Technical Note

# Pediatric Anterior Cruciate Ligament and Anterolateral Ligament Reconstruction With Hybrid Over-the-Top Femoral Fixation, Transphyseal Tibial Fixation, and Tibial All-Epiphyseal Anterolateral Ligament Fixation Using Attached Hamstring Autograft

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**Abstract:** The rise in high-intensity sports among children and adolescents has led to more anterior cruciate ligament (ACL) reconstructions. Techniques have evolved to minimize growth plate damage and decrease failure rates. This article describes a surgical technique for combined ACL and anterolateral ligament (ALL) reconstruction in skeletally immature patients. The procedure uses a hamstring graft with preserved tibial attachment, creates a transphyseal tibial tunnel for the ACL, and routes the graft "over the top" on the femoral side—passing over the posterior aspect of the lateral femoral condyle and emerging extra-articularly on its lateral surface. The graft is then fixed at the anatomic ALL insertion point on the lateral femoral condyle. The remaining portion of the graft is passed deep to the iliotibial band and fixed to the tibia in an all-epiphyseal fashion at the anatomic ALL insertion point.

In recent years, anterior cruciate ligament (ACL) reconstructions in pediatric patients have increased significantly,[1,2] reflecting higher activity levels and increased participation in competitive sports.[2] This trend is also related to a shift from the historically nonoperative management of ACL tears in skeletally immature individuals, in whom reconstruction was often delayed until skeletal maturity was reached.[3]

Given the drawbacks of a prolonged absence from sports activities until skeletal maturity and the risk of joint damage associated with delayed surgery,[4] several physeal-sparing and physeal-respecting techniques have been developed to minimize growth plate injury and enable ACL reconstruction in this population.[5] The selection of the appropriate technique depends on the patient's skeletal age and remaining growth, with the goal of minimizing long-term sequelae and growth-related complications. Physeal-sparing techniques, such as all-epiphyseal reconstruction—which uses horizontally oriented tunnels confined to the epiphysis—and extraphyseal nonanatomic reconstruction—which avoids bone tunnels entirely by routing the graft over the top of the femur or the front of the tibia, passing it under the intermeniscal ligament, and securing it to the periosteum of the tibial metaphysis—are generally indicated for children with substantial remaining skeletal growth, typically those in Tanner stage 1 (prepubertal).[6] Extraphyseal reconstruction is particularly useful in very young

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children, in whom the epiphysis may be too small to accommodate an all-epiphyseal socket. Partial transphyseal approaches, involving a tibial transphyseal tunnel combined with a femoral all-epiphyseal or extraphyseal technique, may also be used, especially in patients in Tanner stages 2 to 3,[6] because the femoral tunnel's horizontal and peripheral placement poses a higher risk of angular and growth disturbances.[7,8] Fully transphyseal techniques, which involve creating more vertical tunnels in the femur and tibia to reduce physeal damage, are more appropriate for patients approaching skeletal maturity, typically those in Tanner stages 3 to 4.[6]

ACL reconstruction in young patients carries an increased risk of failure, with rates reaching up to 23%[9]—and rising to 32% when contralateral injuries are included[10]—prompting the adoption of alternative strategies to minimize failure. Although recent evidence favors quadriceps and bone-patellar tendon-bone (BTB) autografts over hamstring grafts in terms of failure rates in this population,[9] soft-tissue grafts, including iliotibial band grafts, are often preferred in skeletally immature patients because of a lower risk of physis damage compared with grafts with bone plugs, which can lead to growth arrest and subsequent deformities.[6,11] Additionally, lateral extra-articular procedures, such as lateral extra-articular tenodesis (LET) and anterolateral ligament (ALL) reconstruction, are increasingly performed in high-risk patients, potentially providing greater stability, reduced failure rates, and higher return-to-sport rates.[12]

This article describes a technique for combined ACL and ALL reconstruction in skeletally immature patients using hamstring graft, with a transphyseal tibial tunnel for the ACL, over-the-top femoral passage, fixation at the anatomic ALL femoral site, and all-epiphyseal tibial fixation for the ALL. This partial transphyseal technique, which preserves the femoral physis while allowing a transphyseal tunnel on the tibial side, is ideally indicated for skeletally immature patients with 5 to 7 years of remaining growth who are in Tanner stages 2 to 3.[6]

## Surgical Technique

### Patient Positioning and Setup

The patient is placed supine with a pneumatic tourniquet on the upper thigh. After standard limb preparation and draping, the limb is exsanguinated and the tourniquet inflated.

### Graft Harvesting and Preparation

The hamstring tendons are harvested through an anteromedial tibial incision. After exposure of the semitendinosus and gracilis, the vincula are removed, and both tendons are proximally stripped using an open stripper, preserving their tibial insertions. The remaining muscle tissue is cleared, and the free ends are whipstitched with No. 1 Vicryl suture (Ethicon, Somerville, NJ) (Fig 1).

### Arthroscopy

Standard anterolateral and anteromedial arthroscopic portals are created. Joint inspection is performed to confirm the ACL tear and assess for any associated intra-articular injuries. Any identified chondral or meniscal lesions are treated at this stage.

### Over-the-Top Approach

A 3-cm lateral incision is made over the lateral femoral epicondyle, extending proximally to access the over-the-top position. After the iliotibial band is incised, blunt dissection is performed along the posterior aspect of the lateral femoral condyle and joint capsule with a Kelly forceps under arthroscopic visualization until the underlying bone is exposed (Fig 2). A No. 5-0 Ethibond suture (Ethicon) is then passed through this access to shuttle the graft from the joint to the extra-articular space at the lateral femoral condyle.

### ACL Transphyseal Tibial Tunnel

The ACL tibial tunnel is created conventionally, targeting the center of the native ACL footprint. A tibial guide (ACUFEX Director ACL Tip Aimer; Smith & Nephew, Andover, MA) set at 60° is used to create a more vertical tunnel, minimizing physeal damage. The guidewire is placed and assessed arthroscopically before drilling the tunnel to the graft's diameter, which is typically 6 or 7 mm.

### ACL Graft Passage and Fixation

The graft is passed through the tibial tunnel and femoral over-the-top access and is tensioned and fixed to the femoral periosteum at the anatomic ALL site—posterior and proximal to the lateral epicondyle[13,14]—using 3

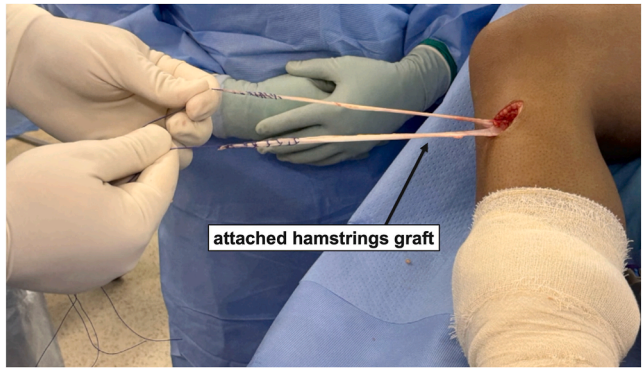


**Fig 1.** Anteromedial view of the right knee and leg. After proximal stripping of the gracilis and semitendinosus tendons with an open tendon stripper—with preservation of their tibial insertions—the free ends are whipstitched using a Vicryl suture.

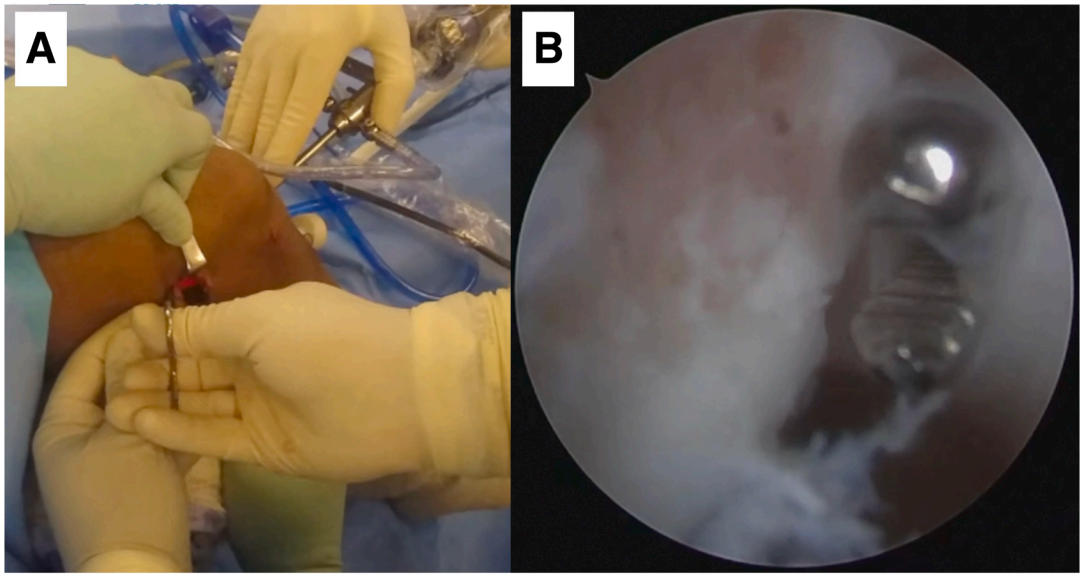


**Fig 2.** (A) Lateral view of the right knee. Blunt dissection is performed in the posterosuperior aspect of the lateral femoral condyle using a Kelly forceps, and the joint capsule is opened under arthroscopic visualization. (B) Arthroscopic view through the anteromedial portal showing the Kelly forceps dissecting the joint capsule in the posterolateral region at the over-the-top position.

interrupted high-strength cruciate sutures (No. 2 Ultrabraid sutures; Smith & Nephew), with the knee flexed at 20° to 30° and a posterior drawer applied. Tibial fixation is then performed using a biocomposite interference screw (Biosure HA; Smith & Nephew), typically 1 mm larger than the drilled tunnel, with the knee flexed to 20° to 30° and a posterior drawer applied (Fig 3).

### ALL All-Epiphyseal Tunnel

A 1-cm incision is made halfway between the Gerdy tubercle and the fibular head. A guidewire is placed at the ALL tibial anatomic point—midway between these landmarks, approximately 0.5 to 1.0 cm distal to the lateral joint line—and inserted into the tibial epiphysis under fluoroscopy, exiting on the medial side (Fig 4). The surgeon takes care to maintain a safe margin above the physis and below the subchondral bone while avoiding conflict with the ACL tunnel by directing the guidewire posteromedially and confirming its trajectory on lateral fluoroscopic images. Once proper positioning is verified, a 6-mm epiphyseal tunnel is drilled.

### ALL Graft Passage and Fixation

The ALL graft is passed beneath the iliotibial band from the femur to the tibial incision and pulled into the tibial tunnel using a shuttle suture. The ALL fixation is performed with a 6-mm interference screw (Biosure HA), with the knee in full extension and neutral rotation. Finally, Lachman and pivot-shift tests are performed to assess reconstruction stability, and the wounds are sutured by layers (Video 1). Pearls and pitfalls of our technique are presented in Table 1, and advantages and disadvantages are listed in Table 2.

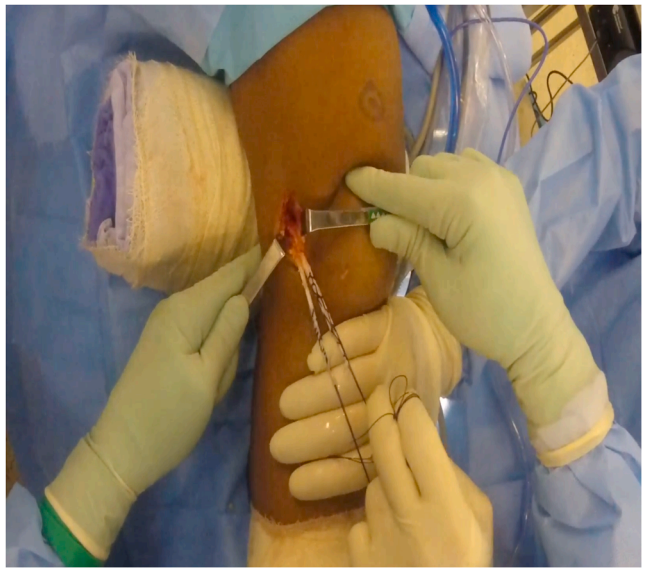

**Fig 3.** Anterolateral view of the right knee. After the hamstring graft is passed through the tibial tunnel and over the top at the lateral femoral condyle, it is tensioned and sutured to the periosteum at a point posterior and proximal to the lateral epicondyle using high-strength sutures while a posterior force is applied to the tibia.

## Discussion

This article describes a combined ACL and ALL reconstruction technique for skeletally immature

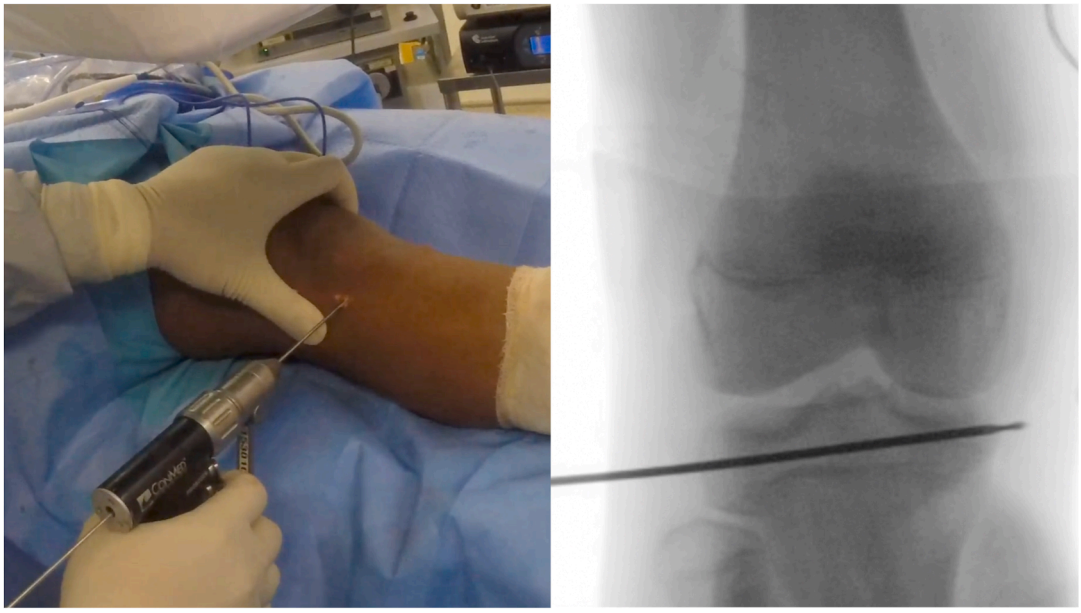

**Fig 4.** To create the tibial tunnel for the anterolateral ligament, the guidewire is positioned midway between the Gerdy tubercle and the fibular head; it is then inserted under fluoroscopic guidance and advanced carefully to avoid the physis and subchondral bone, while the surgeon ensures that it does not converge with the anterior cruciate ligament tibial tunnel.

**Table 1.** Pearls and Pitfalls of Combined ACL-ALL Reconstruction With Over-the-Top Femoral Fixation and Tibial All-Epiphyseal ALL Fixation

| Pearls | Pitfalls |
|---|---|
| The tibial tunnel guide should be set at a 60°-65° angle to create a more vertical transphyseal tunnel, minimizing damage to the tibial physis. | ALL fixation should be performed at full extension and neutral rotation to prevent loss of extension. |
| The surgeon should create the ALL all-epiphyseal tibial tunnel under fluoroscopic guidance, ensuring a safe distance from both the physis and subchondral bone, while avoiding conflict with the tibial tunnel of the ACL. | When accessing the posterior knee capsule to create the over-the-top passage, the surgeon should carefully dissect the intermuscular septum and capsule with blunt instruments, ensuring that the instruments follow the posterior femoral cortex to prevent neurovascular injury. |

ACL, anterior cruciate ligament; ALL, anterolateral ligament.

patients using hamstring autograft. The technique consists of creating a more vertical transphyseal ACL tibial tunnel, an over-the-top femoral graft fixation at the femoral ALL site, and an epiphyseal tibial tunnel for ALL fixation with an interference screw. This approach provides satisfactory stability while preserving the femoral physis and minimizing tibial physeal damage, thereby reducing the risk of failure and growth disturbances.

Several techniques have been described for ACL reconstruction in skeletally immature patients, including transphyseal, all-epiphyseal, and extraphyseal techniques, as well as combinations thereof.[6] Our technique combines all three: a transphyseal tibial tunnel for the ACL, an extraphyseal femoral approach, and an all-epiphyseal tibial tunnel for the ALL. The rationale for the partial transphyseal technique—using a transphyseal tibial tunnel and a physeal-sparing femoral approach—is that femoral physeal injury poses a greater risk of growth disturbances, both because of the more horizontal and peripheral orientation of the anatomic femoral tunnel compared with the vertical and central tibial tunnel, which increases the risk of growth arrest and angular deformities,[7,8] and because of the higher growth potential of the distal femoral physis compared with the tibial physis.[15,16] In 1998, Marcacci et al.[17] described an ACL and extra-articular reconstruction using a 2-strand hamstring graft with preserved tibial insertion. The graft is passed through a tibial tunnel and then through a groove at the over-the-top position on the lateral femoral condyle and is fixed to the femur with staples. The remaining graft is routed beneath the iliotibial band toward the Gerdy tubercle, where it is fixed with a staple. The described technique modifies the approach of Marcacci et al. for pediatric patients, featuring a

**Table 2.** Advantages and Disadvantages of Combined ACL-ALL Reconstruction With Over-the-Top Femoral Fixation and Tibial All-Epiphyseal ALL Fixation

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|---|
| Advantages |
| ACL and ALL reconstruction performed with single graft source, preserving additional graft options in population with greater need for revision |
| Physeal-sparing technique for femoral and ALL tibial fixation, with reduced risk of growth disturbances |
| Disadvantages |
| Two-strand hamstring graft, resulting in smaller intra-articular graft diameter |
| Nonanatomic femoral fixation of ACL |

ACL, anterior cruciate ligament; ALL, anterolateral ligament.

more vertical tibial tunnel to reduce physeal damage, femoral fixation at the anatomic ALL point using high-strength sutures to avoid implants, and anatomic ALL tibial fixation slightly posterior to the Gerdy tubercle through an all-epiphyseal tunnel to preserve the physis.

Regarding graft choice, autografts are preferred in young patients because of higher failure rates of allografts in this population.[18] Soft-tissue grafts such as iliotibial band or hamstring grafts are the most commonly used.[6,19] Grafts with bone plugs such as BTB grafts are avoided in patients with significant remaining growth because the bone plug and interference screws crossing the physis increase the risk of growth disturbances.[11,20,21] The described technique uses a single hamstring graft for both ACL and ALL reconstruction procedures, preserving additional graft options—an advantage in a population at high risk of revision. On the other hand, using a 2-strand hamstring graft, although adequate for extra-articular reinforcement,[22] results in a smaller intra-articular diameter—a limitation of this technique that may raise concerns about its adequacy for ACL reconstruction. However, Zaffagnini et al.[23] reported satisfactory outcomes over a 25-year period using the over-the-top technique with 2-strand hamstring grafts in adults. Studies have reported that intra-articular grafts smaller than 8 mm are associated with higher failure rates[24,25]; however, these studies were conducted on isolated ACL reconstructions, and graft diameter may be a less critical factor when anterolateral procedures are combined with ACL reconstruction.[26] Additionally, preserving the hamstring tendons' tibial insertions may offer benefits such as avoiding the initial phase of avascular necrosis, promoting faster and longer-lasting graft maturation, and providing double tibial fixation with higher pullout strength while maintaining functional outcomes and stability comparable to detached hamstring or BTB autografts.[27]

Aiming to reduce ACL reconstruction failure in high-risk pediatric patients,[28,29] several techniques incorporating lateral extra-articular procedures have been described.[30] The risk of associated ALL injuries in acute ACL injuries has been found to be high.[31] Monaco et al.[32] studied 111 adolescents (mean age, 16.2 ± 1.4 years) and found that combining ACL reconstruction with LET significantly lowered graft rupture rates (0.0% vs 15.0%) without increasing complications compared with isolated ACL reconstruction. Similarly, Perelli et al.[33] evaluated 66 patients, aged 12 to 16 years, who underwent ACL reconstruction with a 4-strand hamstring graft and found that failure rates were significantly lower with combined LET (6.3% vs 14.7%), with no difference in complications. Carrozzo et al.[34] conducted a systematic review of combined ACL reconstruction and LET in 381 skeletally immature patients (mean age, 11.73 years) and found a 4.65% graft failure rate and 95.1% return-to-sport rate after a mean follow-up of 50.1 months. Foissey et al.[35] compared 40 pediatric patients (mean age, 13.8 years) who underwent ACL reconstruction—20 with combined LET and 20 with anatomic ALL reconstruction—and found no difference in outcomes between the techniques. On the basis of these findings and the growing body of adult literature on anterolateral augmentation,[36-38] incorporating an extra-articular procedure in pediatric ACL reconstruction seems to be a reasonable option. The presented procedure is feasible and technically simple, incorporating an anterolateral augmentation that may reduce failure risk without increasing growth disturbances, making it a strong option for ACL reconstruction in skeletally immature patients.

## Disclosures

All authors (C.P.H., A.G.M.d.S., T.M.G., I.F.d.A., I.G.M., A.G., S.Z.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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