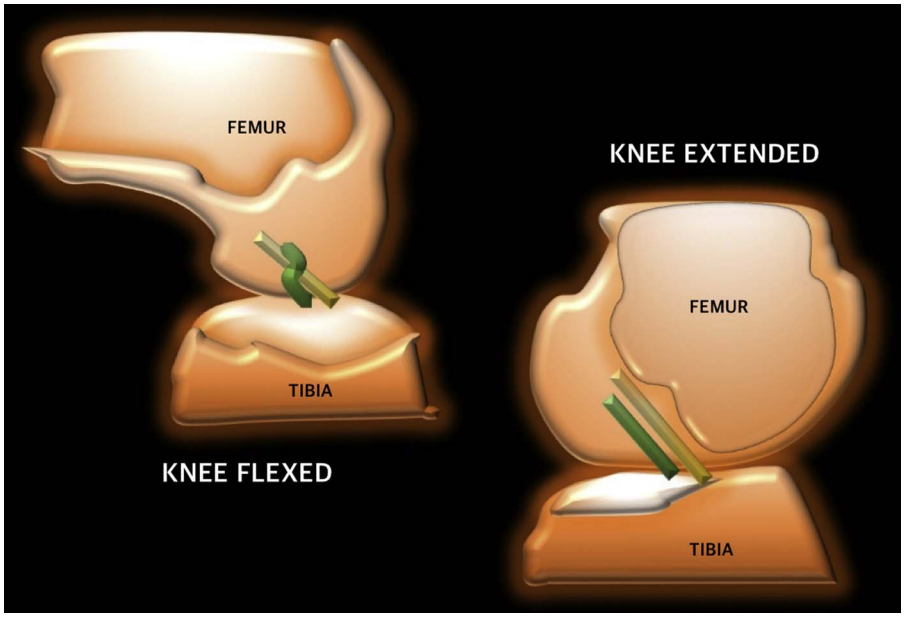

Fig. 1. Sagittal diagrammatic depiction of the knee from flexion through full extension demonstrating the anteromedial bundle (yellow) of the anterior cruciate ligament taut throughout the entire range of knee flexion, while the posterolateral bundle (green) becomes taut at full extension. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

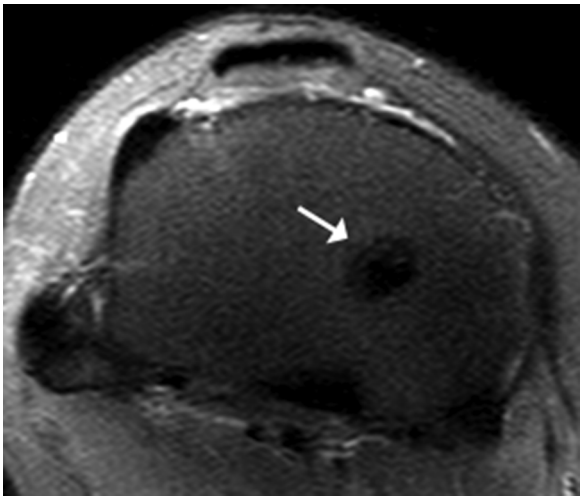

Fig. 2. Fully incorporated hamstring autograft. 41-year-old woman status post anterior cruciate ligament reconstruction with right knee pain. Axial short tau inversion recovery image demonstrates a fully incorporated hamstring autograft with bone marrow signal merging directly with the graft (arrow).

blocks at each end, or a four-strand hamstring soft tissue graft (ST), which is comprised of the semitendinosus and/or gracilis tendons folded upon themselves [2,7–13,15]. The graft harvest site choice is based on surgeon preference and patient factors [14].

Fixation tunnels in the femur and tibia attempt to mimic native ACL attachments [7,8,12,13]. Although there is controversy about ACL tunnel placement, the goal is to best recreate the anatomic femoral attachment on the lateral femoral condyle. The optimal femoral tunnel confers isometry, or the ability of the graft to remain taut through the full range of motion [12]. Improper femoral tunnel position commonly leads to non-traumatic ACL reconstruction failure [13]. Improper tibial tunnel location is present in nearly a third of technical failures [13], largely related to the untoward outcome of femoral roof impingement on the graft [7,12]. The tibial tunnel should be located at the anatomic tibial attachment at the intercondylar eminence [7,8]. At one month following graft placement, about one-third of knees will demonstrate increased signal within the osseous tunnels on fluid sensitive magnetic resonance images (MRI). If proper incorporation occurs, this signal dissipates with time as native bone-graft integration transpires [16] (Fig. 2).

3. Fixation devices

There are numerous options available to the surgeon for fixation of the ACL graft. The variety of devices allow the surgeon to optimize fixation based on factors such as the graft material used (BTB versus ST) or bone density – for instance, cancellous bone in the tibia is softer than the femur, limiting fixation strength [17].

3.1. Classifications

The classification of ACL graft fixation devices is somewhat convoluted in the surgical literature. Original graft fixation devices included screw and washer posts, staples, and sutures tied directly to bone [18]. A series of newer devices have since been devised, many of which share similarities with regard to placement about the osseous tunnel, their relation to the joint line, and their mechanism of fixation.

Fay summarizes the newer, more commonly used ACL fixation devices into interference, suspensory, or transtunnel fixation [18]. Others divide the devices into two categories: intratunnel aperture fixation (eg, interference screw or cross pin) versus extra-articular fixation (eg, cortical fixation suspension devices). Hybrid fixation refers to the use of both intratunnel aperture fixation and extra-articular suspension devices, advocated by some at the tibia to provide stronger initial fixation [19,20]. Intratunnel aperture fixation is also referred to as anatomical or joint line fixation, based on the devices proximity to the joint line. Extra-articular fixation is also referred to as non-anatomical fixation.