Technical Note

Modification of the Hybrid Anatomic Technique for Anterior Cruciate Ligament Reconstruction in Pediatric Patients

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Abstract: The incidence of anterior cruciate ligament (ACL) lesions with Tanner stage ≤4 has been increasing in children. To stabilize the knee, different surgical techniques have been developed for ACL reconstruction in the pediatric population. The use of a hybrid anatomic technique, intra-epiphyseal in the femur and transphysis in the tibia, has been recommended as the technique of choice to reconstruct the ACL in these patients. Despite the favorable results, this technique is not exempt from complications. The aim of this study was to present a simple and reproducible modification of the hybrid anatomic technique for ACL reconstruction in pediatric patients.

The incidence of anterior cruciate ligament (ACL) lesions with Tanner stage ≤4 has been increasing in children.[1,2] To stabilize the knee, different surgical techniques have been developed for ACL reconstruction in the pediatric population.[3-6] According to published results,[7] the use of a hybrid anatomic technique, intra-epiphyseal in the femur and transphysis in the tibia, has been recommended as the technique of choice to reconstruct the ACL in these patients. Despite the favorable results, this technique is not exempt from complications. Those include the failure or breakage of the different retrograde brocade systems and the resulting acute "killer angle" between the femoral tunnel entrance into the joint and the ACL graft.

The aim of this Technical Note is to present a simple and reproducible modification of the hybrid anatomic technique for ACL reconstruction (ACLR) in pediatric patients. It was assumed that this modification would allow for a reconstruction that avoids any damage to the femoral physis, calls for minimal or no x-rays, eliminates the need to use retrograde drill systems, and prevents the killer angle between the graft and the femoral tunnel. Therefore, it can be used in patients with Tanner stages 2, 3, and 4. To confirm the safety and reproducibility of this technique, a cadaveric computed tomography scan study was performed.

Surgical Technique

First, full standard arthroscopic diagnostic surgery is performed. If any meniscal or chondral lesions are found, they are address before the ACLR. Once the ligament injury is confirmed, the semitendinosus and gracilis tendons of the patient are harvested, and the graft is made with the aim of obtaining a minimum diameter of 8 mm.

A minimal cutaneous incision is made on the lateral aspect of the femur, and a longitudinal window is created on the fascia lata. The femoral insertion of the popliteal tendon and the lateral epicondyle are identified. Under arthroscopic visualization from the

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The authors report the following potential conflicts of interest or sources of funding: J.C.M. reports board membership, Smith & Nephew. J.I.E. reports grants, consultant, and other, Smith & Nephew. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received June 7, 2020; accepted September 10, 2020.

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2212-6287/201004

https://doi.org/10.1016/j.eats.2020.09.007

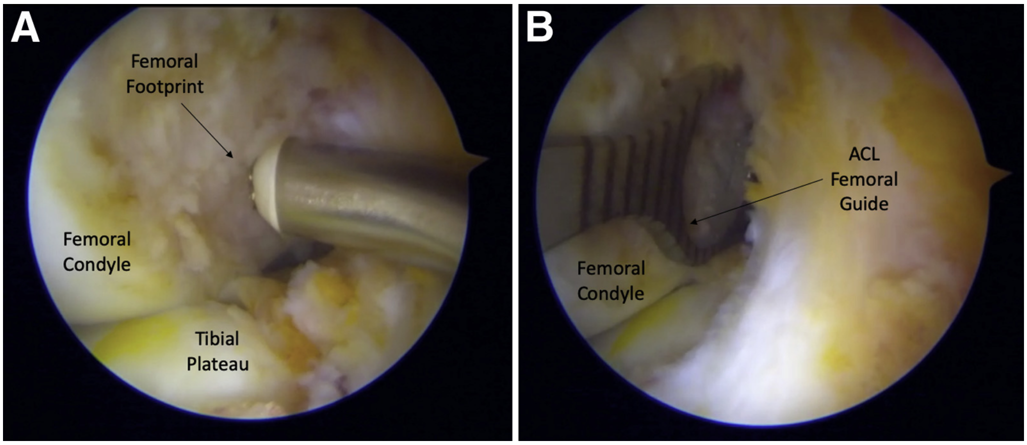

Fig 1. (A) Right knee, view from the high anteromedial portal. Femoral footprint landmark. (B) View from the high anteromedial portal. Pinpoint femoral guide placed through the anterolateral portal to position it in the anatomic femoral footprint of the anterior cruciate ligament.

accessory anteromedial portal, a Pinpoint femoral guide (Smith & Nephew, Andover, MA) is placed through the anterolateral portal to position it in the anatomic femoral footprint of the ACL (Fig 1).

The extra-articular end of the guide is positioned at an intermediate point between the lateral femoral structures previously described, and a 2.4-mm guide wire is placed in an outside-in technique. Then, a full-length femoral tunnel is performed from the outside with a 4-mm drill. Once the total length of the femoral tunnel is measured, a 2.4-mm flexible needle is placed outside-in through it (Fig 2A). The flexible pin is recovered from a low anteromedial portal, and the inside-out part of the tunnel is performed with the Clancy flexible drill (Smith & Nephew) (Fig 2B). The flexibility of the pin prevents the drill from damaging the medial femoral condyle (Fig 3). A tunnel with a minimum diameter of 8 mm and 20 mm in depth is recommended (Fig 4A). The result is a femoral tunnel with a slight curve. Consequently, there is a less acute angle between the future graft and the first millimeters of the tunnel (Fig 4B.

To perform the tibial tunnel, the usual steps of anatomic reconstruction are followed, performing progressive drilling until a diameter of 8 mm is achieved (Fig 5A). A dilator is placed in the tibial tunnel, and the lack of conflict between dilator and the intercondylar notch can be verified in complete extension. Finally,

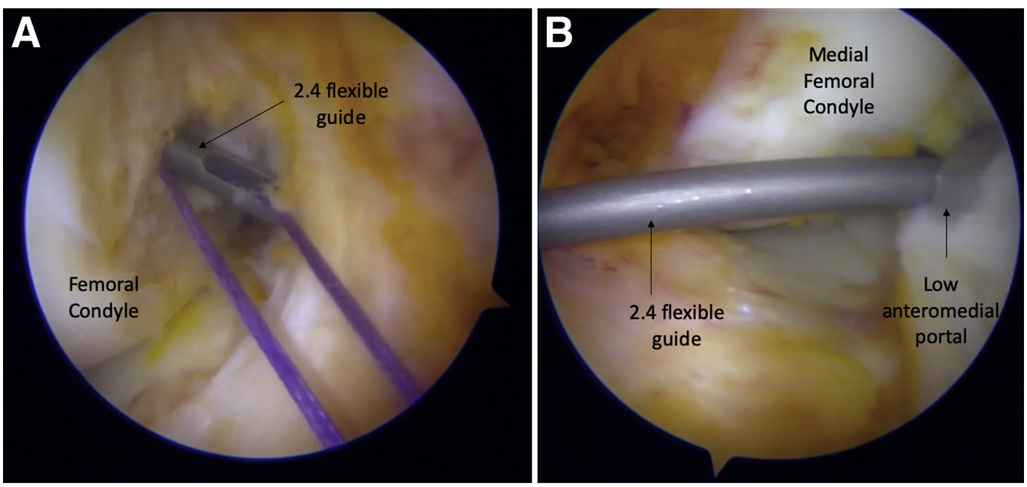

Fig 2. (A) Right knee, view from the high anteromedial portal. A 2.4-mm flexible guide was placed in an outside-in technique. Then, a full-length femoral tunnel was performed from the outside with a 4-mm drill. (B) Right knee, view from the anterolateral portal. The flexible pin was recovered from a low anteromedial portal, and the inside-out part of the tunnel was performed with the Clancy 8-mm flexible drill.

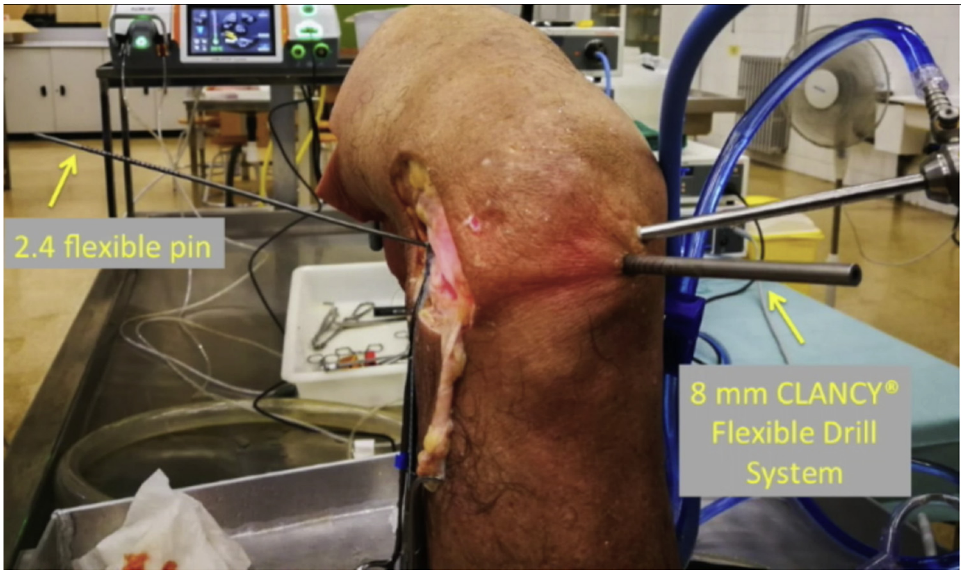

Fig 3. Cadaveric right knee specimen showing the setting of the surgical instruments.

the graft is fixed in the femur with an adjustable cortical suspension device (Fig 5B). It allows for filling the 20-mm femoral tunnel with the plasty and preserving cancellous bone tissue in the most lateral part of the condyle. The graft is fixed at 30° flexion, using a post distal to the tibial physis or an interference screw, dependent on the size of the physis (Fig 6).

A step-by-step description of the surgical technique is summarized in Table 1. Table 2 provides pearls and pitfalls in performing this procedure. Table 3 shows advantages and limitations, and the Video 1 shows the whole technique in detail.

Discussion

There is still controversy as to the appropriate surgical treatment of ACL injuries in skeletally immature patients. Parker et al.[8] described reconstruction by passing hamstring tendons through the anterior aspect of the tibia and over the top of the lateral femoral condyle. Micheli et al.[9] used the iliotibial band as the graft and passed it outside the lateral femoral condyle and through the intercondylar notch. In that case, it was then sutured to the periosteum of the proximal tibia. Despite different ACL reconstruction techniques, there is still discussion about which provides the best results

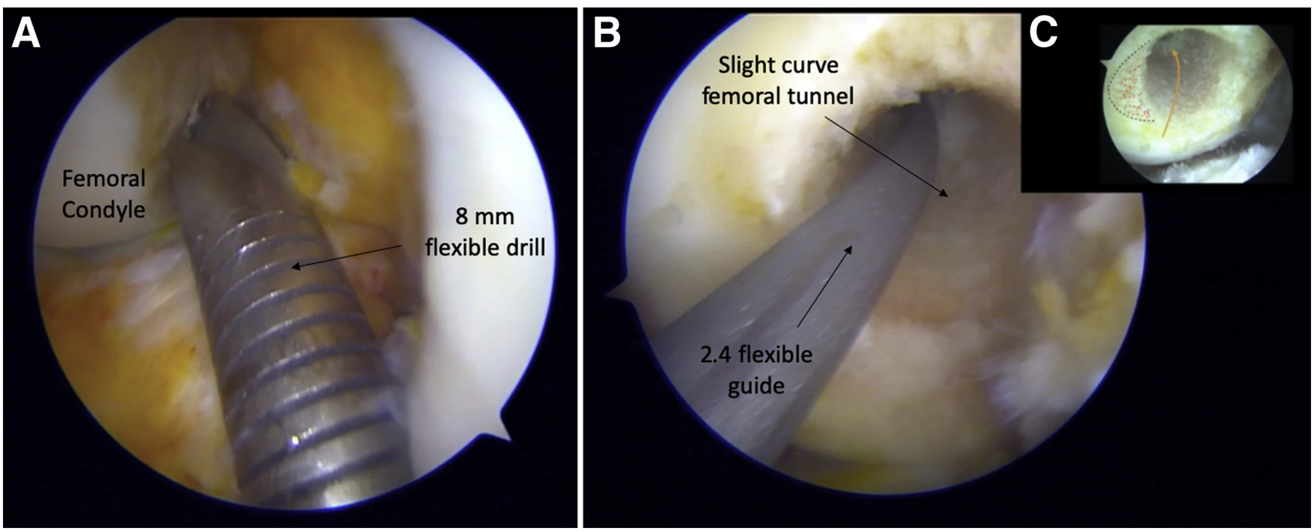

Fig 4. (A) Right knee, view from the high anteromedial portal. A tunnel with a minimum diameter of 8 mm and 20 mm in depth is recommended. (B) Right knee, view from the high anteromedial portal. The result is a femoral tunnel with a slight curve. Consequently, there is a less acute angle between the future graft and the first millimeters of the tunnel.

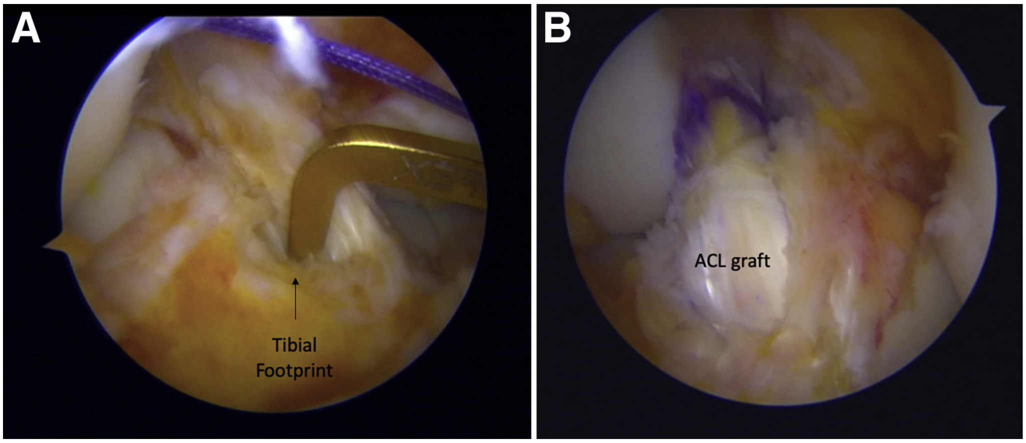

Fig 5. (A) Right knee, view from the anterolateral portal. Tibial tunnel footprint: progressive drilling until a diameter of 8 mm is achieved. (B) Final image of the graft fixed in the femur with an adjustable cortical suspension device.

with the lowest risk of complications for the patient. Several studies have reported premature physeal closure, angular deformities, and leg-length discrepancies with transphyseal ACLR.[10-12] However, a recent systematic review found no statistical difference in the incidence of leg-length discrepancies and angular deformities when comparing transphyseal and physeal-sparing techniques.[11]

Another concerning issue that still is not addressed in the literature is the stress produced in the graft by the acute angle of the femoral tunnel inside the joint. As we have previously stated, when using this modification of the hybrid anatomy technique, we can observe that we obtain a softer angle in the femur that could prevent the shearing effect on the graft.

After analyzing the tomographic data of 8 cadaveric knees in which the femoral tunnel had been performed with the technique that we present here, an average angle of 8° (range 3° to 9°) was observed in the coronal plane, without significant variations in the axial projection. With respect to the relationship between the tunnel and the femoral physis, the average distance was 4 mm (range 3 to 6) and 5 mm (range 2 to 6) in the coronal and sagittal view, respectively.

Fig 6. Right knee. Anteroposterior and lateral x-ray showing no damage to the femoral physis.

Table 1. Step-by-step Modification of the Hybrid Anatomic Technique for Anterior Cruciate Ligament (ACL) Reconstruction in Pediatric Patients

Step	Description
1	The patient is positioned supine at the operative table, with 90° knee flexion, using a distal foot support and a lateral support for the thigh.
2	The semitendinosus and gracilis tendons of the patient are harvested, and the graft is made with the aim of obtaining a minimum diameter of 8 mm.
3	A minimal cutaneous incision is made on the lateral aspect of the femur, and a longitudinal window is created on the fascia lata. The femoral insertion of the popliteal tendon and the lateral epicondyle are identified.
4	From the accessory anteromedial portal, a Pinpoint femoral guide is placed through the anterolateral portal to position it in the anatomic femoral footprint of the ACL.
5	The extra-articular end of the guide is positioned at an intermediate point between the lateral femoral structures, and a 2.4-mm guide wire is placed in an outside-in technique.
6	A full-length femoral tunnel is performed from the outside with a 4-mm drill. Once the total length of the femoral tunnel is measured, a 2.4-mm flexible needle is placed outside-in through it.
7	The flexible pin is recovered from a low anteromedial portal, and the inside-out part of the tunnel is performed with the Clancy flexible drill.
8	To perform the tibial tunnel, the usual steps of anatomic reconstruction are followed, performing progressive drilling until a diameter of 8 mm is achieved.
9	Finally, the graft is fixed in the femur with an adjustable cortical suspension device.
10	The graft is fixed at 30° flexion, using a post distal to the tibial physis or an interference screw, depending on the size of the physis.

The described technique allows for an anatomic reconstruction of the ACL in pediatric patients, avoiding the femoral physis. By making a small lateral incision, and identifying the lateral anatomic structures, it is possible to avoid the use of the image intensifier during surgery. With this modified procedure, it is possible to prevent the acute killer angle between the femoral tunnel and the graft. In addition, it eliminates the need to use retrograde drills and thus the possibility of them failing. Finally, we recommend this technique in patients with Tanner stages 2, 3, and 4, with tibial fixation with a post or interferential screw, depending on the size of the tibial physis.

Table 2. Pearls, Pitfalls, and risks

Pearls
- The correct preoperative planning is essential to formalize the indication of this surgical technique
- If any meniscal or chondral lesions are found, they should be addressed before the anterior cruciate ligament reconstruction
- The flexibility of the pin prevents the drill from damaging the medial femoral condyle
- We recommend having previous experience in knee arthroscopy, as this is a particularly demanding technique
- A tunnel with a minimum diameter of 8 mm and 20 mm in depth is recommended
- A dilator is placed in the tibial tunnel, and the lack of conflict between dilator and the intercondylar notch can be verified in complete extension
Pitfalls and Risks
- This technique should not be used extensively, as it is indicated in patients with Tanner stages 2, 3, and 4 and tibial fixation with a post or interferential screw, depending on the size of the tibial physis.

Table 3. Advantages and Limitations

Advantages
Avoids any damage to the femoral physis
Minimal or no x-rays needed
Eliminates the need to use retrograde drill systems
Prevents the “killer angle” between the graft and the femoral tunnel
Can be used in patients with Tanner stages 2, 3, and 4
Risks and Limitations
Moderate learning curve
Technically demanding procedure
Experience needed in knee arthroscopy and anterior cruciate ligament reconstruction
Need to use specific material such as flexible guides and drills
Risk of medial femoral condyle cartilage injury when introducing the drill through the low anteromedial portal, which is prevented using the flexible guide and drills
Risk of injury to the posterior cruciate ligament when introducing the flexible pin guide into the femur; easily avoidable when pulling the shuttle suture at the end of the flexible guide

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