Sports Tips & Tricks: Technical Evaluation of ACL Graft Dimensions: Staying out of Trouble

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Background

The anterior cruciate ligament (ACL) is approximately 30mm long and 10mm wide.[1] It consists of two bundles, anteromedial (AM) and posterolateral (PL), which contribute in varying degrees to knee stability.With the knee extended, the PL bundle is tightened and the AM bundle is lax; as the knee is flexed, the AM bundle tightens and the PL bundle relaxes. Consequently, the PL bundle plays an important role in rotational stability in extension. Proximally, the ACL originates from the posteromedial surface of the lateral femoral condyle and inserts distally on the anterior aspect of the tibial plateau.

Today, ACL rupture is usually treated surgically, most commonly in young patients with bone-patellar tendon-bone (BPTB) or hamstring tendon (HT) autograft. While bone to bone healing remains the gold standard in ACL reconstruction, there are several postoperative disadvantages of the BPTB graft, including anterior knee pain, quadriceps weakness, possible patella fracture, patellar tendon rupture, and infrapatellar contracture.[1,2] During the last decade, there has been an increased use of HT grafts due to the lower rate of postoperative morbidity with fewer donor-site complications. While the quadrupled graft has been shown to have a higher load to failure compared with the BPTB,[3] there are also several concerns with the use of HT grafts: failure to achieve immediate rigid fixation to bone (slower than BPTB),[4] lower stiffness compared with the BPTB graft or the native ACL, risk of increased laxity at medium- to long-term follow-up, tunnel widening, weakness of the hamstring musculature with difficulties controlling internal tibial rotation, and reduced strength in deep flexion.

Regardless of graft used, preparing and sizing the graft intraoperatively is a very calculated process. This review provides a basis for the determination of certain graft parameters and illustrates tips for successful outcomes.

Technique

BPTB ***(Figure 1)***

While harvesting the graft, the osteotomy site on the tibia is started 8-10mm above the insertion of the patellar tendon to allow for a functionally shorter graft without compromising the insertion site on the tubercle. This allows the bone plug to be seated higher in the tunnel (i.e. closer to the joint). In contrast, creating the tibial limb of the osteotomy closer to the tibial tubercle may result in a shearing of the patellar tendon. The tibial tunnel is then drilled. The angle of the tunnel is generally approximately 50-52 degrees and the length of the tunnel is 10mm more than the length of the harvested graft. This ensures that the graft will remain entirely within the tunnel after fixation. The tibial bone plug is sized to 10x30mm. The goal of tibial tunnel fixation is to provide the most stable and robust fixation without protrusion of the plug from the tunnel distally. Once in place, 30mm of graft will be intraarticular and the remaining length of graft will be seated in the tibial tunnel.

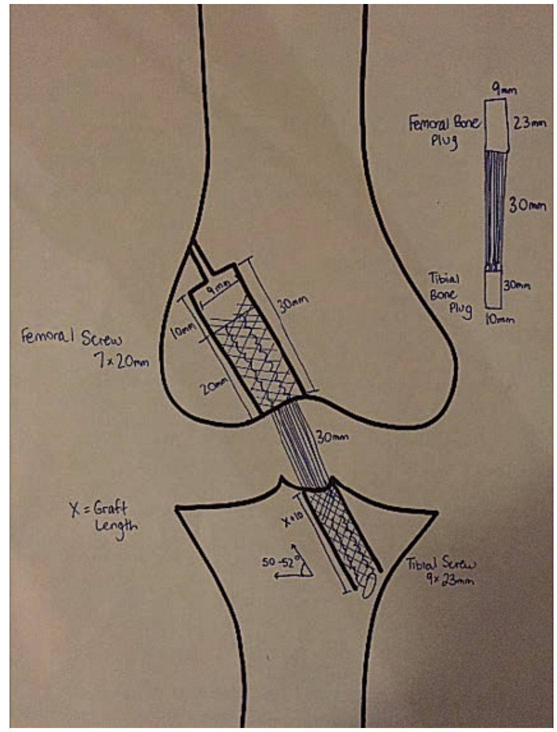

Figure 1. Bone patellar tendon bone graft schematic.

The femoral tunnel is reamed to 9mm wide and 30mm long. The length of the tunnel avoids lateral femoral blowout. The femoral bone plug is sized to 9x23mm. When the knee is positioned in flexion on the operative table, the distance from the top of the tibial tunnel to the top of the intercondylar notch is approximately 25mm. As a result of the femoral and tibial tunnels being drilled independently (i.e. non-linear), if the bone plug is greater than 25mm in length, the plug will be difficult to clear the tunnel and change direction to fit up into the femoral tunnel. The width of the plug corresponds to the amount of bone reamed for the femoral tunnel. Comparing a 9mm to 10mm tunnel, the radius of the tunnel is increased from 4.5mm to 5mm, therefore thinning the size of posterior wall by 0.5mm. This increases the risk of posterolateral condylar blowout and catastrophic graft failure. Once recessed to the appropriate level flush with the medial face of the lateral femoral condyle, the femoral tunnel is notched and tapped prior to insertion of the femoral interference screw (7x20mm).

Hamstring ***(Figure 2)***

After harvesting the hamstring tendons, any remaining muscle attached to the tendons is removed as this does not contribute to the overall tensile strength of the graft. The tendons are folded in half through a suture button (usually 180mm graft harvest results in 90mm quadrupled graft). To calculate the size of the button needed, the length of the femoral tunnel (30mm) is subtracted from the length of the entire femoral condyle (Z). Eight millimeters is then added to this. The 8mm represents the radius of the suture button that is required to be outside the tunnel for the button to flip on itself. Further, [(Z-X)+8] must be less than or equal to the button loop size. Since the buttons are sized in increments of 5mm, if the calculation, for example, yields 16mm, a 20mm button must be used. The graft is trimmed for a 9mm diameter tunnel. Again, 30 of graft remains intraarticular. The graft length remaining in the tibial tunnel plus 10mm is equal to the tibial tunnel length. This helps to account for the obliquity of the tunnel.[5] The graft in the tibial tunnel is whip stitched prior to insertion.

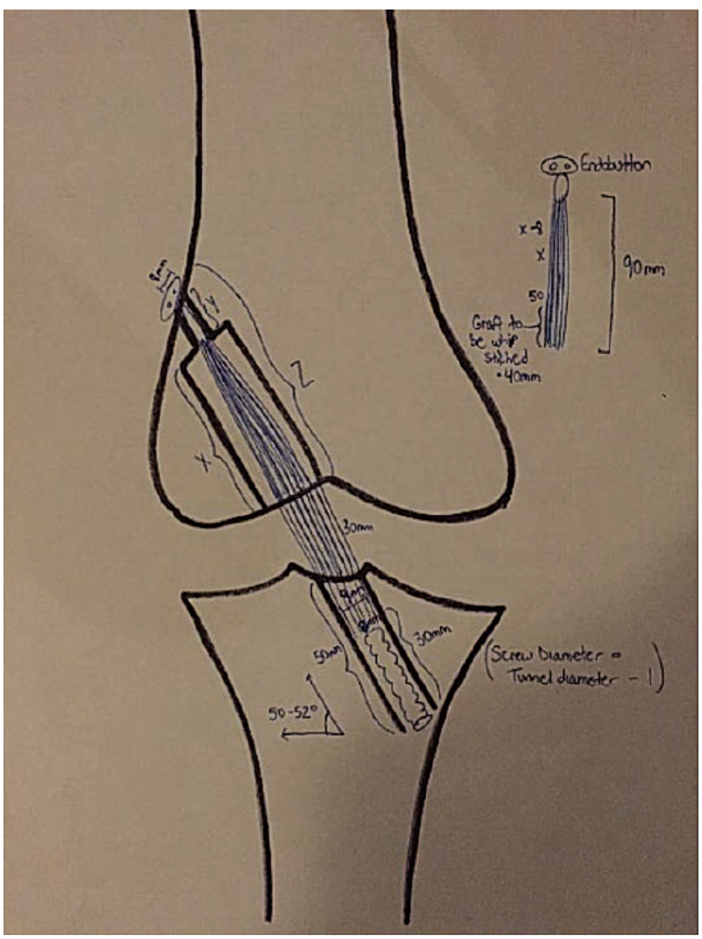

Figure 2. Hamstring graft schematic

Key Principles

Regardless of graft and tunnel preparation techniques, certain overarching principles should be taken into consideration when performing an ACL reconstruction:

Graft Size

Unlike bone-patellar tendon-bone grafts, the diameter of a hamstring autograft is quite variable.[6] In a retrospective analysis of 296 patients undergoing hamstring autograft ACL reconstruction, Park et al. did not observe any failures in patients with graft diameters of 8 mm or greater.[7] Among patients with a graft size of less than 8mm, they noted a revision risk of 5.2%. Similarly, in a retrospective review of 256 patients, Magnussen et al. report that 16 of 18 revision ACL reconstructions occurred in patients with hamstring autografts less than or equal to 8mm in diameter, with a revision risk of 16.4% noted in patients under age 20 among this cohort.[6] Thus, a graft >8mm in a young person portends the best outcome regarding re-rupture rate. Regarding, functional recovery, Mariscalco et al. retrospectively evaluated 263 consecutive patients undergoing hamstring autograft ACL reconstruction. After controlling for age, sex, BMI, graft parameters, and femoral tunnel drilling technique, a 1mm increase in graft size was noted to correlate with higher KOOS scores. Revision was not required in any patient with a graft >8mm in width, but in 18.3% of patients under 18 years old with grafts <8mm.[8]

Certain factors put patients at risk for smaller autografts. These include patient weight less than 50kg, height less than 140cm, body mass index less than 18, and leg circumference less than 37cm.[9] If graft width is not sufficient, there are several alternative options. First, augmentation with allograft is a possibility. This discussion must be undertaken with the patient prior to surgery. Second, the use of a 5-strand graft (3 strands from the longer and more robust semitendinosus and a doubled gracilis) can be employed.[10] Finally, conversion to a BPTB graft is also an option.[11]

Interference Screw Length and Width

Interference screw use is recognized as one of the standard techniques for ACL graft fixation. Initial work by Kurosaka in 1987 followed in 1994 by Kohn and Rose showed in a cadaveric model that using a 9mm interference screw afforded greater stability than using a 7mm screw with a gap size of 1mm. This is especially true on the tibial side.[12,13] With regard to screw length, earlier studies showed that at least a 20mm screw was required to maximize pullout strength. Brown et al. reported no difference between 20mm and 25mm screws.[14] However, more recent studies, albeit in a porcine model, are beginning to show that there is no significance in displacement, load to failure, and stiffness between interference screws 12.5, 15, or 20mm in length.[15] Further study is required in humans to evaluate these differences and their effects on pullout strength.

Backup Fixation/Bailout

Tibial fixation is the weakest link in ACL reconstruction.[16] Possible reasons for relatively low fixation strength include decreased bone mineral density compared with the tibia or excess graft tension during flexion. In addition, the line of force relative to the tibial tunnel is in line, as opposed to the obliquely oriented femoral tunnel. Repetitive loading may then lead to graft slippage. Therefore, the surgeon should be prepared with multiple backup options should the fixation not prove adequate or if the surgeon believes the ultimate load to failure will be substantially augmented by supplemental fixation. These include tying the graft over a bicortical screw post, using staples, using a suture anchor, or recessing the graft further into the femoral tunnel. In one study evaluating three methods of tibial fixation, namely an interference screw alone, an interference screw backed by a suture anchor, and an interference screw backed by a 4.5mm bicortical screw, ultimate load to failure was substantially increased by adding backup fixation. There was no significant difference in load to failure between the backup fixation groups.[17]

Conclusion

Multiple techniques have been described for ACL reconstruction and there are several factors to consider when deciding upon graft choice, fixation options, and post-operative rehabilitation. Determination of graft size, tunnel size and position, and femoral and tibial fixation options are critical to a successful outcome. An understanding of the technical aspects is critical, but a conceptual grasp of the "why" is perhaps more important.

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