Anterior Cruciate Ligament Reconstruction in the Adolescent: A Hybrid Approach to Physeal-respecting Autograft Reconstruction

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Introduction

The incidence of anterior cruciate ligament (ACL) injuries in the pediatric and adolescent population continues to increase.[1] The literature supports earlier surgical intervention since nonoperative management is associated with chondral and meniscal damage.[2,3] While patients with wide-open physes who have more than two years of growth remaining benefit from physeal-avoiding techniques, patients approaching skeletal maturity may be addressed with a technically simpler hybrid reconstruction. We describe a technique that utilizes a femoral physeal-avoiding tunnel and a physeal-respecting tibial tunnel while still allowing use of a five-strand, larger diameter hamstring graft to stabilize the knee.

Background

Patients approaching skeletal maturity can be addressed with a hybrid technique that is technically simpler than complete physeal-sparing techniques. The hybrid ACL reconstruction consists of placing a physeal-sparing femoral tunnel and physeal-respecting tibial tunnel. Unlike the femoral tunnel, the tibial tunnel is drilled across the tibial physis and a soft tissue graft is placed across the physis with fixation distal to the physis. Surgeons must adhere to fundamental principles to minimize the risk of physeal damage, improve technical reproducibility, and fully utilize the autograft tissue available to maximize graft diameter. The overall goal of the hybrid reconstruction is to reconstruct the pediatric knee using autograft tissue with minimally invasive methods. These methods allow for both unrestricted growth and knee stability, a return to healthy fitness, and optimal outcomes.

Preoperative Evaluations and Indications

Before ACL reconstruction, a determination of skeletal maturity will guide the surgeon to choose the appropriate technique. On average, male adolescents cease lower extremity growth between ages 15 and 16, while females cease lower-extremity growth between ages 13 and 14.[4] The tibial physis begins to close in a central location and closes earlier than the femoral physis. In cases where skeletal age is ambiguous, a single anteroposterior radiograph of the left hand can determine maturity based on the Greulich and Pyle atlas.[5]

For a hybrid physeal-sparing or respecting approach to be indicated, one should note a tibial physis that demonstrates early evidence of approaching skeletal maturity, including physeal narrowing, central closure of the tibia, and increasing sclerosis about the physis.[6] These findings correlate to approximately two or fewer years of remaining lower extremity growth. If a greater amount of growth remains, a physeal-sparing surgery is indicated. Conversely, adolescents who are skeletally mature can be approached with the standard adult technique, though the five-strand autograft described may still be of benefit to minimize graft failure in these patients.

Procedure

For the adolescent approaching skeletal maturity, this technique uses a five-strand hamstring autograft hybrid reconstruction utilizing both an all-epiphyseal, physeal-avoiding femoral tunnel, and a physeal-respecting tibial tunnel with interference screw fixation supplemented with low-profile backup fixation.

Graft Preparation

The 5-strand hamstring autograft consists of a tripled semitendinosus and a doubled gracilis.[7] After the hamstring autograft is harvested and care is taken to maximize tendon length, the tendons are placed on the graft preparation table to assess the feasibility of obtaining a final graft length of 8 to 9 centimeters (cm) after folding. For the tripled semitendinosus, the folds are marked out on the tendon approximately 8, 16, and 24 cm from the end in order to ensure a folded length of 8 cm. An additional 1.5 cm is also marked for securing the tripled end. The gracilis is prepared similarly to ensure that it has a folded length matching that of the semitendinosus. Both the semitendinosus and gracilis are whipstitched using high strength non-resorbable sutures (Fiberloop, Arthrex, Naples, FL). Femoral fixation is prepared using the TightRope RT (Arthrex, Naples, FL).

A 5-strand hamstring autograft utilizing both a tripled semitendinosus and a doubled gracilis allows for a larger diameter graft to overcome the biomechanical limitations of a smaller graft common in younger patients (Figure 1).[7] While a larger graft size will impart stronger biomechanical properties, a larger tunnel crossing the physis also presents a slightly increased risk of physeal arrest. Therefore, to minimize tunnel size without compromising graft diameter, graft ends are kept under compression using two, graft sizer blocks or graft tubes. This prevents the graft from swelling at the ends, thus minimizing tunnel size and potential physeal damage.[8] The femoral and tibial graft ends are sized independently for appropriate tunnel diameter. The graft is moistened with a gentamycin and saline solution to lower the risk of bacterial seeding.[9]

Preparing the Femoral Tunnel

When the patient is being prepared for surgery, both the lateral femoral condyle and the center of the condyle are outlined with a marking pen. To avoid the lateral collateral ligament, the starting point for drilling the femoral tunnel is anterior to the midline. Keeping the trajectory below and parallel to the physis in the coronal plane helps to maximize tunnel size while maintaining an all-epiphyseal position (Figure 2).

When debriding the residual ACL stump, a small portion of the native ACL fibers are left intact. This allows for ingrowth of the graft as well as a landmark for tunnel drilling.[10,11] The ACL guide is centered at the native femoral stump and the tunnel is directed to the proper area of the femoral condylar ring. Once the insertion point for the guide pin is determined, a small incision is made sharply through the iliotibial (IT) band. This will function as the trans-IT band endoscopic portal to later confirm that the button is resting securely on the lateral

Figure 2. Intraoperative photograph of the outlined lateral femoral condyle to mark tunnel trajectory and the appropriate alignment of the femoral guide for tunnel drilling.

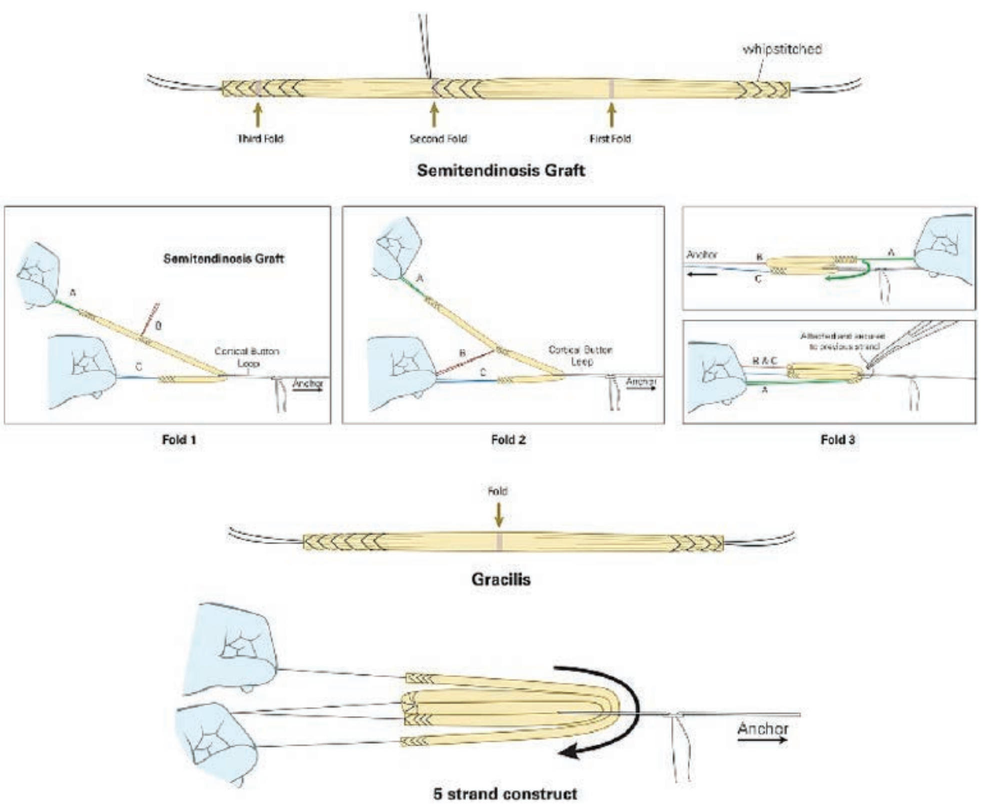

Figure 1. Illustration demonstrating measurements and technique for preparation of the five-strand hamstring autograft. *(Acknowledgement: Michael Mustar, medical illustrator, Case Western Reserve University).*

femoral cortex.[12] To maintain an all-epiphyseal position, the tunnel is typically drilled at an angle between 90-100°. A FlipCutter (Arthrex, Naples, FL) can be used to drill this angle.

Preparing the Tibial Tunnel

Since the proximal tibial physis ceases growth earlier than the femoral epiphysis and contributes significantly less to overall growth, the tibial tunnel can be prepared with a physeal-respecting rather than physeal-sparing approach.

As initial arthroscopy is performed, a small portion of the residual ACL is left at the tibial insertion to promote ingrowth of the graft as well as to provide an anatomic landmark for graft placement. An ACL guide is inserted into the anteromedial portal and centered over the native ACL stump. To minimize physeal damage, set the tunnel to be drilled at an angle of 60-70°. A guide pin is first inserted using the tibial guide, and the tunnel is drilled with a standard reamer based on the measured size of the tibial side of the prepared graft.

Measuring Interference Screw Length

The arthroscope is inserted through the tibial tunnel in a retrograde fashion to visualize the physis. If the physis is open and present, a small ruler is inserted to measure the distance from the distal aspect of the tunnel to the physis. The length of the interference screw should be just short of the physis as recent studies have demonstrated that screw fixation across the physis will cause a temporary growth arrest.[13]

Passing the Graft

Under arthroscopic visualization, the graft is advanced slowly to the point where the button is about to exit the guide pin hole. The button is flipped under arthroscopic visualization and gentle tension is maintained on the graft. Confirmation of the position of the button is performed by inserting the arthroscope through the incision at the distal lateral femur. This has previously been described as the trans-IT band endoscopic portal.[12] The suture limbs are followed with the arthroscope to find the button and ensure that it is resting flush of the femoral cortex and fully flipped (Figure 3). A small probe may be inserted through the endoscopic portal to gently maneuver the button if necessary. Short, quick bursts of fluid will allow for clear visualization.

The graft is fully advanced into the femoral tunnel. The knee is cycled while the graft is under tension. The appropriately sized tibial interference screw is inserted so its length remains short of physis. The authors use a bioabsorbable screw with bone ingrowth properties (Delta screw, Arthrex, Naples Fl).

Backup fixation

Two arthroscopic anchors are used to augment the distal tibial fixation (PushLock, Arthrex, Naples, FL). Two drill holes are created lateral to the medial collateral ligament (MCL) and distal to the tibial tunnel with a standard arthroscopic technique. Suture limbs from the ACL graft are then fed through the anchor and secured, allowing for low profile supplemental fixation while respecting the physis.[14]

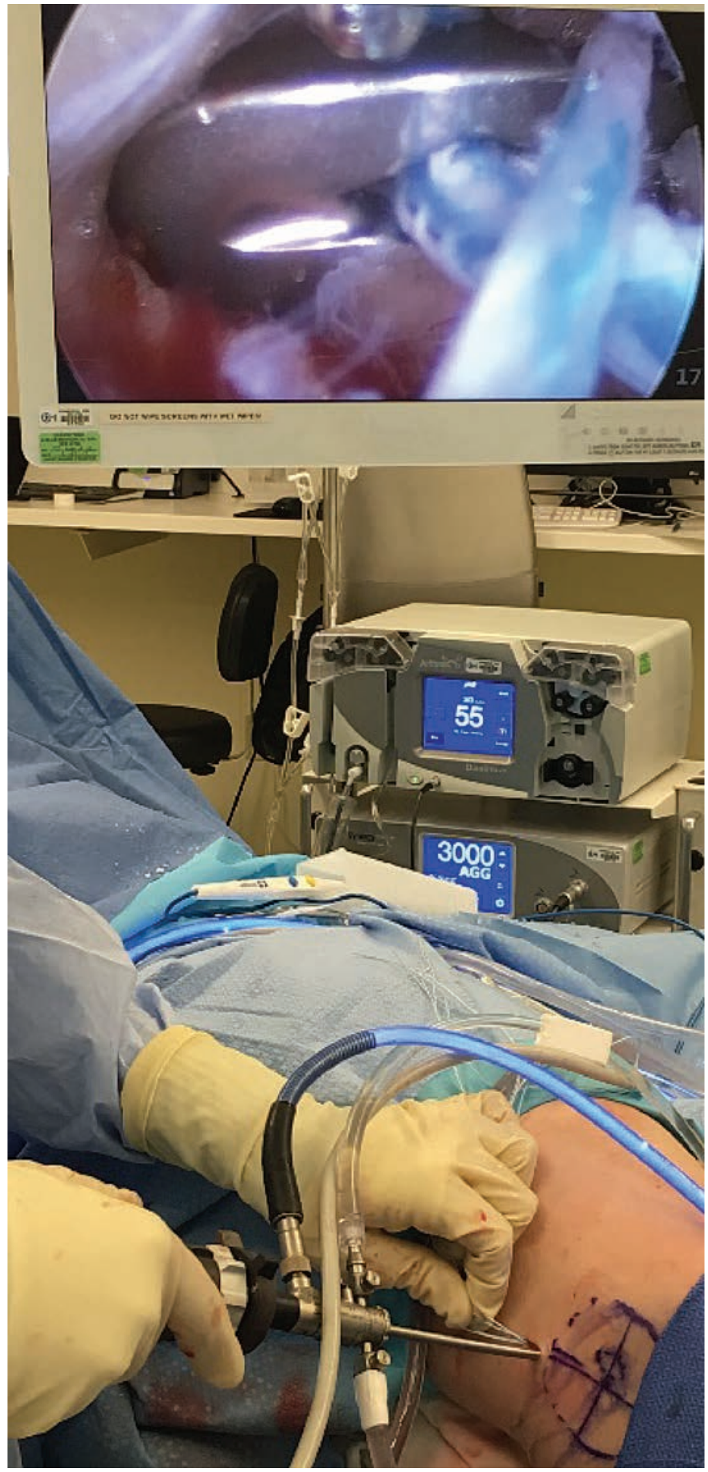

Figure 3. Intraoperative photograph showing the arthroscope in the trans-IT band portal and visualization of the button fully flipped and resting on the lateral femoral cortex.

Postoperative Protocol

The post-operative rehabilitation protocol consists of a controlled progression of activity focused on returning athletes to full competitive return to play at 9 months. The rehabilitation protocol provides patients with early return to motion, endurance, and a graduated strengthening program. The protocol also incorporates a proprioceptive, neuromuscular training program involving multiple hop tests that teaches injury prevention strategies for both lower extremities to prevent future knee injuries upon return to sports.

Discussion

Pediatric and adolescent ACL injuries continue to occur at an increasing rate. Based on the risk of further injury, operative reconstruction has typically been indicated for individuals planning to return to sports. While individuals who have greater than two years of growth remaining require specialized procedures, we describe a physeal-respecting hybrid approach that allows for autograft reconstruction with a five-strand hamstring graft in adolescents with fewer than two years of growth remaining. Using an all-epiphyseal femoral tunnel and a physeal-respecting approach to the tibia with graft fixation distal to the physis, this technique respects the remaining growth of pediatric patients while also stabilizing the affected knee.

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