Physeal-Sparing Technique for Femoral Tunnel Drilling in Pediatric Anterior Cruciate Ligament Reconstruction Using a Posteromedial Portal

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Abstract: Pediatric anterior cruciate ligament (ACL) tears present a technical dilemma for orthopaedic surgeons. Multiple surgical techniques have been described to protect the distal femoral and proximal tibial physes. We present an ACL reconstruction technique performed on a 12-year-old girl with open physes who sustained an ACL tear after a noncontact twisting injury while playing soccer. A hamstring autograft reconstruction was performed by use of a posteromedial portal to drill the femoral tunnel in an all-epiphyseal fashion at the anatomic footprint of the native ACL. This case provides a new surgical technique to achieve anatomic fixation for ACL reconstruction in a skeletally immature individual using a posteromedial portal to drill a physeal-sparing lateral femoral tunnel for anatomic ACL reconstruction. This advancement may make drilling the femoral tunnel less technically challenging compared with other proposed methods while maintaining the lateral wall of the distal femur.

The management of pediatric anterior cruciate ligament (ACL) injuries remains controversial. Although nonoperative treatment of pediatric ACL injuries is historically recommended, the reported results of nonoperative treatment are poor. A growing body of evidence favors the treatment of ACL tears in skeletally immature patients with surgical reconstruction. Conservative treatment of ACL tears in adolescents commonly leads to meniscal and articular cartilage damage that may lead to early degenerative joint disease. Graf et al. reported on 12 skeletally immature patients with ACL tears. Eight patients in the group underwent hamstring and quadriceps strengthening and returned to sports with a brace. All 8 patients had further instability events, and 7 of the 8 patients had further damage to the meniscus. Graf et al. concluded that physical therapy and bracing did not prevent instability or new meniscus tears.

Anatomic ACL reconstruction in adults has been shown to better restore knee biomechanics in previous cadaveric and recent in vivo studies. Anatomic reconstruction of the ACL in both adult and pediatric populations therefore is ideal. ACL tears in children with open physes of the distal femur and proximal tibia present the orthopaedic surgeon with a dilemma because conventional anatomic adult reconstruction techniques can violate the growth plate and may lead to physeal arrest. There is no consensus on the surgical treatment technique in preadolescent children with ACL tears. Multiple nonanatomic physeal-sparing techniques have been described, but few reconstruct the ACL at its native footprint. We propose a unique method of accessing an anatomic position while avoiding the physis by drilling an all-epiphyseal femoral tunnel through a posteromedial portal using intraoperative fluoroscopic imaging, along with arthroscopic visualization (Table 1). This technique has not been described previously.

A 12-year-old girl sustained an isolated noncontact twisting injury to her right knee while playing soccer 1 month before initial presentation. Physical examination and magnetic resonance imaging confirmed the diagnosis of an ACL tear. She had been weight bearing as tolerated and undergoing physical therapy for range of
motion and strengthening before surgical intervention. The patient’s knee had a mild effusion and 0° to 130° of range of motion of the injured knee compared with 5° of extension to 140° of knee flexion on the normal side. She had a grade 3 Lachman test with a soft endpoint. She stood 5 ft 2 in (1.575 m) tall and weighed 100 lb (45.4 kg). The patient’s mother is 5 ft 4 in (1.625 m) tall, and the father is 6 ft (1.83 m) tall. Left-hand radiographs were taken in the office to assess skeletal age by use of the digital atlas of skeletal maturity of Gilsanz and Ratib. The patient was determined to have open growth plates and a corresponding skeletal age of 12 years. We elected to perform physeal-sparing ACL reconstruction with hamstring autograft with the patient’s and mother’s consent.

**Technique**

Standard anterolateral and anteromedial portals are established for the diagnostic arthroscopy, and the knee is flexed to 90° on a 12-towel bump with the popliteal fossa free of pressure (Fig 1, Video 1). In this case a 30° arthroscope was used, but a 70° arthroscope could be used to improve visualization. Soft-tissue autografts or allografts are prepared for use in the standard manner. The posteromedial compartment of the knee is assessed arthroscopically by intercondylar notch visualization. A spinal needle is used to localize the correct position of the posteromedial portal, and a superficial longitudinal

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**Table 1. Steps of Procedure, Technical Tips, and Hazards**

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<tr>
<th>Steps of Procedure</th>
<th>Technical Tips</th>
<th>Hazards</th>
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<tr>
<td>Starting posteromedial portal</td>
<td>When placing the posteromedial portal, the knee should be flexed over a large bump and the popliteal fossa should be free. Use a spinal needle and make your incision proximal to distal so that you can “cheat it” up or down if you are off. Start slightly inferior to the normal position (just distal to the joint line).</td>
<td>One may have an inability to access the posteromedial compartment, and care must be taken to avoid the saphenous nerve and vein. Placing the portal under direct visualization and having a bump under the posterior thigh well proximal to the popliteal fossa will help protect the posterior neurovascular structures.</td>
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<td>Directing portal placement and protecting neurovascular structures</td>
<td>Directing the posteromedial portal, the surgeon should use a straight “snap.” Use a cannula that is 8.25 mm wide or larger and 9 cm in length. Dissect through the septum if present. Use a switching stick and a cannulated obturator to place the cannula.</td>
<td>Careful dissection should be carried out to avoid injuring neurovascular structures.</td>
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<td>Placing cannula across posterior compartment</td>
<td>Use fluoroscopic imaging to ensure correct location. Place the cannula right on the bone at the ACL footprint on the lateral femoral condyle.</td>
<td>There is often a septum between the posteromedial and posterolateral compartments. The cannula should protect the posterior neurovascular and posterior articular surfaces from the reamer.</td>
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<td>Placing guide pin and drilling femoral tunnel</td>
<td>Guide pin placement and drilling of the femoral tunnel should be performed under arthroscopic and fluoroscopic imaging to avoid violating the growth plate and enable placing the pin in the correct position.</td>
<td>Unlike using the AAMP, when using the PMP, extending the knee causes the guide pin to exit more proximally and flexing the knee causes the pin to exit more distally.</td>
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<td>Selecting graft to use and fixing graft</td>
<td>Autograft, allograft, soft-tissue graft, or graft with bone blocks can be used. A flip button–type device, interference screw, or molly bolt–type fixation can be used for fixation because the drill holes do not cross the physeis.</td>
<td>We have only used soft tissue (hamstring autograft) for the graft. For fixation, we have only used a flip button on the femoral side and a post and washer on the tibial side. All other options are only proposed and will be tested.</td>
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AAMP, accessory anteromedial portal; PMP, posteromedial portal.
incision is made with a No. 15 scalpel. A posteromedial portal is established by blunt dissection with a straight hemostat under direct visualization with the knee in 90° of flexion to move the sartorial branch of the saphenous nerve posteriorly. The portal position is sufficient to bypass the posteromedial femoral condyle and reach the ACL footprint on the lateral femoral condyle, viewed from the anterolateral portal, looking medial to the posterior cruciate ligament (PCL). A lateral-view fluoroscopic image shows the switching stick inserted through the posteromedial portal to reach the ACL footprint. The portal position is sufficient to reach the ACL footprint on the lateral femoral condyle with a switching stick placed through the posterior septum behind the PCL, viewed from the anterolateral portal looking lateral to the PCL. To reach the ACL footprint, a cannulated obturator inside the cannula is placed over the switching stick to place the cannula directly on the ACL footprint. An anteroposterior-view fluoroscopic image shows the switching stick reaching the ACL footprint on the lateral femoral condyle.

A 4-mm EndoButton reamer (Smith & Nephew, Andover, MA) is used to drill through the lateral femoral cortex. The thickness of the lateral femoral bone is measured off of the 4-mm reamer. The passing suture is then passed through the cannula into the femoral tunnel and out the anterior lateral skin. The loop end coming out of the cannula and the tails coming out of the anterior lateral skin are snapped together (Figs 5A and 5B). The lateral bone bridge depth is measured with an EndoButton depth gauge (Smith & Nephew) through the cannula and into the femoral tunnel under direct arthroscopic guidance. Fluoroscopic guidance may confirm the correct position of the depth gauge. This determines the size of the continuous loop needed for the EndoButton.

The tibial tunnel is drilled and fixed as described previously. The tibial guide (Arthrex) is used under fluoroscopic guidance to prepare an all-epiphyseal tibial tunnel as described by Anderson3 in 2004. The guide is inserted through the anteromedial portal, and the pin is drilled from the incision used to harvest the semitendinosus and gracilis to the ACL footprint on the tibia (Fig 6). The loop portion of the passing suture is retrieved from the knee joint with a suture grasper (atraumatic suture grasper; Arthrex) so that the loop end is pulled through the tibial tunnel (Fig 5C). The anterior portion of the femoral tunnel is chamfered to aid graft passage. The graft is passed and secured on the lateral femoral cortex with an EndoButton (15-mm
Continuous Loop EndoButton [Smith & Nephew] in this case) (Figs 5D, 7A, and 7B). The tibial graft is secured to a post and washer (Smith & Nephew) (Figs 7C and 7D). Fluoroscopic imaging and arthroscopic visualization verify appropriate graft placement.

The patient was placed in a hinged knee brace locked in extension for weight bearing and then allowed to unlock the brace as quadriceps function returned. At 3 weeks, she was allowed full weight bearing in an unlocked short knee brace, which continued for 3 weeks. Three months postoperatively, the patient had no pain or feelings of instability. She was examined and had a negative Lachman test and anterior and posterior drawer test. She was cleared for straight-line running with no cutting until further follow-up. At the 6-month postoperative visit, the patient had no subjective complaints of pain or instability. She had no effusion or joint-line tenderness and had achieved full range of motion from 0° to 140°. Strength assessment of the quadriceps showed that the operative side had achieved greater than 90% of the strength and circumference of the contralateral knee. Lachman, anterior drawer, and pivot tests were negative. By use of a KT-1000 arthrometer (MEDmetric, San Diego, CA), anterior tibial translation was measured as 4 mm, 5.5 mm, 7 mm, and manual maximum of 8.5 mm on the right (affected) and 6 mm, 7 mm, 9 mm, and manual maximum of 9 mm on the left (unaffected). At this visit, the patient had an International Knee Documentation Committee (IKDC) Subjective Knee Evaluation score of 90.8 and a Lysholm score of 100. She was cleared to return to cutting, twisting, and pivoting activities at this time. At the 1-year postoperative clinic visit, she had an IKDC Subjective Knee Evaluation score of 100 and a Lysholm score of 100. Her 1-year postoperative radiographs showed open growth plates with an excellent position of hardware and tunnels (Fig 8).
Discussion

There is a need for a safe technique for anatomic ACL reconstruction in the pediatric population that does not compromise the growth plates and risk femoral malalignment or limb-length discrepancy. Behr et al. described the anatomic ACL origin as typically less than 3 mm from the growth plate. This location makes it difficult to place a truly anatomic femoral tunnel without violating the growth plate. Kocher et al. reported 15 cases of growth disturbance from their survey of the Herodicus Society study, of which 8 resulted in arrest of the lateral distal femoral physis.

Controversy still exists regarding the best surgical management in this patient population, and there are a variety of operative techniques for ACL reconstruction in skeletally immature patients to minimize damage to the physis. Guzzanti et al. described a technique using soft-tissue grafts and an epiphyseal tibial tunnel with the use of eccentric tibial and femoral tunnels for ACL reconstruction in preadolescent patients. This method used a staple in the femoral epiphysis where the graft was looped through, sutured to itself, and sutured to the tibial periosteum. Lawrence et al. described the use of intraoperative computed tomography scanning to confirm drilling of the lateral distal femoral epiphysis in an all-inside trans-epiphyseal reconstruction using interference screws for fixation. Anderson described an all-epiphyseal technique for the femoral tunnel in which an EndoButton washer is placed on the lateral distal femoral cortex through a lateral incision. Other modifications of the all-epiphyseal ACL reconstruction include retrograde drilling and nonanatomic reconstructions. Kocher et al. described a physeal-sparing technique using the central one-third of the iliotibial band as the graft, where it is left attached to the Gerdy tubercle, passed...
Fig 6. The tibial guide pin is drilled in an all-epiphyseal fashion, by use of fluoroscopy and arthroscopy for guidance. (A) A mini C-arm is used throughout the procedure to confirm appropriate guide pin placement and the location of the physis. (B) A lateral-view fluoroscopic image of the knee is used to avoid the physis while drilling the tibial guide pin. (C) The tibial guide pin is drilled from the soft-tissue graft harvest site into the joint space, as visualized from the anterolateral portal.

Fig 7. (A) A lateral-view fluoroscopic image confirms placement of the EndoButton on the lateral femoral cortex, pictured with an approximate location for femoral tunnel placement. (B) An anteroposterior-view fluoroscopic image shows fixation of the EndoButton, secured on the lateral femoral cortex. (C) Tibial fixation is achieved with a post and spiked washer, as shown on an anteroposterior-view fluoroscopic image. (D) The post and spiked washer are seen through the skin incision on the tibia.
through the knee under the intrameniscal ligament, and sutured in a femoral manner to the intermuscular septum and periosteum and in a tibial manner to the periosteum. This technique uses both intra-articular and extra-articular stabilization.9 Redler et al.10 detailed a transphyseal technique for pubescent patients using a quadrupled hamstring tendon autograft with an over-the-top alignment guide placed through the tibial tunnel to establish a femoral tunnel in transtibial fashion.

Using the posteromedial portal closely mimics the technique for ACL reconstruction performed through an accessory anteromedial portal and does not require flexible reamers or retrograde cutting devices. Using the posteromedial portal for drilling the femoral tunnel allows anatomic placement of the femoral tunnel while avoiding disruption of the epiphysis. Anatomic tunnel placement has been shown to be ideal in restoring proper biomechanics.11-13

Our patient has had an excellent functional outcome based on her scores of 100 for both the IKDC and Lysholm outcome measures. This technique resulted in high patient satisfaction, allowing her to return to full activities. Postoperative evaluation with the KT-1000 arthrometer showed normal anterior translation with a side-to-side difference of less than 3 mm at 6 months and 1 year postoperatively, suggesting integrity of the ACL quadrupled hamstring autograft. No growth disturbances or alignment issues were noted on follow-up; however, the patient will continue to be followed up until skeletal maturity to assess the status of her femoral and tibial physes and evaluated for total growth in height, along with the presence or absence of angular deformities of the knee.

The posteromedial portal has been shown in this article to be a safe working portal that may benefit surgeons during reconstruction of pediatric ACL tears. This surgical technique is recommended for experienced surgeons who are comfortable working through the posteromedial portal. We believe that this advancement can make drilling the femoral tunnel less technically challenging compared with other proposed methods while maintaining the lateral wall of the distal femur. In fact, this approach may be less likely to damage the articular cartilage and more easily access the ACL femoral footprint than other currently used techniques. The operative time is only slightly longer because of the use of intraoperative radiography and placement of the posteromedial portal. It does not take extra time to prepare the knee, drill the tunnels, or pass the graft compared with conventional ACL reconstruction.

Potential complications of this approach include the surgeon’s unfamiliarity with working through the posterior portal and the risk of damage to the surrounding structures, such as the saphenous nerve and its branches, saphenous vein, popliteal tibial nerve, popliteal artery, popliteal vein, and articular cartilage of the posteromedial femoral condyle. We suggest placing the posteromedial portal with the knee in 90° of flexion and confirming drill and reamer placement often with intraoperative fluoroscopy.
ACL reconstruction in the skeletally immature patient presents a dilemma for the surgeon. Multiple options for graft placement and fixation are available, without clear evidence of the superioritiy of any 1 technique. We propose that drilling the femoral tunnel through a posteromedial portal can be performed to reach the anatomic ACL footprint in prepubescent patients efficiently and safely, with excellent clinical and functional postoperative results. Further studies are needed to assess the biomechanical consequences of using the posteromedial portal for ACL reconstruction.

References