Technical Note

Physeal-Sparing Anterior Cruciate Ligament Reconstruction with Iliotibial Band Autograft in the Skeletally Immature Knee

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Abstract: Conventional adult anterior cruciate ligament reconstruction techniques are controversial in skeletally immature patients due to the risk of iatrogenic physeal damage and potential growth disturbance. The physeal-sparing, combined intra- and extra-articular anterior cruciate ligament reconstruction using an autogenous iliotibial band was developed to mitigate this risk in prepubescent, skeletally immature patients, with excellent functional outcomes and a low revision rate. This article describes the surgical details of this reproducible reconstruction technique.

Introduction

Anterior cruciate ligament (ACL) tears were once considered uncommon in children. However, there has been a dramatic rise in the frequency of ACL tears in skeletally immature athletes over recent years. This has been attributed to the increase in youth sports participation, year-round training and competition, early sport specialization, and better identification of these injuries.[1-3] As a result, there has been a sharp increase in the number of ACL reconstruction (ACLR) procedures being performed in this population. A study of New York State reported a near three-fold increase in the rate of ACL reconstructions performed in children under the age of 20 years over the past two decades.[4]

Historically, ACL deficiencies in skeletally immature patients were managed with nonoperative strategies, such as the use of a brace, physical therapy, and activity modification. These methods were used as a temporizing measure until the child reached skeletal maturity, at which time a traditional adult-type ACL reconstruction could be safely performed.[2] However, the enhanced understanding of the outcomes observed with nonoperative management and surgical delay in prepubescent patients has led to recent recommendations for early operative intervention.[2,5]

A variety of "physical-respecting" ACL reconstruction techniques have been proposed and modified over the years to allow for continued growth in patients with open physes.[2,5-8] These approaches using soft-tissue grafts either avoid the physis completely (e.g., "all-epiphyseal"[9-12]) or involve only a small area of the physis (e.g., "transphyseal"[13-17]). In this article, we further describe one physeal-sparing technique that entails a combined intra- and extra-articular ACL reconstruction using an iliotibial band (ITB) autograft (Fig 1; Video 1). This approach has demonstrated excellent functional outcomes, minimal risk of growth disturbance, and a low graft-rupture rate in skeletally immature prepubescent children at more than 6 years from surgery.[6,18,19]

Surgical Technique

Indications

The combined intra- and extra-articular ACLR using an autogenous iliotibial band is used in the setting of

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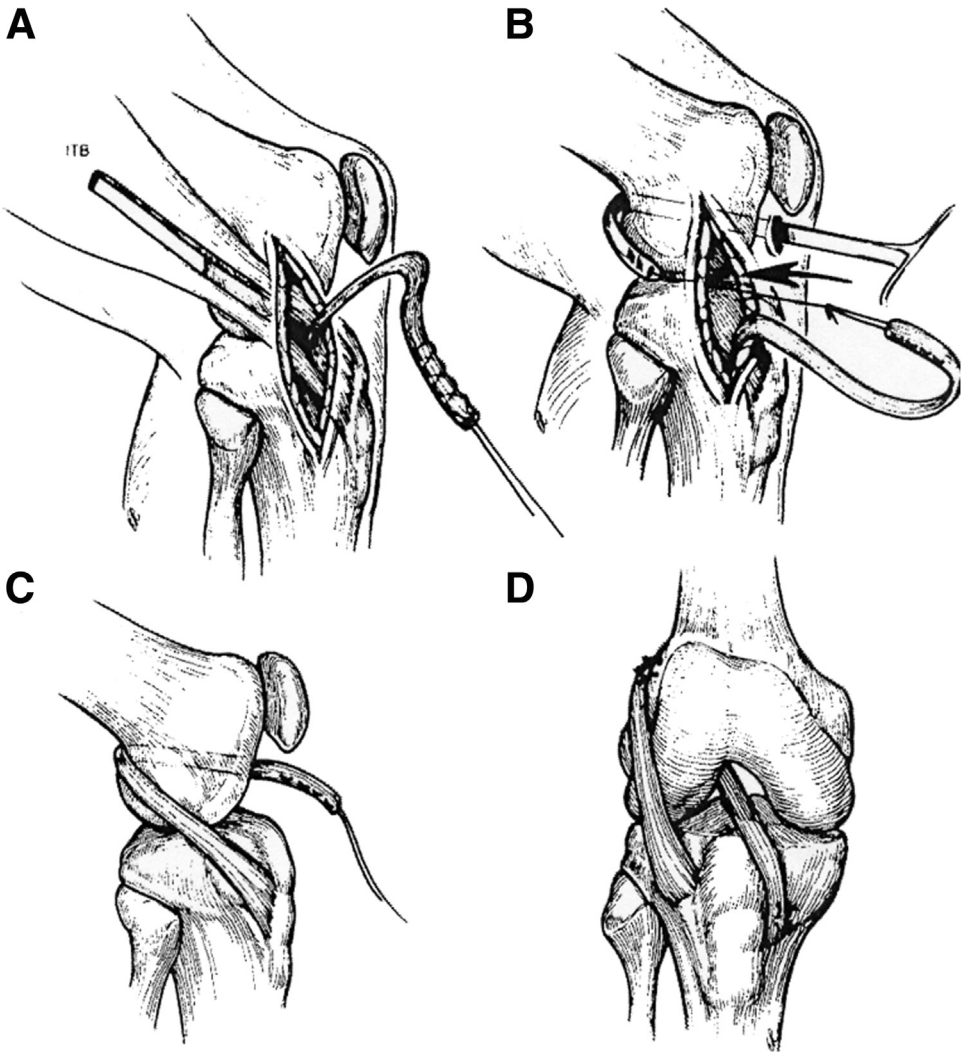

Fig 1. Schematic demonstrating the physeal-sparing, combined intra-articular and extra-articular anterior cruciate ligament reconstruction using an iliotibial band autograft. Note the extra-articular and intra-articular components.

ACL insufficiency, either secondary to congenital limb anomaly or mechanical injury, in patients deemed at risk for iatrogenic physeal damage and growth disturbance.[6,7,18] As such, this technique is used in prepubescent patients with open physes, significant remaining growth potential, and smaller knees where the epiphyseal space would make an all-epiphyseal ACLR challenging.

Patient Positioning and Setup

The patient is placed supine on a standard operating room table with the operative knee hanging off the table. A lateral thigh post is placed for support when performing the medial compartment assessment during the diagnostic arthroscopy. The arms are placed on their respective arm boards perpendicular to the patient's body. Examination under anesthesia is performed to confirm Tanner staging and verify ACL insufficiency. A pneumatic tourniquet is applied to the proximal aspect of the thigh, taking care to maintain sufficient lateral thigh exposure for graft harvesting. The surgical extremity is prepared and draped in a standard fashion. The incisional sites are marked for ITB harvesting, tibial access, and anterolateral and anteromedial arthroscopy portals (Fig. 2).

ITB Harvest

An incision is made at the lateral joint line and continued 4 to 6 cm obliquely to the superior border of the ITB. The proximal ITB is separated from the subcutaneous tissue with use of a periosteal elevator beneath the lateral aspect of the thigh. The anterior and posterior borders of the ITB are identified and incised 2 cm proximal to Gerdy's tubercle to develop a 1-cm-wide strip of graft (Fig. 3). The anterior and posterior splits are extended proximally in line with the ITB fibers. The ITB graft is transected as proximal as possible using a curved meniscotome or a tendon stripper, aiming to extract 15 cm of graft. The free proximal end of the graft is removed from the incision site and

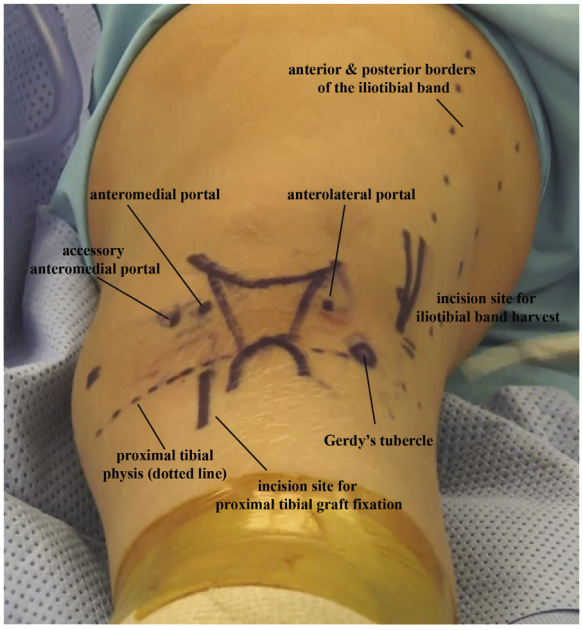

Fig 2. Annotated markings for the skin incisions prior to performing the physeal-sparing, combined intra-articular and extra-articular anterior cruciate ligament reconstruction using an iliotibial band autograft. For graft harvesting, a mark is made 4 to 6 cm from the lateral joint line to the superior border of the iliotibial band. For the medial proximal tibia incision, a mark is made from the tibial tubercle and carried 3 to 4 cm distally, staying medial to the tibial tubercle and distal to the tibial physis. A line from Gerdy's tubercle to the tibial tubercle can help approximate the location of the proximal tibial physis. For the anterolateral portal, a mark is made at the inferior pole of the patella just lateral to the patellar tendon. For the anteromedial portal, a mark is made at the joint line just medial to the patellar tendon. This portal can be translated medially to aid in the trajectory of the full-length clamp around the posterolateral aspect of the lateral femoral condyle when the graft is brought intra-articular; alternatively, an accessory anteromedial portal can be used.

tubularized using a whipstitch with five throws in each direction to facilitate graft passage (Table 1). The distal end of the graft is released from the joint capsule and lateral patellar retinaculum, leaving the ITB attached distally at Gerdy's tubercle (Fig. 4).

Tibial Preparation

An incision is made over the medial aspect of the proximal tibia, creating a 3 to 4 cm incision in the region of the insertion of the pes anserinus, medial to the tibial tubercle and distal to the tibial physis. Dissection is carried to the periosteum.

Portal Establishment and Diagnostic Arthroscopy

The operative knee is placed in extension along the table, and standard vertical anterolateral viewing and anteromedial working portals are created, as marked. A standard diagnostic arthroscopy is performed. Any meniscal or chondral injury is managed at this time.

Graft Passage

A minimal notchplasty is performed to aid visualization posteriorly, taking care to protect the perichondral ring of the distal femoral physis near the "over-the-top" position.[1] A full-length clamp is placed through the anteromedial portal to bring the free end of the graft through the "over-the-top" position and out of the anterolateral incision (Fig. 5). The lead sutures on the graft are grabbed to pull the graft through the notch and out of the anteromedial portal.

Through the tibial incision, shape a small groove in the anteromedial aspect of the proximal tibial epiphysis just under the intermeniscal ligament. This facilitates graft passage and guides the graft placement on the tibia more posteriorly. The free end of the graft is grasped (Fig. 6) to bring the graft through the joint, under the intermeniscal ligament in the anteromedial epiphyseal groove (Fig. 7) and out of the tibial incision.

Graft Fixation

With the knee placed into 90° of flexion and the foot in neutral rotation (Fig. 8), the ITB graft is fixed to the intermuscular septum and periosteum of the posterolateral femoral condyle with two mattress sutures. With the knee then placed into extension along the table, the periosteum is incised longitudinally and distal to the proximal tibial physis. Periosteal flaps are developed. The graft is sutured to the periosteal flaps with the graft under tension (Fig. 9). The graft can be supplemented with a post, if necessary. A Lachman test and assessment of range-of-motion are performed to assess for knee stability. The procedure is completed by final

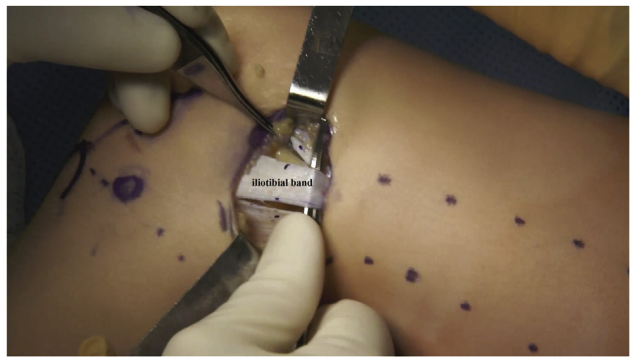

Fig 3. The patient is placed supine on a standard operating room table with the left knee hanging from the table. An incision is made at the lateral joint line and continued 4 to 6 cm obliquely to the superior border of the iliotibial band. The anterior and posterior borders of the iliotibial band are identified and incised 2-cm proximal (dotted line) to Gerdy's tubercle to develop a 1-cm-wide strip of iliotibial band. The anterior and posterior splits are extended proximally in line with the iliotibial band fibers.

Table 1. Pearls and Pitfalls

Pearls
Preoperative
Emotional maturity is important to assess as adherence to postoperative activity limitations and active participation in the intensive rehabilitation regimen are critical for favorable outcomes.
Transepicondylar distance can be used to calculate the length of the iliotibial band required.[31]
Intraoperative
The free end of the graft should be "bulleted" during tubularization to help facilitate passage of the graft through the posterolateral capsule.
The free end of the graft should be folded into thirds, wrapped in a moist sponge, and tucked under the skin to prevent desiccation during arthroscopy.
An inferolateral sling of ACL should be left to decrease the likelihood of the graft subluxating into the lateral compartment.
Tibial fixation should be performed medial to the tibial tubercle apophysis to avoid iatrogenic injury.
Postoperative
A slower return to sports is protective against subsequent ACL injury.[32] Inability to return to full activity, including cutting and pivoting sports, is always a risk and is more likely when the initial surgical indication is a multiligamentous injury or a congenital insufficient or absent ACL.
Emotional maturity is important to assess
Pitfalls
Intraoperative
Insufficient harvesting of the iliotibial band fascia can result in a graft that is too short to effectively secure to the tibia. It is recommended to attempt to harvest a 15-cm-long graft.
Overly aggressive dissection around the posterolateral aspect of the femoral condyle or overly vigorous posterior notchplasty can cause injury to the perichondral ring and possible deformity.

ACL, anterior cruciate ligament.

closure of all skin incisions and placement of a hinged knee brace set at 0 to 90°.

Rehabilitation

Activity is limited to touch-down weight-bearing for the first 6 weeks following surgery. Mobilization is begun immediately, initially limited to 0 to 90° for the first 2 weeks in the protective hinged knee brace, before progressing to the full range-of-motion. For the first three months, rehabilitation includes range-of-motion, proprioception, and closed-chain strengthening exercises, patellar mobilization, and electrical stimulation, with subsequent progression to straight-line jogging, plyometric exercises, and sport-specific exercises. Return to full activity is assessed at 6 months from surgery. A functional knee brace is recommended during cutting and pivoting exercises for the first 2 years.

Discussion

Enhanced knowledge of the outcomes seen with nonoperative treatment of ACL tears in young athletes and the importance of normal physeal function during skeletal development has led to the development of various physeal-respecting and physeal-sparing reconstruction techniques, including partial- or complete-transphyseal[13-15] and all-epiphyseal[9-12] techniques. Transphyseal techniques use vertical tunnels to minimize the cross-sectional area of damage. However, transphyseal ACLR using soft-tissue grafts and extraphyseal fixation in skeletally immature patients has been found to create physeal bars, even in the absence of growth arrest.[20] Attempting to achieve anatomic reconstruction by increasing obliquity of the femoral tunnel heightens the risk of physeal injury.[21,22] In the case of all-epiphyseal techniques, femoral tunnels are made parallel to the physis. However, there have been cases reported of limb-length discrepancy and angular deformity due to physeal overgrowth, and

Fig 4. The iliotibial band of the left leg flexed at the knee is released proximally to extract a 15-cm-long graft. The free proximal end of the graft is removed from the incision site and is whipstitched with five throws in each direction for control. Note that the end of the graft has been tubularized and "bulleted" to help facilitate intra-articular passage. The distal end of the graft is released from the joint capsule and lateral patellar retinaculum, leaving the iliotibial band attached distally at Gerdy's tubercle.

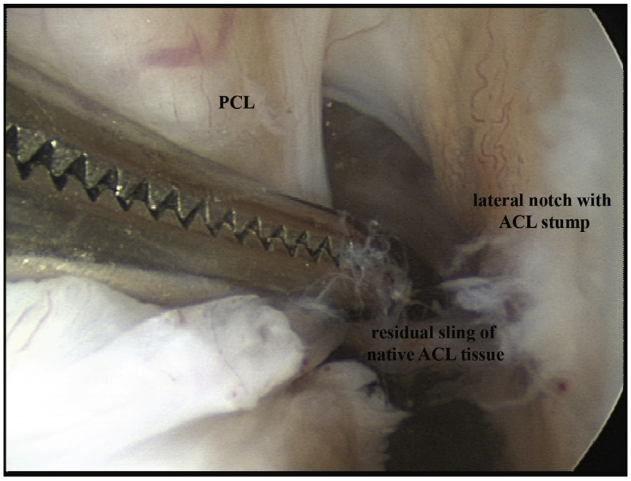

Fig 5. A full-length clamp is placed through the anteromedial portal to bring the free end of the graft through the "over-the-top" position and out of the anterolateral incision. A Schnidt Tonsil Forceps can be used instead of a clamp in smaller patients. Note the residual sling of anterior cruciate ligament tissue left inferiorly to help prevent inferolateral subluxation of the graft. ACL, anterior cruciate ligament; PCL, posterior cruciate ligament. Viewing through the anterolateral portal.

the need for additional surgeries, despite taking care to protect the physis.[23-26]

The physeal-sparing, combined intra-articular and extra-articular ACLR using an autogenous ITB in prepubescent, skeletally immature patients mitigates the risk of iatrogenic physeal damage and potential growth disturbance by avoiding tunnels and intraosseous fixation.[6,18,19] First devised by Micheli at al.[7] and further

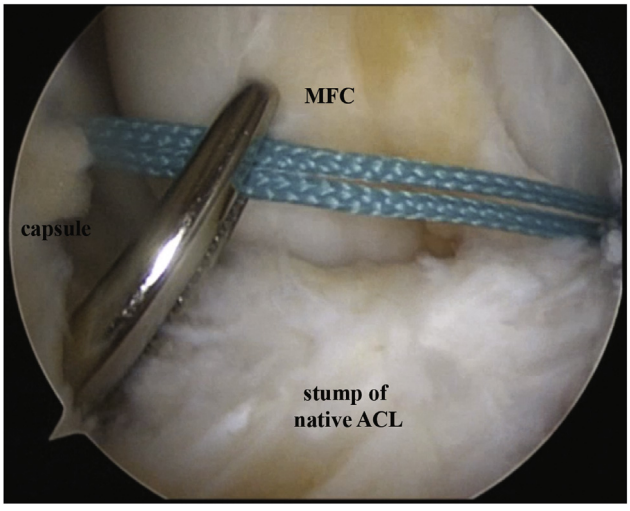

Fig 6. Following intra-articular passage of the graft suture, a clamp is passed from the anteromedial portal under the intermeniscal ligament and is used to grasp the suture on the free end of the graft. Note that a small groove in the anteromedial aspect of the proximal tibial epiphysis can be shaped just under the intermeniscal ligament to facilitate graft passage and to bring the graft placement on the tibia more posteriorly. MFC, medial femoral condyle. Viewing through the anterolateral portal.

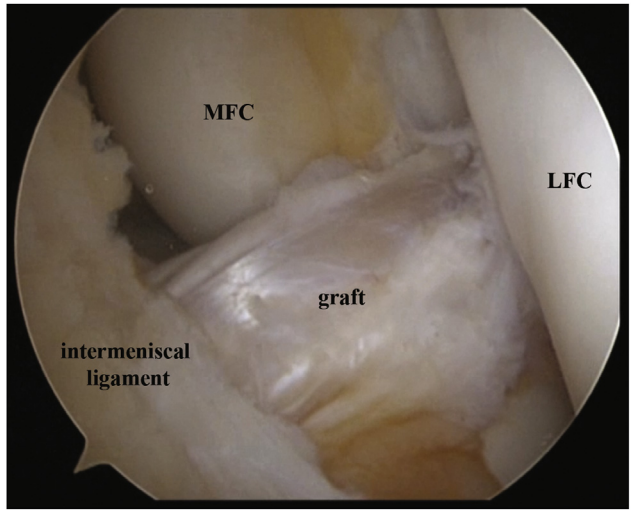

Fig 7. The graft is pulled through the joint, under the intermeniscal ligament in the anteromedial epiphyseal groove, and out of the tibial incision. LFC, lateral femoral condyle; MFC, medial femoral condyle. Viewing through the anterolateral portal.

Fig 8. With the left knee placed into 90° of flexion and the foot in neutral rotation, the extra-articular portion of the graft is sutured to the lateral intermuscular septum and periosteum of the posterolateral femoral condyle using two mattress sutures. This comprises the "extra-articular tenodesis" portion of the ACL reconstruction.

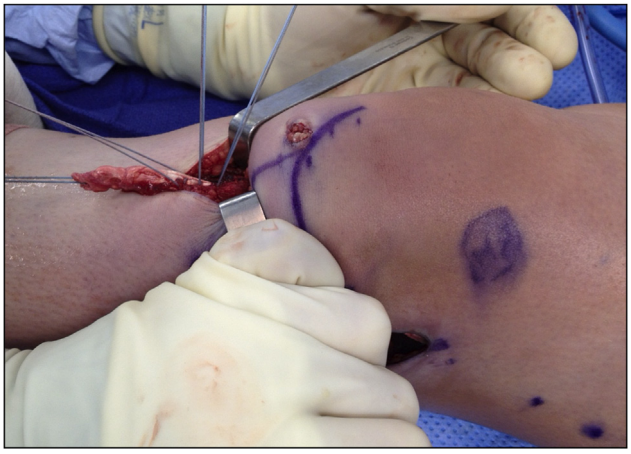

Fig 9. With the left knee placed into extension along the table, the periosteum is incised longitudinally and distal to the proximal tibial physis. Periosteal flaps are developed. The graft is sutured to the periosteal flaps under tension using a Mason-Allen type stitch (medial-to-lateral, then anterior-to-posterior), making three passes total. The suture construct is such that tying the sutures further tensions the graft.

described by Kocher et al.,[6,18] this technique has shown favorable outcomes in skeletally immature patients. At a mean follow-up of 5.3 years in 44 children with a mean age of 10.3 years, all patients, except for 3 with congenital limb deficiencies, returned to sports involving cutting or pivoting.[6] The mean functional scores at final follow-up were 96.7 ± 6.0 points and 95.7 ± 6.7 points out of 100 on the International Knee Documentation Committee (IKDC) subjective knee assessment and Lysholm Knee Scoring Scale (LKSS), respectively; the revision rate was low at 4.5%.[6] Similar results were found at a mean follow-up of 6.2 years in a study of 237 patients.[18] The mean pediatric-IKDC and LKSS scores in this larger, longer-term study were both 93. There were low rates of revision (5.8%), arthrofibrosis (2.1%), and septic arthritis (0.4%).[18] At a mean follow-up of 3.0 years in 22 knees, the mean scores were 96.5 on the pediatric-IKDC and 95 on the LKSS; 3 knees (14%) required operative revision.[19] No clinical or radiographic growth disturbances or angular deformities occurred in any of these studies.[6,7,18,19] More research is necessary to determine outcomes when this technique is performed in conjunction with other stabilizing procedures, such as anterolateral ligament reconstruction.[27-30]

This evidence suggests that when performed appropriately, the use of this physeal-sparing ACLR approach in prepubescent, skeletally immature patients can mitigate the risk of physeal damage, while providing excellent functional outcomes, a low revision rate, and minimal risk of growth disturbance.[2,18]

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