Technical Note

Pediatric Anterior Cruciate Ligament Reconstruction With Over-the-Top Femoral Position and All-Epiphyseal Tibial Tunnel

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Abstract: In pediatric anterior cruciate ligament reconstruction, many factors should be considered: (1) risk of growth disturbance; (2) high risk of re-tear; (3) determination of the skeletal age, which is sometimes challenging; and (4) no single technique indicated for all patients. The choice of the technique mostly depends on the patients' age and growth potential. Whereas prepubescent patients can be safely treated with physeal sparing techniques (i.e., the Kocher-Micheli technique or its modifications), in postpubescent patients physeal respecting or adult-type reconstructions are generally indicated. In pubescent patients, both all-inside all-epiphyseal and partial transphyseal techniques can be safely performed, but these are not without shortcomings. With the goal of overcoming some of the drawbacks of the existing techniques, the authors describe this technical note. The technique entails an over-the-top femoral position of a 6-strand hamstring graft and an all-epiphyseal tibial tunnel. The femoral physis is completely preserved, and only a 4.5 mm transphyseal tunnel is drilled in the tibia with an all-epiphyseal tibial half socket. With this technique, the graft diameter is adequate, there is no need for fluoroscopy, no risk of graft/tunnel mismatch, and a modified Arnold-Coker lateral tenodesis can be associated via the same lateral incision.

Although the exact incidence of anterior cruciate ligament (ACL) tears in skeletally immature patients is still debated, a 2.3% annual increase of ACL injuries has been reported in this population.[1] In skeletally immature patients, early ACL repair/reconstruction may improve knee function, avoid strict activity modification, and reduce progressive chondral and meniscal injuries caused by recurrent instability.[1]

Pediatric patients with ACL tears represent a very specific population because of the risk of growth disturbance, but also a high risk of ACL re-rupture (4.3%-25%) and contralateral ACL injury (2.9%-15.6%).[2] Different techniques have been described for pediatric ACL reconstruction, with the goal of minimizing the risk of physeal damage. These include (1) physeal-sparing techniques (intra-articular, extra-articular, and combined intra-/extra-articular), (2) partial transphyseal, and (3) physeal respecting or complete transphyseal techniques. Based on the patients' age and growth potential, the most commonly used techniques include: 1) Kocher-Micheli,[3] 2) all-inside, all-epiphyseal,[4] (3) partial transphyseal (transphyseal on the tibial side and physeal sparing on the femur),[1] and (4) transphyseal.[5]

Although no evidence is currently available regarding precise indications, all of these techniques should be in the armamentarium of surgeons performing ACL reconstruction in patients with open physes, because the choice of the surgical procedure mostly depends on the patient's age and growth potential. In prepubescent patients, the Kocher-Micheli technique has shown to be safe with good long-term outcomes and minimal damage to the physes.[3] Pubescent patients can be safely treated with all-inside all-epiphyseal or partial transphyseal (transphyseal on the tibial side and physeal sparing on the femur) techniques.[1,3] Postpubescent patients are generally treated with transphyseal techniques, and these can be (1) physeal respecting techniques (short tunnels, soft tissue grafts, and extracortical fixation on both tibial and femoral sides)

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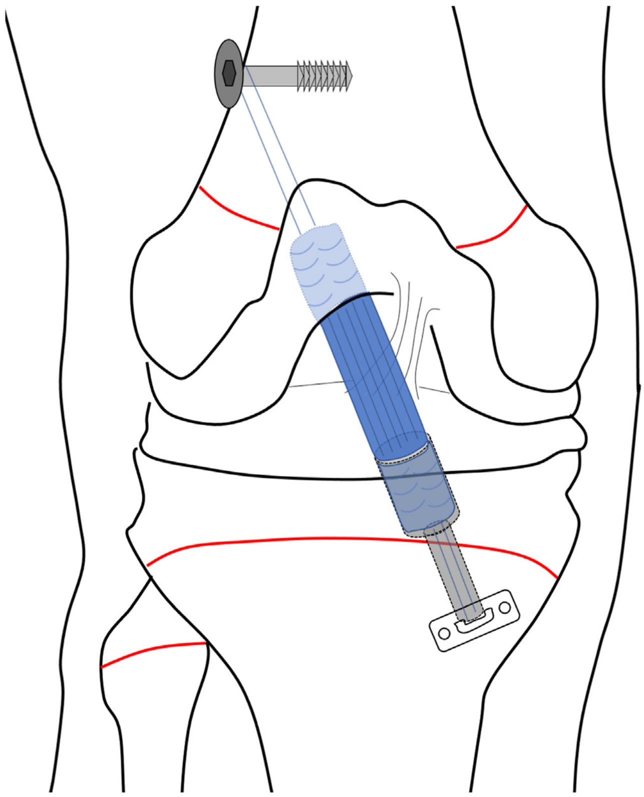

Fig 1. Diagram of the technique described in this article. A 6-strand hamstring graft (or soft tissue quadriceps graft) is positioned over the top on the femur and in an all-epiphyseal tibial half tunnel. The tibial tunnel is created drilling the 4.5 mm retrodrill through the tibial physis and then retro-drilling only the epiphysis.

for patients with minimal residual growth potential or (2) adult-type reconstruction techniques for patients with closed physes.[5]

With the goal of overcoming some of the drawbacks of the existing techniques, the authors describe a technique for pediatric ACL reconstruction in pubescent patients. The technique described in this technical note entails an over-the-top femoral position of a 6-strand hamstring graft and an all epiphyseal tibial tunnel. The rationale of the technique is to completely preserve the femoral physis and to drill only a 4.5 mm transphyseal tunnel on the tibia with an all-epiphyseal tibial half socket (Fig 1). With this technique, the graft diameter is adequate, there is no need for fluoroscopy, no risk of graft/tunnel mismatch, and a modified Arnold-Coker lateral tenodesis can be associated via the same lateral incision.

Surgical Technique

Indications

This technique is indicated in pubescent patients (girls between 12 and 14 years of age and boys between 13 and 15 years), with a Tanner stage of 3 or 4 and a growth potential of less than 2 years (Table 1). The growth potential is evaluated in a multimodal fashion, including (1) age, (2) Tanner stage, (3) evaluation of the growth plates on the knee magnetic resonance imaging scan, (4) growth charts filed by the family pediatrician, (5) patient's and parents' height, and 6) speed of shoes' size change. When the growth potential is controversial, a wrist X-ray film is obtained for Greulich-Pyle evaluation of the skeletal age.

Table 1. Indications for Pediatric Anterior Cruciate Ligament Reconstruction With Over-the-Top Femoral Position and All-Epiphyseal Tibial Tunnel

Indications
Non-repairable ACL tears (preservation of <90% of the ACL stump)
Patients at mild risk of growth disturbance (pubertal phase)
Tanner stage 3-4
Growth potential of 2 years
Females 12-14 years of age, males 13-15 years of age

ACL, anterior cruciate ligament.

Patient Positioning

The patient is administered spinal or general anesthesia and positioned supine on the operating table. A tourniquet is placed on the proximal thigh. Intravenous antibiotic prophylaxis is performed.

A lateral post can be used with the bed intact to obtain leg abduction away from the table and knee flexion up to 120°. A thorough examination with the patient under anesthesia is then carried out. The leg is then elevated, and the tourniquet is inflated to 200 mm Hg.

Graft Harvesting

A 3 cm longitudinal skin incision is made on the anteromedial (AM) aspect of the tibia (Video 1). The incision is placed 2 cm medial to the tibial tubercle, started 3 cm below the joint line and prolonged distally. In skinnier patients the pes anserinus can be palpated under the skin and the incision centered on the tendons. The sartorial fascia is incised proximally and parallel to the tendons. Deep to the retracted sartorial fascia the gracilis tendon proximally and the semitendinosus tendon distally are visualized. The gracilis first and then the semitendinosus tendons are then pulled out with a blunt hook or suture passer. The strong vinculum connecting the semitendinosus and the medial head of the gastrocnemius and all the other minor vincula should be released. An open tendon stripper is used to harvest the tendons (ConMed Linvatec, Largo, FL). The tendons are then detached from the pes anserinus (Video 1).

Graft Preparation

The graft is then taken to the back table for preparation. The residual vincula and muscle are removed. Gracilis and semitendinosus are kept attached together. The muscle-tendon junction end (END1) and the pes anserinus end (END2) of the hamstrings are held with 2 Kocher clamps (Fig 2). Both ends are armed with no. 2 high-resistance

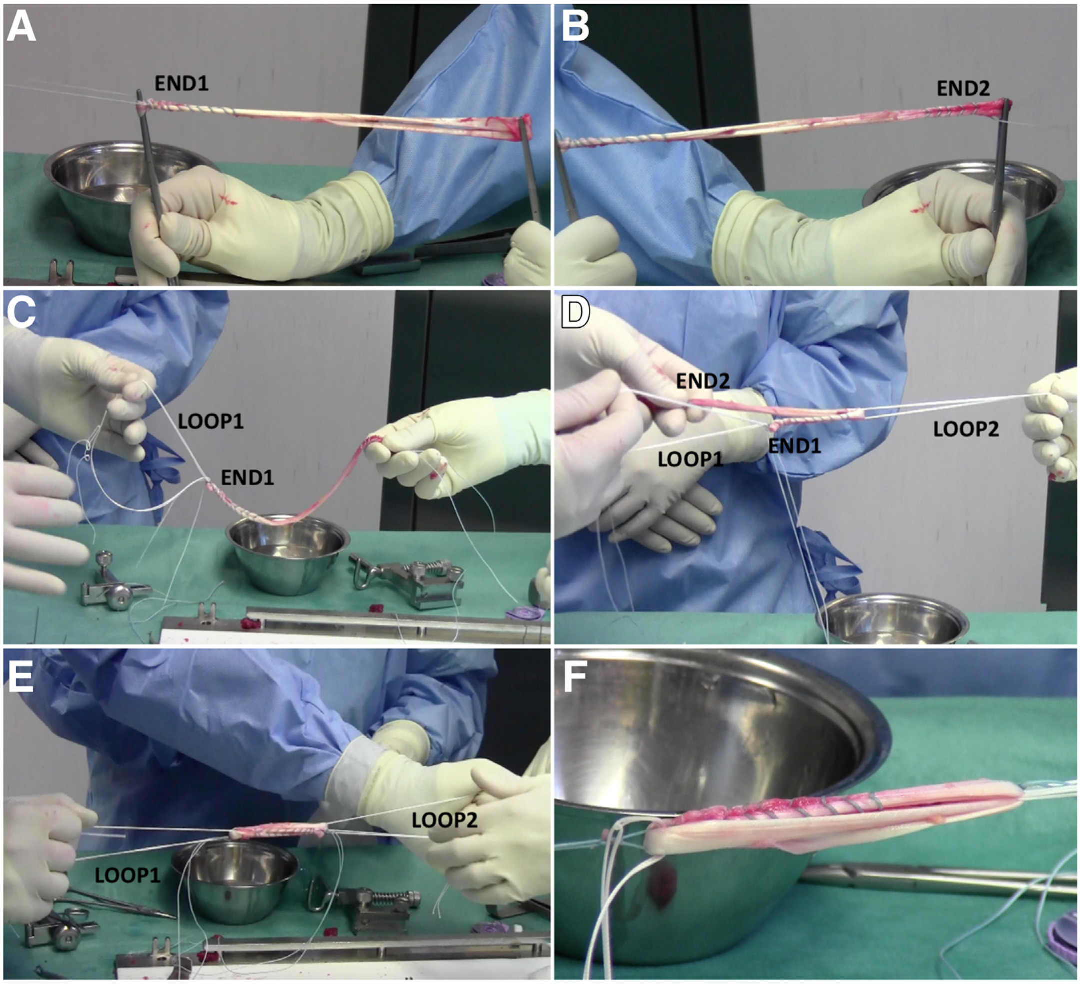

Fig 2. Graft preparation. (A) Gracilis and semitendinosus are kept attached together. (B) The muscle-tendon junction end (END1) and the pes anserinus end (END2) of the hamstrings are held with 2 Kocher clamps. Both ends are armed with no. 2 high-resistance sutures (Fiberloop; Arthrex, Naples, FL). (C) The suture at END1 is then knotted to an adjustable loop device (TightRope ABS, Arthrex), called LOOP1. (D) The END2 is then passed inside a second adjustable loop (LOOP2) device (TightRope ABS), then inside LOOP1, and then knotted to LOOP2. (E) LOOP1 will be used for tibial fixation and LOOP2 for femoral fixation. (F) In this fashion, a 6-strand hamstring graft is obtained.

sutures (Fiberloop; Arthrex, Naples, FL) for 2 to 3 cm, depending on the quality of the graft. The suture at END1 is then knotted to an adjustable loop device (TightRope ABS or ACL TightRope RT; Arthrex), called LOOP1. The END2 is then passed inside a second adjustable loop (LOOP2) device (TightRope ABS), then inside LOOP1, and ultimately knotted to LOOP2. In this fashion, a 6-strand hamstring graft is obtained (Fig 2). The tails of the Fiberloop sutures can be used to arm together the ends of the 6-strand construct with a free needle (first 2 cm from both ends). LOOP1 will be used for tibial fixation and LOOP2 for femoral fixation. The graft is then sized, pre-tensioned at around 15N, and presoaked in Vancomycin (Vancomycin 500 mg in 100 mL of saline solution).

Arthroscopy and Knee Balance

Arthroscopy is performed through standard AM and anterolateral (AL) portals. Any associated pathology (i.e., meniscal tears and chondral injuries) is identified and treated at this point. The remaining ACL stump is removed with a mechanical shaver until the tibial footprint and the intercondylar notch are well visualized. Alternatively, the ACL stump on the tibial side can be preserved, according to the surgeon's preference.

Lateral Femoral Incision and Over-the-Top Passage Creation

A 4 cm skin incision to the lateral femur is performed at the level of the posterior femoral cortex starting slightly distal to the lateral femoral epicondyle and extending it proximally (Fig 3). An 8 to 10 mm large strip of the iliotibial band is harvested longitudinally, just anterior to the intermuscular septum and preserving the distal insertion. The iliotibial band strip is then armed with a #2 braided absorbable suture (i.e., Vicryl

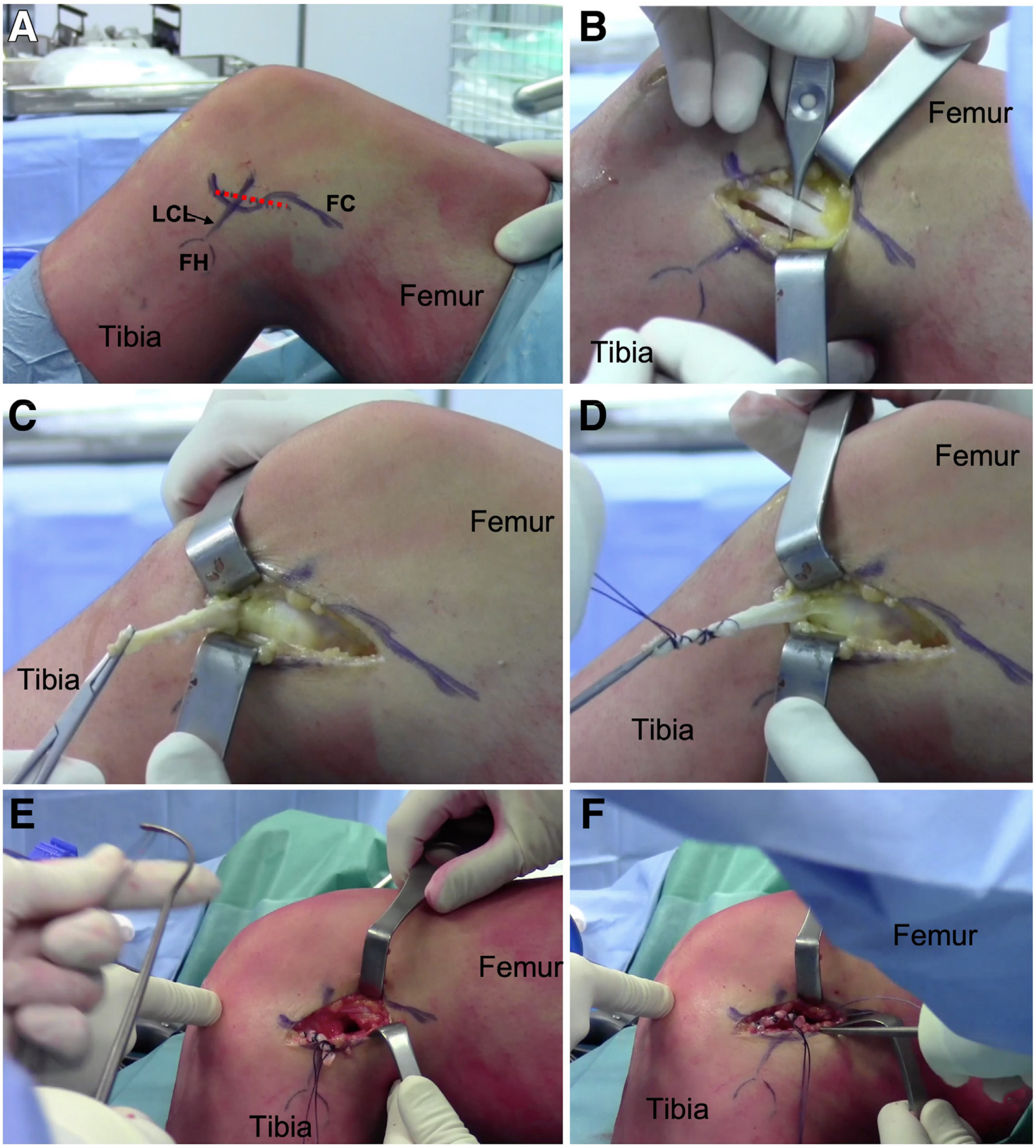

Fig 3. Lateral femoral incision and over-the-top passage creation (left knee, patient supine). (A) A 4 cm skin incision (dotted red line) to the lateral femur is performed at the level of the posterior femoral cortex starting slightly distal to the lateral femoral epicondyle and extending it proximally (FH, fibular head; FC, femoral cortex; LCL, lateral collateral ligament). (B) An 8 to 10 mm large strip of the iliotibial band is harvested longitudinally, just anterior to the intermuscular septum. (C) The distal insertion of the strip preserved. (D) The iliotibial band strip is then armed with a no. 2 braided absorbable suture (i.e., Vicryl no. 2; Ethicon, Somerville, NJ). (E) The vastus lateralis is bluntly separated from the intermuscular septum and retracted anteriorly. After bluntly creating an aperture in the intermuscular septum and being able to palpate the posterior capsule and condyles, a hook loaded with a shuttle suture is used to puncture the posterior capsule in the over-the-top position. (F) The hook is inserted through the lateral incision, advanced along the posterior femoral cortex, and then used to puncture the posterolateral capsule under arthroscopic visualization.

no. 2; Ethicon, Somerville, NJ). The iliotibial band strip will be used later for lateral extra-articular tenodesis. The vastus lateralis is bluntly separated from the intermuscular septum and retracted anteriorly. Metzenbaum scissors are used to bluntly create a hole in the septum. The scissors must be kept in contact with the posterior femoral cortex, aiming the intercondylar notch, in order to avoid damages to the neurovascular bundle (Table 2). A finger is used to enlarge the septum opening, until the posterior aspect of the condyles and the posterior capsule can be palpated. A Gaff hook or a curved Kelly clamp loaded with a no. 2 shuttle suture (i.e., Vicryl no. 2) are used to puncture the posterolateral capsule in an over-the-top position (Figs 3, 4). This can be done in two different ways, according to the surgeon's preference: (1) from distal to proximal, the

Table 2. Technical Tips and Rationale for the Tips

Surgical step	Technical Tip	Rationale
Preoperative	MRI evaluation of the ACL stump	If >90% of the ACL stump is preserved, ACL repair can be considered
Preoperative	Measure on the MRI the longest half socket drillable in the tibial epiphysis (this is usually 18-20 mm)	Avoid to damage the tibial physis when retrodrilling the tibial half socket
Graft choice	Use soft tissue grafts (6 strand HS tendons or a 6-7 cm quadriceps tendon without bone block)	Avoiding bone blocks a the level of the physes and reducing the risk of growth disturbance
Lateral approach to the distal femur	Harvest an 8-10 mm iliotibial band strip, before creating the over-the-top passage for the graft.	This wil create more space to work around the lateral femoral condyle
Lateral approach to the distal femur	bluntly incise the intermuscular septum when approaching the posterior knee capsule	Avoid neurovascular damages
Over-the-top position	Use a Gaff hook or a curved Kelly clamp to punture the posterior knee capsule. Make sure the instruments are sliding along the posterior femoral cortex	Avoid neurovascular damages
Over-the-top position	The over-the-top passage for the graft can be created using the instrument (Gaff hook or curved Kelly clamp) both from the lateral incision and from the arthroscopic portals, based on the size and shape of the instrument used. When using the arthroscopic portal, place your index finger in the lateral incision to protect the neurovascular bundle and drive the intrument outside of the incision.	Avoid neurovascular damages
Tibial tunnel creation	Set the tibial tunnel guide at a 65° angle to have a more vertical 4.5 mm transphyseal tibial tunnel	This will minimize the damage to the tibial physis and avoid placing the tibial button in proximity of the physis
Tibial fixation	Tibial fixation ahould be performed first	The graft will fully seat in the tibial half socket
Femoral fixation	Use a 6.5 mm half threaded cancellous screw and a regular washer without teeth	Avoid damage to the adjustable loop
Femoral fixation	Place the screw in the center of the femoral diafisis as far proximal as you can	Avoid damage to the femoral physis
Femoral fixation	Place the adjustable loop around the screw and tension the loop/graft, before tightening down the screw	Easier loop passage and tentioning when the screw is not fully tightened
Femoral fixation	Do not overtighten the graft	Avoid growth disturbance
Lateral tenodesis	Lateral plasty fixation sould be performed at 30° of knee flexion and foot in neutral rotation	Avoid overconstraining the lateral compartment

ACL, anterior cruciate ligament; HS, hamstrings; MRI, magnetic resonance imaging.

hook is inserted into the AL portal, used to puncture the posterolateral capsule, and then guided out of the lateral incision with a finger or (2) from proximal to distal, the hook or the Kelly clamp are inserted through the lateral incision, advanced along the posterior femoral cortex and then used to puncture the posterolateral capsule under arthroscopic visualization. The shuttle suture is then left in the over-the-top position for future graft passage (Fig 4).

Tibial Tunnel Drilling

An ACL tibial guide is inserted into the joint through the AM portal and positioned on the native ACL footprint. The guide is set to 60° to 65° to achieve an almost perpendicular position with respect to the tibial physis and minimize physeal damage. A 4.5 mm retrodrilling reamer (Flipcutter; Arthrex) is drilled through the tibial physis aiming at the center of the tibial ACL footprint (Fig 5). The tibial guide is then removed, and the drill sleeve is tapped into the AM tibia bone. The blade of the reamer is then flipped to the desired diameter. An all-epiphyseal half socket is then created. The length of the half socket is measured on the patient's magnetic resonance imaging scan before surgery to avoid physeal damage and is usually around 18 mm (Table 2). Another shuttle suture is placed through the

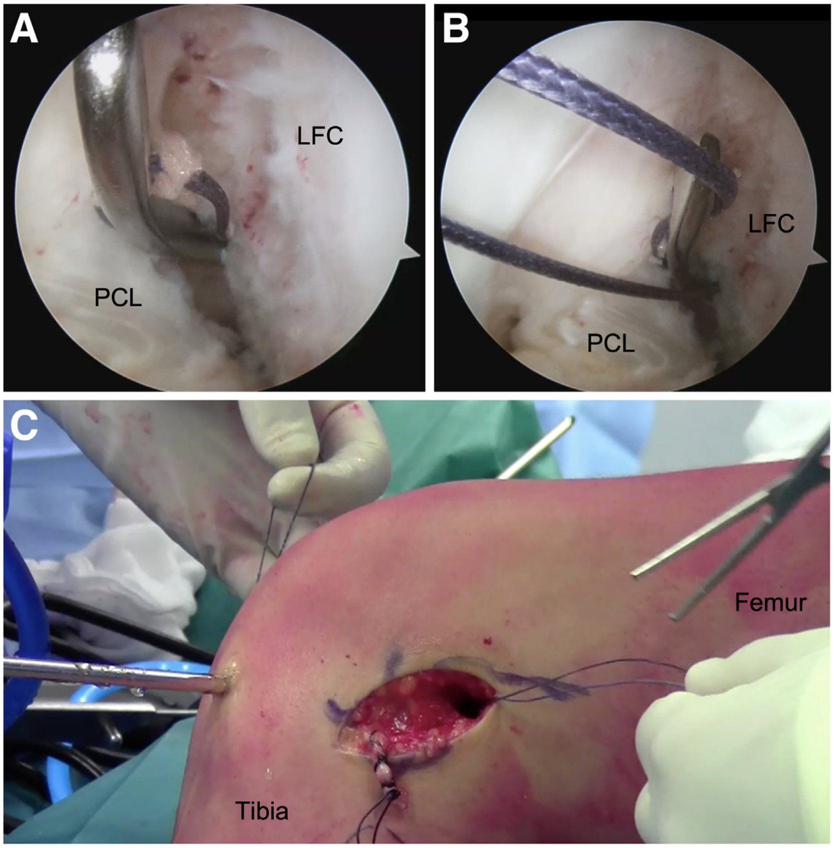

Fig 4. Over-the-top passage creation (left knee, patient supine, knee 90° of flexion). (A) Arthroscopic visualization (AL portal view) of the hook loaded with a shuttle suture and placed in the over-the-top position. (B) The shuttle suture is then retrieved from the AM portal (AL portal view). (C) Shuttle suture is then left in place for future graft passage. AL, anterolateral; AM, anteromedial; LFC, lateral femoral condyle; PCL, posterior cruciate ligament.

tibial tunnel. This is used to retrieve the over-the-top shuttle suture through the tibial tunnel (Fig 5).

Graft Passage and Fixation

The graft is passed into the joint through the femoral incision, from proximal to distal. LOOP1 is used to pull the graft into the tibial half socket (Fig 6). Tibial fixation is then performed, by tightening the adjustable loop sutures over an 11 mm extracortical button (TightRope ABS Button).

The loop device for proximal fixation (LOOP2) is visualized from the proximal incision. The lateral femoral cortex is then exposed. A 4.5 mm drill tip is used to palpate the anterior and posterior femoral cortices and drill a hole at the center of the shaft. The drill hole should be placed proximal enough to allow for graft tensioning and to avoid the femoral growth plate. A 35 mm long, 6.5 mm cancellous half threaded screw with a washer is then partially inserted into the femur. The loop is then placed around the screw and tightened with the knee in full extension. The screw is then tightened down to the bone (Fig 6).

Lateral Extra-Articular Tenodesis

The knee is brought in a figure of four position, in order to easily palpate the lateral collateral ligament. Two small longitudinal incisions are made anterior and posterior to the lateral collateral ligament. A suture passer is passed through these incisions, deep to the lateral collateral ligament. The knee is brought back to 90° of flexion and the suture passer is used to pass the iliotibial band strip (Fig 7) deep to the lateral collateral ligament. The end of the iliotibial band strip is then folded and fixed to itself with a no. 2 braided absorbable suture (i.e., Vicryl no. 2), resulting in a modified Arnold-Coker lateral extra-articular tenodesis. This is performed with the knee at 30° of flexion and the foot neutrally rotated. Final anteroposterior and lateral x-ray views are then obtained (Fig 8).

Tibial Fixation Alternative Option

In the younger patients of the age group in which this technique is indicated (Table 1), a modification of this surgical procedure can be used to avoid high resistance sutures across the tibial physis (Fig 9). In these cases, the graft is prepared as described above with 2 extra Vicryl no. 2 sutures on the tibial end of the graft. The tibial tunnel is drilled as described before, with the addition of a second 2 mm all-epiphyseal tunnel, parallel to the joint line. This is performed with a tip Acufex ACL tibial guide (Acufex; Smith & Nephew,

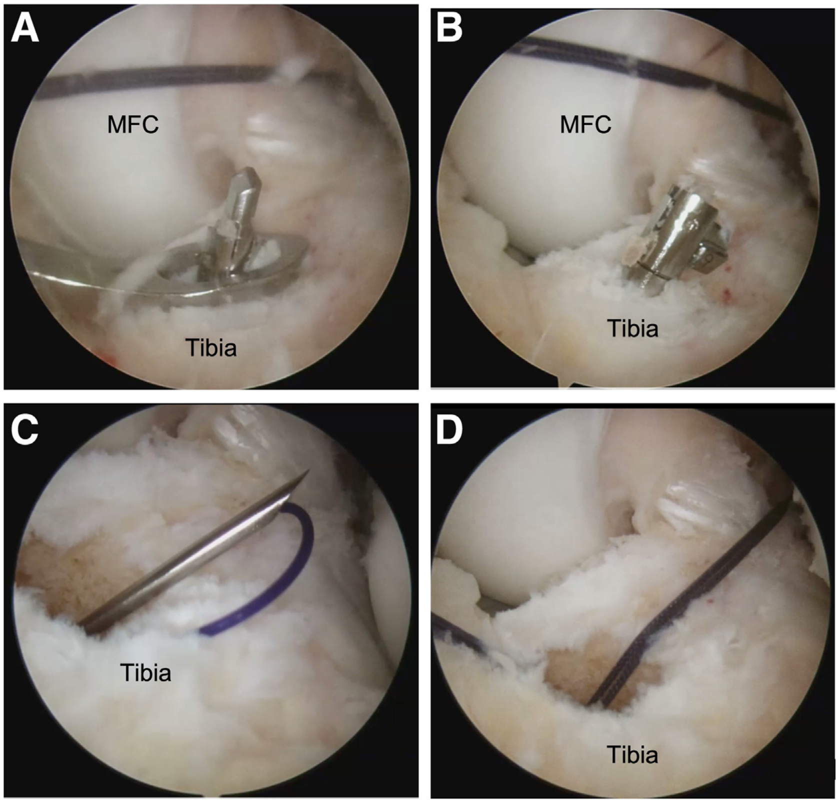

Fig 5. Tibial tunnel creation (Left knee, arthroscopic visualization from anterolateral portal). (A) An ACL tibial guide is inserted into the joint through the anteromedial portal and positioned on the native ACL footprint. A 4.5 mm retrodrilling reamer (Flipcutter; Arthrex, Naples, FL) is drilled through the tibial physis aiming at the center of the tibial ACL footprint. (B) The tibial guide is then removed, and the blade of the reamer is then flipped to the desired diameter. An all-epiphyseal half socket is then created according to the planned length (usually 18 mm). (C) Another shuttle suture is placed through the tibial tunnel. (D) This is used to retrieve the over-the-top shuttle suture through the tibial tunnel. ACL, anterior cruciate ligament; MFC, medial femoral condyle.

Andover, MA) inserted into the tibial half socket and a 2 mm ACL guidewire, drilled starting from the AM tibia 5 mm distal to the joint line and ending inside the tibial half socket. This is done without fluoroscopy. A no. 2 PDS shuttle suture (Ethicon) is then inserted with a spinal needle inside the 2 mm tunnel. The 2 Vicryl no. 2 sutures arming the graft are retrieved from the 4.5 mm transphyseal tunnel and the TightRope ABS device is retrieved from the all-epiphyseal 2 mm tunnel. The 2 Vicryl no. 2 sutures are knotted on an Endobutton (Smith & Nephew Endoscopy). The button is also fixed to the periosteum with 2 no. 2.0 non-absorbable stitches (i.e., Ti-Cron no. 2.0; Medtronic, Dublin, Ireland) to avoid a floating button after Vicryl resorption. The TightRope ABS device is attached to a TightRope ABS 11 mm button. With this modification, no non-resorbable high resistance sutures are placed across the physis.

Postoperative Regimen

After surgery, immediate weightbearing and full range of motion are allowed. A knee brace is usually not necessary. During the first 6 weeks full range of motion should be achieved, and strengthening exercises are commenced. Non-cutting and non-twisting sports such as swimming, biking, and running in a straight line are allowed at 12 weeks after surgery. Return to full activity is usually allowed between 9 and 12 months after surgery. Exceptions to this protocol may be dictated by combined chondral or meniscal repair procedures, age, and compliance of the patient.

Discussion

Pediatric ACL reconstruction is definitely a challenge for the orthopaedic surgeon. In this particular population, many factors should be considered: (1) the risk of growth disturbance makes the surgery more demanding than in skeletally mature patients; (2) the risk of retear is higher compared with adults; (3) determining the skeletal age is sometimes challenging and multifactorial, with no established reliable methods; (4) one technique is not indicated for all patients; (5) timing for return to play is usually longer compared to adults (between 9 and 12 months after surgery).

Regarding the choice of the surgical technique, this mostly depends on the patients age and growth potential. Whereas prepubescent patients can be safely treated with the original Kocher-Micheli technique or its modifications, in postpubescent patients physeal respecting or adult type reconstructions are generally indicated.

In pubescent patients, both all-inside all-epiphyseal and partial transphyseal techniques can be safely

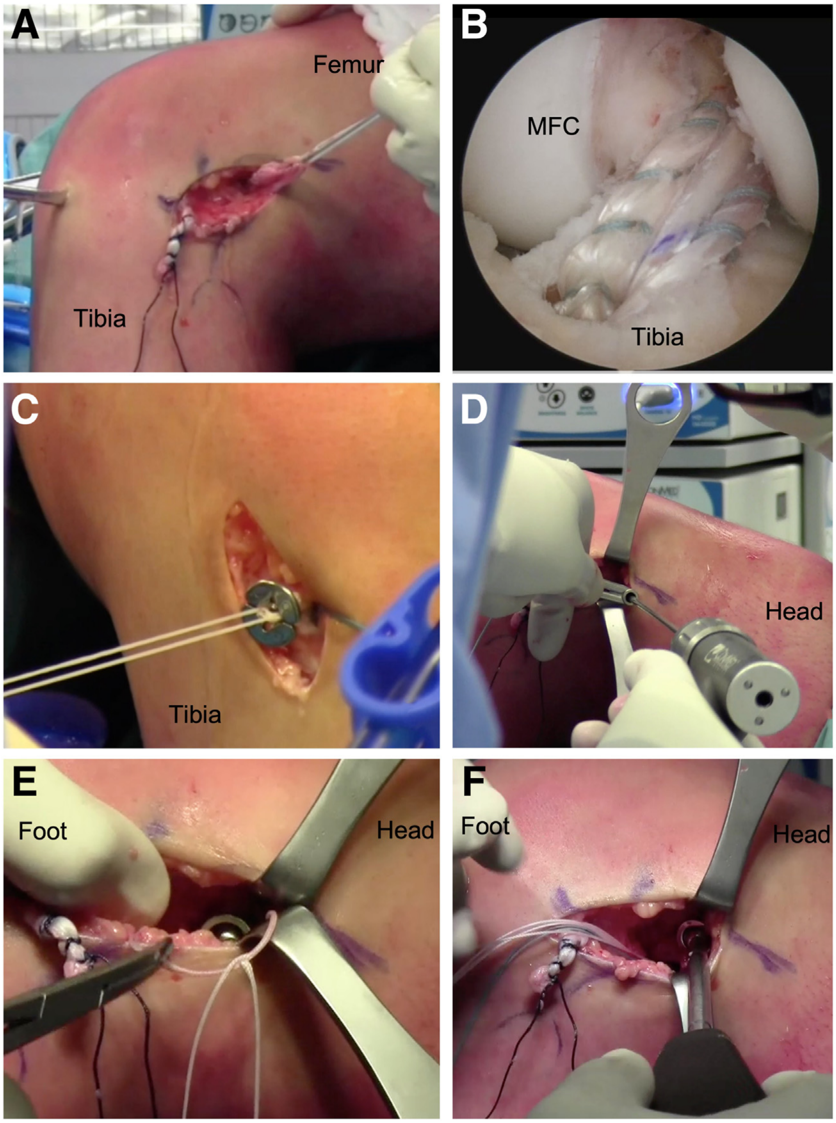

Fig 6. Graft passage and fixation (left knee, patient supine). (A) The graft is passed into the joint through the femoral incision, from proximal to distal. (B) LOOP1 is used to pull the graft into the tibial half socket (anterolateral portal view). (C) Tibial fixation is then performed by tightening the adjustable loop sutures over an 11 mm extracortical button (TightRope ABS Button, Arthrex, Naples, FL). (D) The lateral femoral cortex is then exposed, and a 4.5 mm drill tip is used to drill a hole at the center of the shaft. (E) A 35 mm long, 6.5 mm cancellous half threaded screw with a washer is then partially inserted into the femur. The loop is then placed around the screw and tightened with the knee in full extension. (F) The screw is then tightened down to the bone. MFC, medial femoral condyle.

performed, but these procedures are not without shortcomings. The shortcomings of all-inside all-epiphyseal pediatric ACL reconstruction include (1) the need for fluoroscopy to correctly place the tunnels and, in some cases, this is not even enough to avoid physeal damage[4]; (2) graft-tunnel mismatch can be a complication (a too-long graft can result in a lax ligament and a too-short graft might not seat properly in the sockets, with poor tendon-bone integration); (3) in small knees, the all-epiphyseal tibial tunnel is very horizontal, with the risk of creating a large oval intra-articular aperture during retrograde drilling.[6] The drawbacks of partial transphyseal technique include (1) a small vertical tunnel is created through the tibial physis and (2) to minimize the physeal damage, a small graft (usually a 2-strand semitendinosus autograft) is generally used. In addition, both techniques do not entail an associated AL tenodesis. There is some agreement among authors that AL tenodesis/AL ligament reconstruction should be indicated in patients at high risk of ACL re-rupture and pediatric patients certainly represent a risky population.[7]

With the goal of overcoming some of the drawbacks of the existing techniques, the authors developed the technique described in this paper. This technique has several advantages (Table 3): (1) no direct damage to the femoral growth plate; (2) minimal damage to the tibial physis (4.5 mm drill hole); (3) no need for intraoperative X rays, as opposed to all-inside all-epiphyseal pediatric ACL reconstruction; (4) no risk of graft-tunnel mismatch; (5) larger intra-articular graft (usually a 6-strand hamstring or soft tissue quadriceps graft) than with partial transphyseal techniques; (6) anatomical reconstruction (over-the-top position is

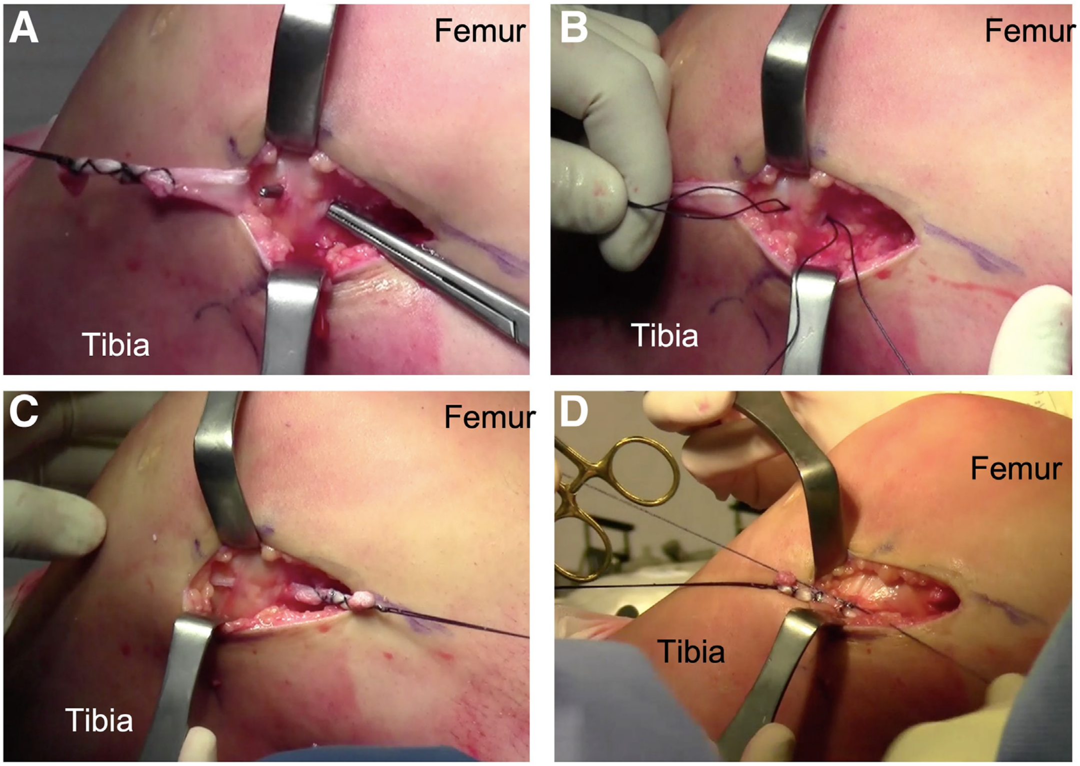

Fig 7. Modified Arnold-Coker lateral extra-articular tenodesis (left knee, patient supine, knee 90° of flexion). (A) After palpating the lateral collateral ligament in a figure-of-4 position, 2 small incisions are made anterior and posterior to the lateral collateral ligament. A suture passer is passed through these incisions, deep to the lateral collateral ligament. (B, C) The suture passer is used to pass the iliotibial band strip under the lateral collateral ligament. (D) The end of the iliotibial band strip is then folded and fixed on itself, resulting in a modified Arnold-Coker lateral extra-articular tenodesis. This is performed with the knee at 30° of flexion and the foot neutrally rotated.

considered anatomical by many authors); (7) easy adjustment of the graft tension because of the adjustable loops; (8) the possibility of combining a lateral tenodesis through the same lateral incision; and (9) no risk of having a too short graft, as opposed to partial transphyseal techniques.

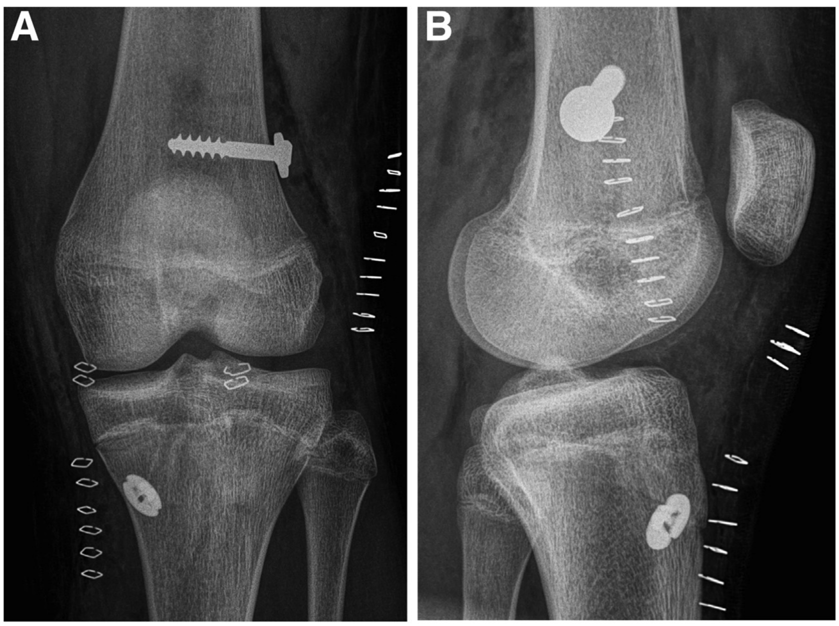

Fig 8. Final anteroposterior (A) and lateral (B) x-ray views.

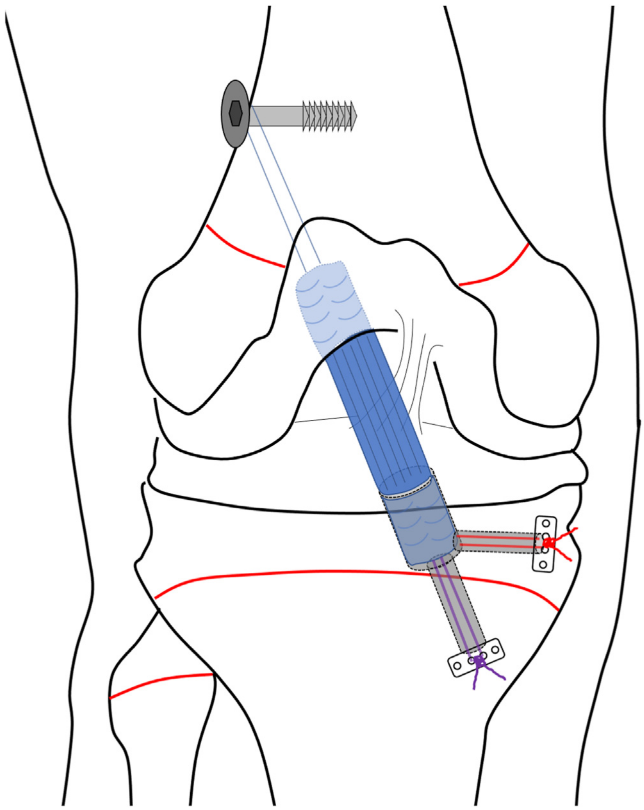

Fig 9. Diagram of an alternative option for tibial fixation. A modification of this surgical procedure can be used in order to avoid high resistance sutures across the tibial physis The graft is prepared as described before with the adjunct of 2 Vicryl no. 2 sutures (Ethicon, Somerville, NJ) on the tibial end of the graft. The tibial tunnel is drilled as described before, with the addition of a second 2 mm all-epiphyseal tunnel, parallel to the joint line. The 2 Vicryl no. 2 sutures arming the graft are retrieved from the 4.5 mm transphyseal tunnel (purple sutures on the diagram) and the TightRope ABS device (Arthrex, Naples, FL) is retrieved from the all-epiphyseal 2 mm tunnel (red sutures on the diagram). The 2 Vicryl no. 2 sutures are knotted on an Endobutton (Smith & Nephew Endoscopy, Andover, MA). The TightRope ABS device is attached to a TightRope ABS 11 mm button (Arthrex).

The main disadvantages of this technique include the 4.5 mm tunnel through the tibial physis and fixation across the tibial growth plate (Table 3). However, drilling small and perpendicular tunnels through the growth plate has been proven to be safe, with minimal damage to the physis and no risk of growth disturbance. Regarding the suspension fixation spanning across the growth plate, this has been described for pull-out tibia spine avulsion fixation.[8] In addition, the described technique has been used at our institution for the past 5 years with no complications regarding growth disturbance. However, in the younger patients of the age group in which this technique is indicated (Table 1), the technique can be modified in order to avoid high resistance sutures across the physis (Fig 9). With this modification, the surgeon can still benefit from the advantages of creating the tibial tunnel as described (no fluoroscopy, no horizontal tibial tunnel with large intra-articular aperture), but at the same time can avoid the across-the-physis fixation.

Table 3. Advantages and disadvantages of this technique compared to the existing techniques

Advantages
Physeal sparing on the femoral side
Minimal damage on the tibial physis (4.5 mm drill hole)
No need for intraoperative X ray films, as opposed to all-inside all-epiphyseal pediatric ACL reconstruction
No graft-tunnel mismatch, as opposed to all-inside all-epiphyseal pediatric ACL reconstruction
Large intra-articular graft, as opposed to partial transphyseal pediatric ACL reconstruction
Anatomical reconstruction (over-the-top position is considered anatomical by many authors)
Easy adjustment of the graft tension
Lateral tenodesis can be performed through the same lateral incision
No risk of having a too short graft, as opposed to partial transphyseal pediatric ACL reconstruction
Disadvantages
4.5 mm transphyseal tibial tunnel
Across the tibial physis fixation

ACL, anterior cruciate ligament.

Disclosure

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