Technical Note

Modified MacIntosh (Over-the-Top Iliotibial Band Autograft) Technique for Pediatric Anterior Cruciate Ligament Reconstruction Using Knotless All-Suture Anchor Fixation

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Abstract: Anterior cruciate ligament (ACL) injury is a significant cause of injury among pediatric patients with an increasing incidence. ACL insufficiency can lead to lifelong disability as further joint deterioration occurs in the form of meniscal and subsequently chondral pathology. Techniques for pediatric ACL reconstruction can broadly be classified as physeal-sparing and non–physeal-sparing. Bone age is frequently used when deciding which technique to employ. Patients are candidates for physeal-sparing, over-the-top iliotibial band reconstruction (i.e., modified MacIntosh II) when they have >4 years remaining before skeletal maturity. The modified Macintosh procedure provides both intra- and extra-articular rotational and translational constraint. This Technical Note describes the senior author's modified MacIntosh technique using knotless all-suture anchor fixation in a suture staple technique to mitigate risk of physeal damage.

Anterior cruciate ligament (ACL) injury is a significant cause of injury among pediatric patients with an increasing incidence in the United States and abroad.[1,2] ACL insufficiency can lead to lifelong disability as further joint deterioration occurs in the form of meniscal and chondral pathology.[3-8] This impacts both the physical and mental health of pediatric patients as their identities and views of self-worth are often tied to athletic activity.[9] Pediatric sport specialization, an ever-growing trend, increases the risk of ACL injury.[1,10] Pediatric ACL injuries were historically treated nonoperatively until skeletal maturity.[11] Over time, the paradigm has shifted toward time-zero treatment for ACL injury to avoid the deleterious effects of ACL insufficiency.[3-8]

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Many techniques have been described to treat pediatric ACL insufficiency. These techniques are broadly classified as physeal-sparing (PS) and non–physeal-sparing (NPS).[12-14] PS techniques are used in younger adolescents and have the advantage of avoiding physeal bone tunnels. PS techniques include variations of the classically described MacIntosh II (i.e., over-the-top iliotibial band [ITB] reconstruction)[15-17] and all-epiphyseal reconstructions.[18,19] NPS techniques are used in older adolescents who have a lower potential for growth disturbance.[12-14] NPS techniques attempt to minimize physeal trauma with perpendicular drill tunnels crossing 1 or both of the femoral/tibial physes.[12-14]

It is the preference of the senior author (C.W.N.) to perform PS ACL reconstruction when patients have >4 years remaining before skeletal maturity based on bone age studies. For patients with Sherman 1 ACL tears,[20] ACL repair in an all-epiphyseal technique may be used. For patients with midsubstance ACL tears, an over-the-top intra- and extra-articular ITB reconstruction (i.e., modified MacIntosh II) may be performed. This Technical Note presents the senior author's modified MacIntosh technique for pediatric ACL reconstruction using knotless all-suture anchor fixation.

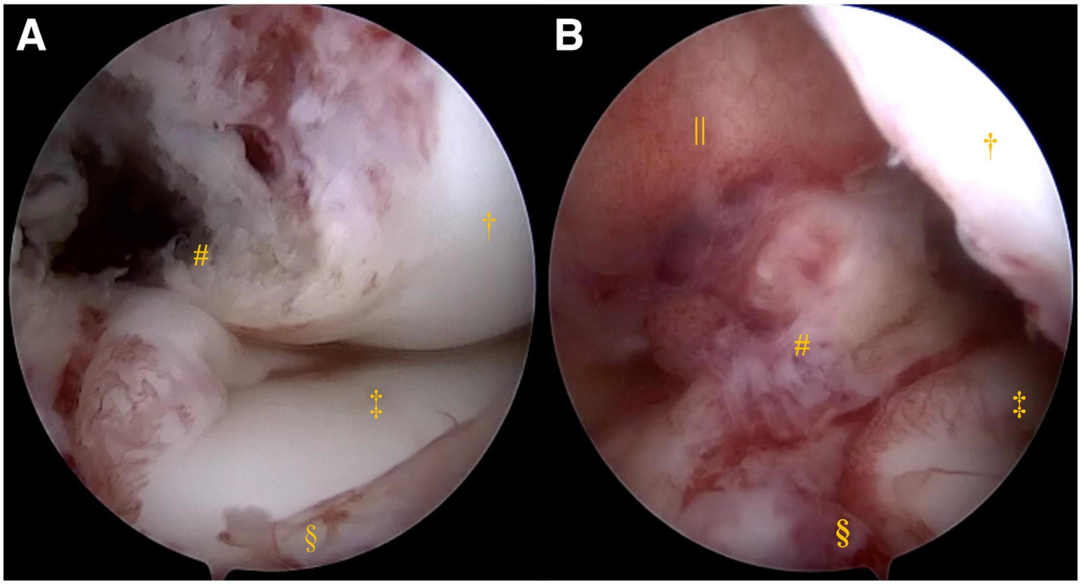

Fig 1. Left knee arthroscopic photographs from an anterolateral viewing portal of the lateral notch (A) and tibial anterior cruciate ligament (ACL) insertion (B) depicting ACL insufficiency with the remnant ACL sclerosed to the posterior cruciate ligament. †Lateral femoral condyle. ‡Lateral tibial plateau. §Anterior horn lateral meniscus. ||Medial notch posterior cruciate ligament insertion. #Remnant ACL fibers.

Surgical Technique

Diagnostic arthroscopy is performed to confirm that the torn ACL is not amenable to PS ACL repair (Fig 1, Video 1). Concomitant pathology is treated (Fig 2), and ACL remnant debridement is performed. A 5- to 6-cm longitudinal incision is made laterally from Gerdy's tubercle tracking proximally over the lateral epicondyle (Fig 3). Blunt dissection is performed to the ITB. Soft tissue is cleared off the ITB anteriorly, posteriorly, and proximally to ensure full-width visualization (Fig 4). A separate 2- to 3-cm incision is then made 15 cm proximal to the lateral epicondyle (Fig 3). The ITB is identified proximally in a similar fashion. Subcutaneous exposure of the ITB is then connected between the 2 incisions by tunneling with a Cobb elevator (Fig 4).

A No. 15 scalpel is used to create a small stab incision at the posterior one-third of the ITB at the approximate level of the joint line (without capsular penetration). Long Metzenbaum scissors are used to extend the fascial incision proximally to the proximal incision. Another stab incision is made 2 cm anterior from the posterior one-third rent (Fig 5A), and the process is repeated (Fig 5B). After confirming a length of 15 cm, the 2-cm strip of ITB is cut transversely at the proximal incision to complete the proximal harvest. The 2-cm by 15-cm strip of ITB, now cut proximally, is delivered out of the wound distally (Fig 6).

A FiberLoop suture (Arthrex) is used to whipstitch 2 to 4 cm of the free end of the harvested ITB (Fig 6). The 2-cm-wide swath of ITB is released down to the level of Gerdy's tubercle for increased mobilization and left attached distally (Fig 6A). This insertion is necessary to anchor the harvested ITB strip for eventual extra-articular and intra-articular reconstruction. Also note that the deep Kaplan's fibers are not released from the posterior ITB to preserve their function as a rotational constraint.[21]

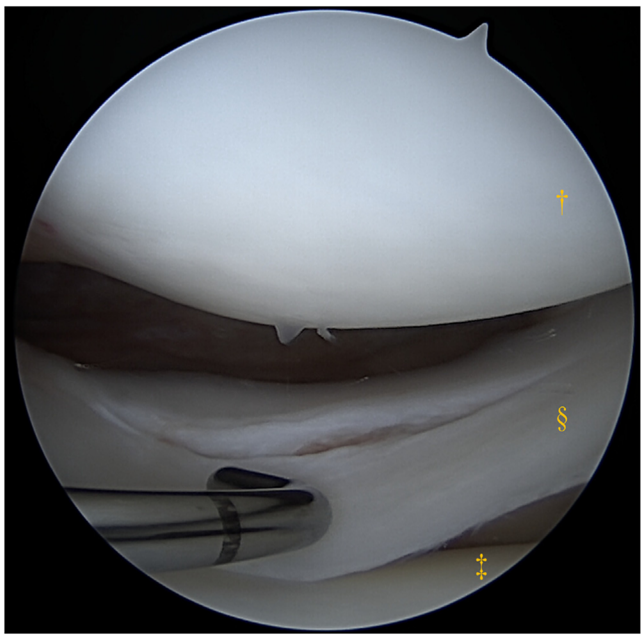

Fig 2. Left knee arthroscopic photograph from an anterolateral viewing portal of the medial compartment demonstrating a horizontal mid-body medial meniscus tear. †Medial femoral condyle. ‡Medial tibial plateau. §Medial meniscus.

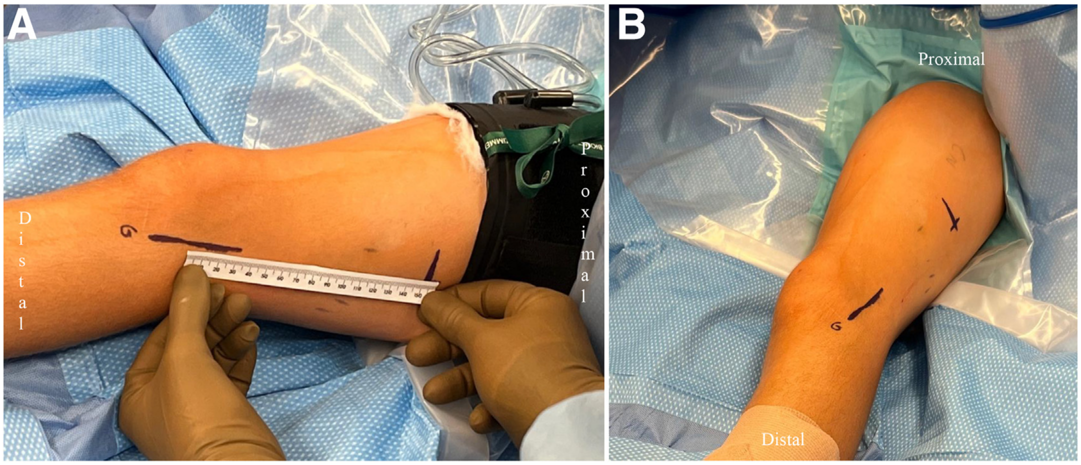

Fig 3. Left lateral lower extremity clinical photograph viewing from the lateral aspect of the knee with a measurement made 15 cm proximal to the lateral epicondyle. A 5- to 6-cm longitudinal incision is made at the lateral knee from Gerdy's tubercle and tracking over the lateral epicondyle proximally. A separate 2- to 3-cm transverse incision is then made 15 cm proximal to the lateral epicondyle. (G, Gerdy's tubercle.)

Dissection is performed along the posterolateral aspect of the femoral condyle, through the intermuscular septum, and into the notch intra-articularly. An arthroscope is used to visualize a clamp as it enters the notch (Fig 7A). The looped end of a FiberLink suture (Arthrex) is delivered to the clamp from the anteromedial portal (Fig 7B) and brought around the posterolateral femoral condyle (Fig 7 C and D). The FiberLink is then used as a shuttle suture to deliver the whipstitched ITB autograft into the joint (Fig 7E). The free end of whipstitched ITB is then exiting the anteromedial portal (Fig 7F).

Fig 4. Left lateral lower extremity clinical photograph viewing from the lateral aspect of the knee demonstrating blunt dissection with a Cobb elevator to clear soft tissue off the iliotibial band proximally toward the proximal incision (transverse purple line). (ITB, iliotibial band.)

An extra-articular tenodesis of the ITB autograft into the periosteum at the posterolateral femur is performed to act as an extra-articular rotational constraint. The knee is placed into 30° of flexion with neutral rotation, and tension is pulled on the whipstitched ITB. A 1.3-mm FiberTape (Arthrex) is used to pass a horizontal mattress stitch through the ITB and periosteum at the approximate location of the intermuscular septum (Fig 8). This is reinforced with a figure-of-8 suture.

A 2-cm anteromedial proximal tibia incision is made and dissection is performed down to bone. A hemostat is used to bluntly dissect proximally into the joint (Fig 9A). A shaver is used to clear the fat pad from around the hemostat, and a burr is used to create a small trough in the anterior tibial bone (Fig 9B) to improve local biology via bleeding to promote long-term incorporation at the graft-bone interface (Fig 9C). The free end of the ITB autograft is retrieved and shuttled beneath the fat pad and beneath the intermeniscal ligament with a hemostat clamp (Fig 9D).

The periosteum over the anteromedial tibia is incised longitudinally. Fluoroscopy is used to confirm an extraphyseal, proximal metaphyseal location (Fig 10), and a double-loaded 2.6-mm FiberTak anchor (Arthrex) is placed at the anteromedial proximal tibia angled away from the physis (Fig 11A). The ITB autograft is fixed to the proximal tibia by use of the FiberTak anchor in suture staple configuration (Fig 12).[22] The periosteum is reapproximated back over the distal portion of the autograft with an absorbable figure-of-8 suture (Fig 11B).

The knee is taken through range of motion to confirm full flexion and extension. Lachman's and pivot-shift

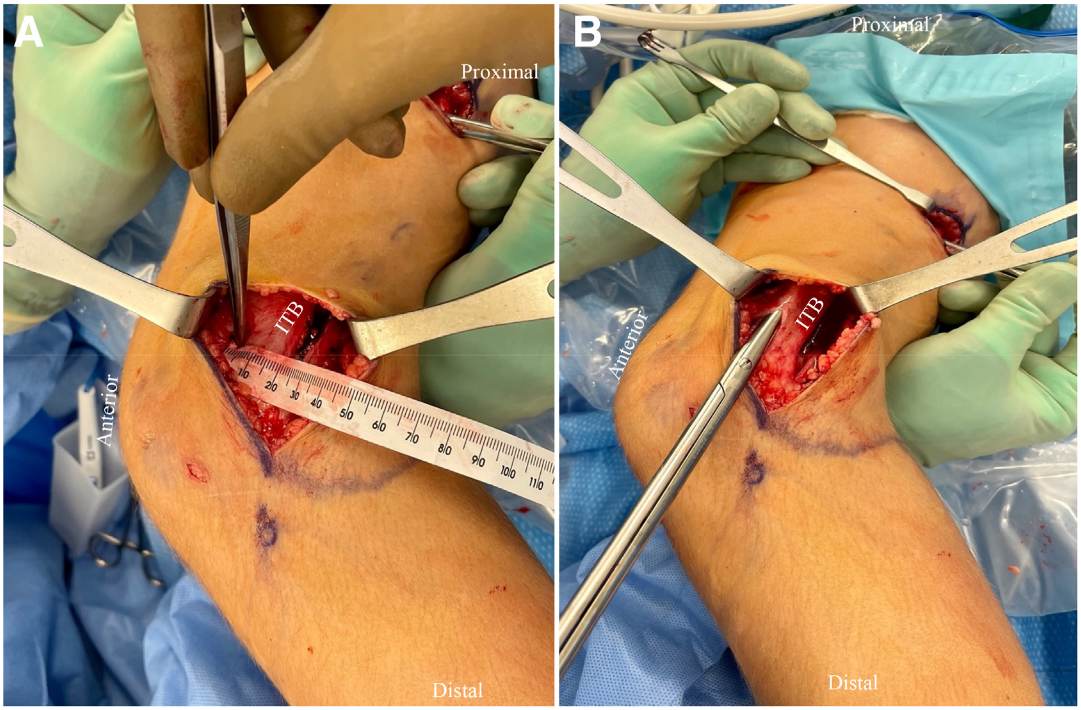

Fig 5. Left lateral lower extremity clinical photograph viewing from the lateral aspect of the knee. (A) A measurement is made 2 cm anterior from the previously created posterior one-third iliotibial band rent to confirm appropriate graft width. Another stab incision is made, and the rent is extended proximally with Metzenbaum scissors to achieve a 15-cm × 2-cm swath of ITB autograft (B). (ITB, iliotibial band.)

examinations are confirmed to be equivalent to the contralateral side (based on preoperative contralateral assessment). Appropriate intra-articular tension is confirmed arthroscopically (Fig 13). The tourniquet is let down, and hemostasis is achieved both extra- and intra-articularly as postoperative hemarthrosis may disproportionately predispose pediatric patients toward arthrofibrosis. After multilayered skin closure, the knee is placed in a hinged knee brace locked in extension.

Rehabilitation Protocol

If concomitant meniscal pathology is treated, the patient is kept toe-touch weightbearing for 2 to 6 weeks depending on tear/repair morphology. Active range of motion is restrained to 0° to 30° for weeks 0 to 2 and then 0° to 90° for weeks 2 to 6 before progression is allowed as tolerated. In the absence of concomitant meniscal pathology, the patient is kept toe-touch weightbearing for the first few days until quadriceps

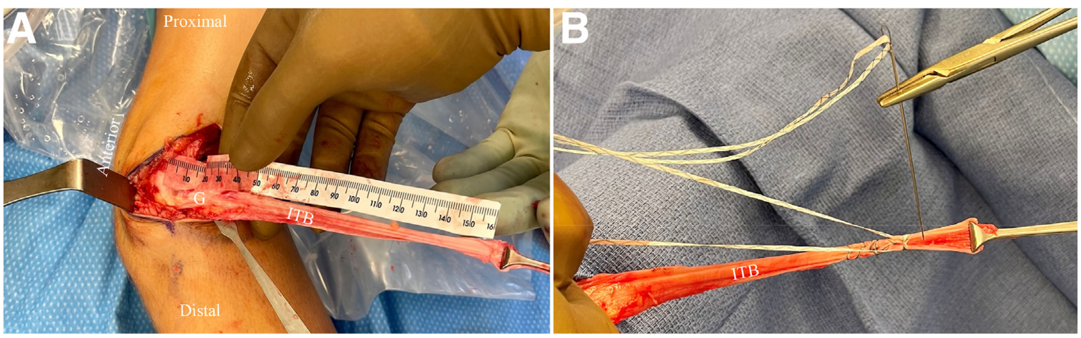

Fig 6. Left lateral lower extremity clinical photograph viewing from the lateral aspect of the knee. The 15-cm × 2-cm iliotibial band graft, which has been transected proximally but still has its insertion preserved distally at Gerdy's tubercle, is delivered out of the distal wound (A) and measured to confirm appropriate autograft length. The autograft is then whipstitched (B) with a FiberLoop. (G, Gerdy's tubercle; ITB, iliotibial band.)

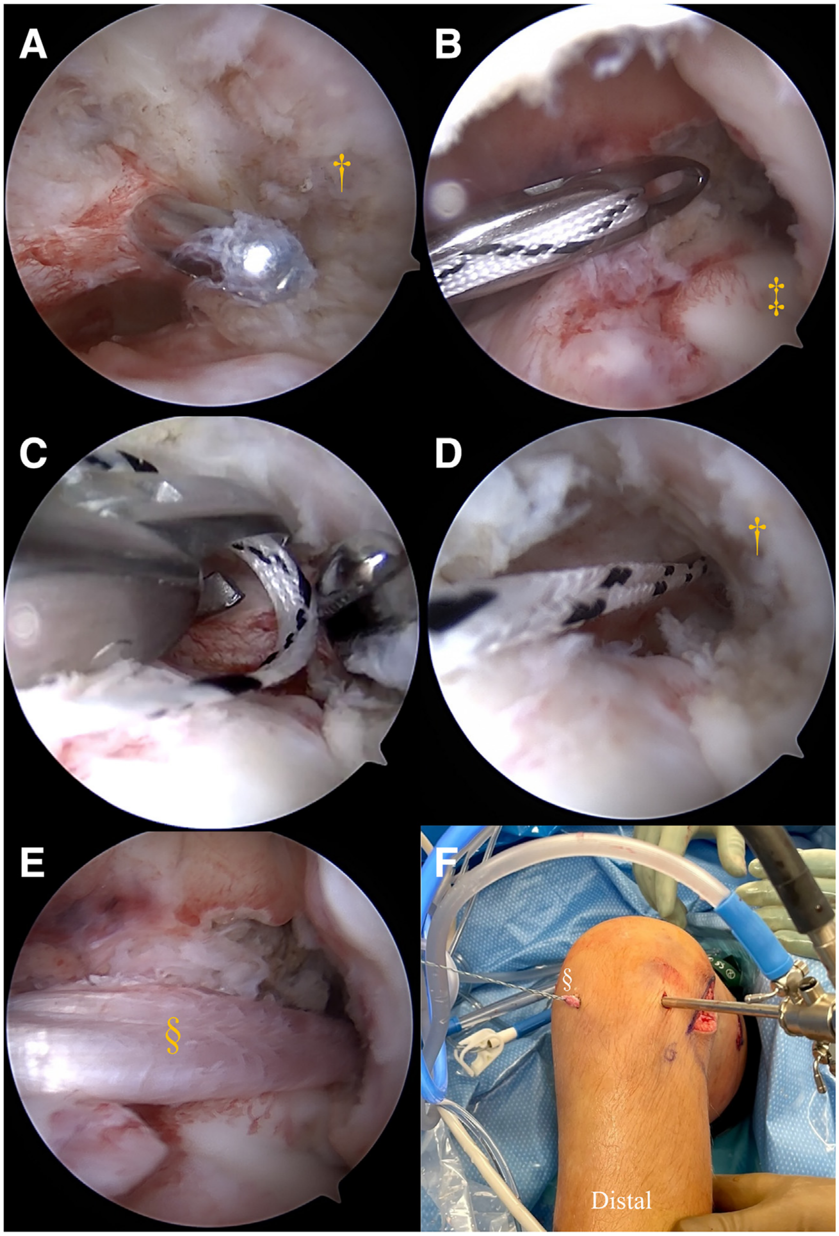

Fig 7. Left knee arthroscopic photographs from an anterolateral viewing portal demonstrating intra-articular visualization of a Kelly clamp as it passes around the posterolateral femoral condyle and into the notch (A), introduction of a FiberLink (Arthrex) shuttle suture via a loop grasper through the anteromedial portal (B), delivery of the shuttle suture to the Kelly clamp (C), passage of the shuttle suture around the posterolateral condyle (D), and introduction of the iliotibial band (ITB) autograft via the shuttle suture (E). (F) Left lateral knee clinical photograph demonstrating delivery of the ITB autograft out the anteromedial portal. †Lateral border of the notch. ‡Lateral tibial plateau. §ITB autograft.

activity has returned. Range of motion is not limited. Irrespective of meniscal pathology, the patient is kept from running for 3 months.

Discussion

This technique prioritizes respecting physeal anatomy while improving tibial translational and rotational control. Although its indications are narrow, the modified MacIntosh procedure is a valuable technique for arthroscopists to keep in their armamentarium for pediatric ACL tears. The modified MacIntosh has been described by previous authors,[15,16] but the addition of knotless all-suture anchor fixation at the proximal tibia is unique to the currently described technique. All-suture anchor fixation at the proximal tibia metaphysis further decreases the risk for iatrogenic physeal damage.

The pendulum has appropriately shifted toward earlier surgical intervention for pediatric ACL tears to avoid the long-term deleterious effects of ACL insufficiency.[3-8] The choice between PS and NPS techniques is influenced by various factors, including patient age and skeletal maturity.[12-14] Pediatric ACL reconstruction retear rates range between 4.5% and 10%, with revision ACL reconstruction retear rates approaching 20%.[23-25] Reasons for pediatric ACL retear are multifactorial, but studies suggest that younger patient age, graft type, and surgical technique all influence

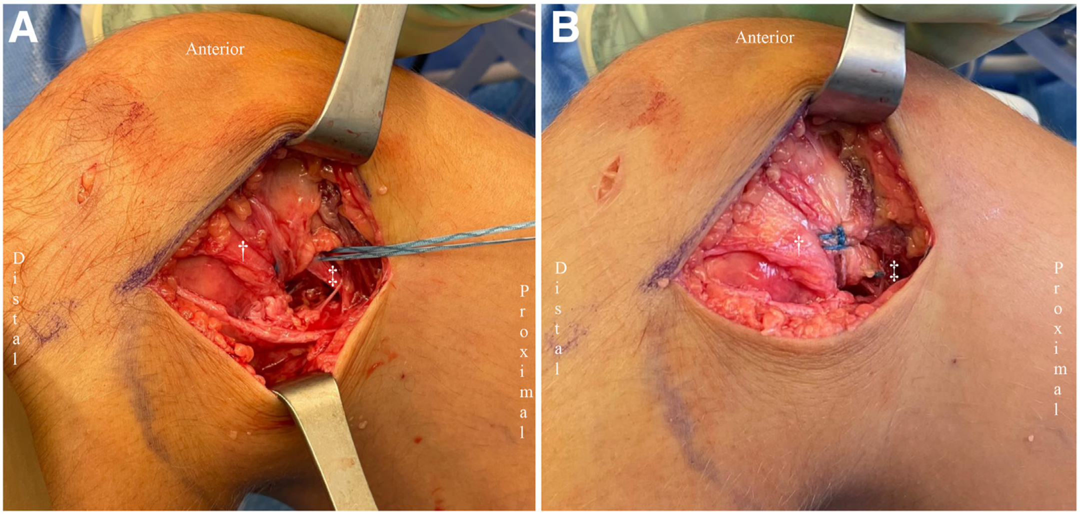

Fig 8. Left lateral knee clinical photograph demonstrating extra-articular tenodesis of the iliotibial band (ITB) autograft into periosteum at the posterolateral femur to act as an extra-articular rotational constraint. The knee is placed into 30° of flexion, and tension is pulled on the whipstitched ITB. A 1.3-mm FiberTape (Arthrex) is used to pass a horizontal mattress stitch through the ITB autograft (†) and periosteum at the approximate location of the intermuscular septum (‡). This is reinforced with a figure-of-8 suture.

retear rates.[25] Surgeons have recently revisited historical ACL reconstruction techniques to improve tibial rotational control.[17,26] Recent literature suggests that the addition of a lateral extra-articular tenodesis to adolescent ACL reconstructions decreases failure rates.[26] The over-the-top ITB reconstruction (i.e., modified MacIntosh II)[17] performed in this technique provides extra-articular restraint in a manner analogous to lateral extra-articular tenodesis and theoretically provides the same benefits to rotational control.

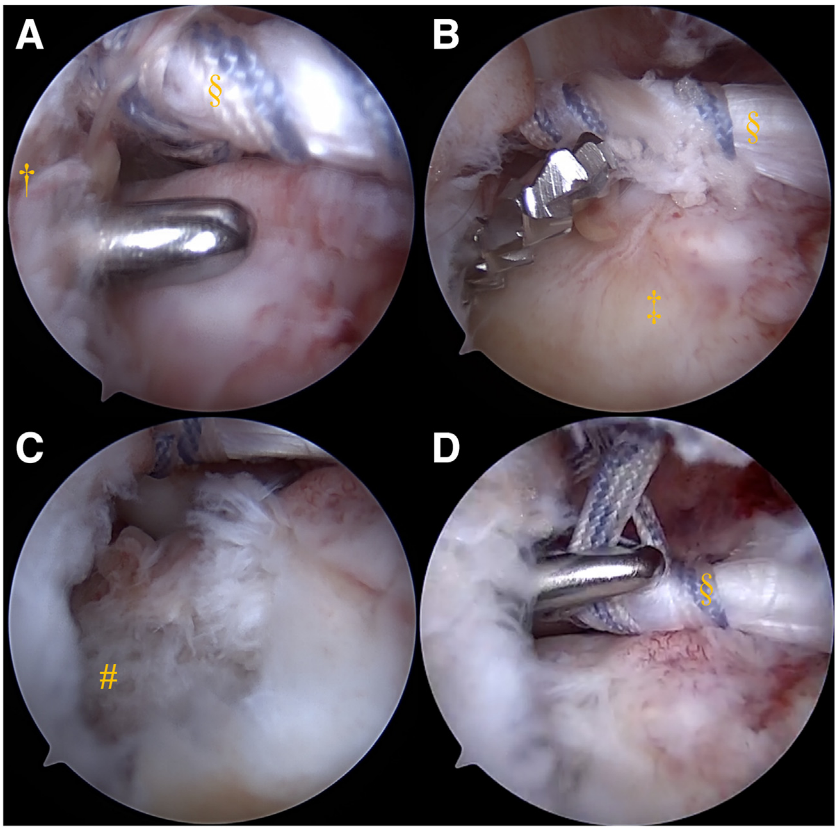

Fig 9. Left knee arthroscopic photographs from an anterolateral viewing portal demonstrating tunneling of a hemostat clamp underneath the fat pad (A), rasp introduction under the fat pad to debride proximal anterior tibial bone (B), proximal anterior tibia after debridement to promote long-term incorporation at the graft-bone interface (C), and use of a hemostat clamp to retrieve the autograft beneath the fat pad and deliver it out of the joint for fixation at the epiphysis (D). †Hoffa's fat pad. ‡Proximal anterior tibia. §Iliotibial band autograft. #Area of debrided bone.

Fig 10. Left knee anteroposterior fluoroscopic radiograph demonstrating an extra-physeal, proximal metaphyseal location for the FiberTak (Arthrex) drill guide.

Despite the modified MacIntosh technique's nonanatomic nature in ACL footprint morphology, biomechanical testing has demonstrated restoration of translational and rotational constraints,[27,28] and long-term clinical outcomes studies are reassuring.[29,30] Kocher et al. have demonstrated a 4.5% failure rate at 5 years[30] and a 6.6% retear rate over a 23-year period.[29]

Several pearls and pitfalls of this technique exist (Table 1). Advantages of the technique include its PS nature, the addition of intra- and extra-articular rotational restraints, the use of autograft tissue, and the use of an all-suture anchor to minimize risk to the physis (Table 2). Disadvantages include nonanatomic tibial and femoral ACL footprint fixation and a narrow indication window (Table 2). Despite literature support for joint protection into young adulthood,[29] further research is needed to evaluate the long-term chondroprotective effects of PS ACL reconstruction techniques into late adulthood.

Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: J.A.R. is on the Editorial Board and Social Media Board for *Arthroscopy*. S.F.D. is a board or committee member for AOSSM and AANA, is a paid presenter or speaker for AO North America, has received research support from Arthrex, is on the Editorial or Governing Board for *Arthroscopy*, and has received publishing royalties or financial or material support from Springer. C.W.N. is a board or committee member for AAOS, AOSSM, and AANA; is on the Editorial or Governing Board for *Arthroscopy*; has received publishing

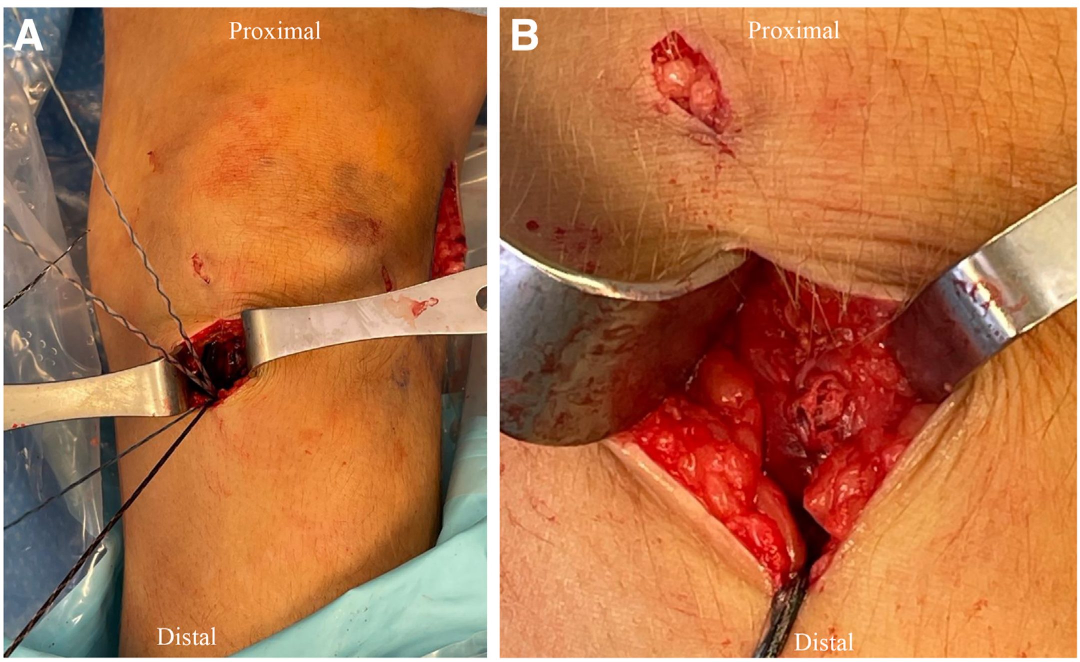

Fig 11. Left anterior knee clinical photographs demonstrating placement of a double-loaded 2.6-mm FiberTak (Arthrex) anchor at the anteromedial proximal tibia (A) and closure of periosteum over the iliotibial band autograft now fixated via the FiberTak suture staple (B).

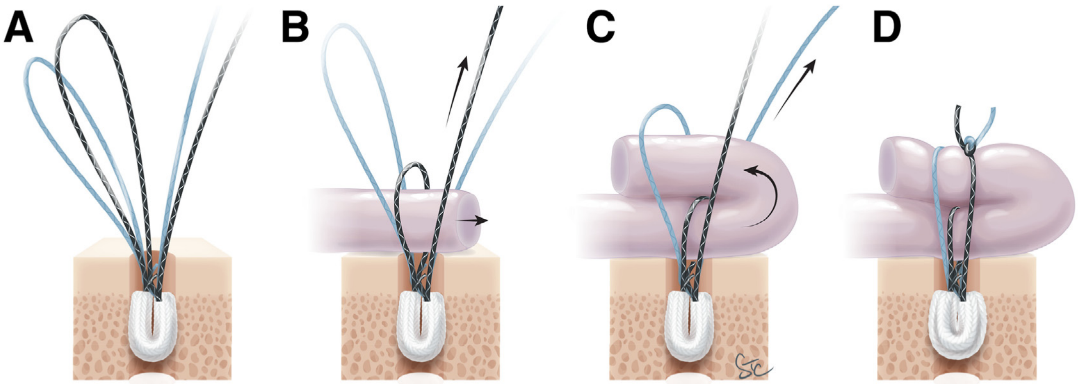

Fig 12. Illustration of 2.6-mm FiberTak (Arthrex) suture staple. The free end of the autograft is placed through both loops in the anchor, and the distal loop is converted through the anchor (A-C). After the distal loop is fully tensioned (C), the autograft is then again delivered retrograde through the proximal loop (D). The proximal loop is converted through the anchor (D). Both loops are sequentially tensioned to confirm final fixation. The free ends of suture from the FiberTak anchor are tied together and cut (D).

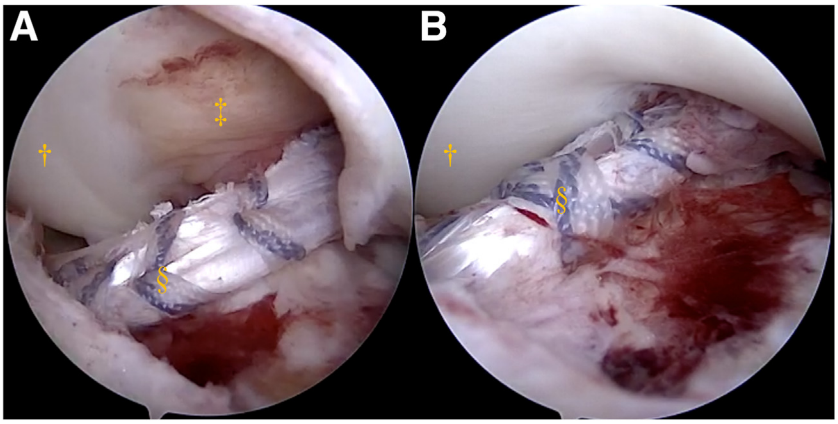

Fig 13. Left knee arthroscopic photographs from an anterolateral viewing portal demonstrating final positioning of the iliotibial band autograft with the notch in both knee flexion (A) and extension (B). †Medial femoral condyle. ‡Medial notch posterior cruciate ligament insertion. §Iliotibial band autograft.

Table 1. Pearls and Pitfalls of the Modified MacIntosh Technique for Anterior Cruciate Ligament Reconstruction

Pearls	Pitfalls
Ensure plenty of length of the iliotibial band (>15 cm)	Take caution to limit injury to the physes
Suture extra-articular iliotibial band to the femur to add rotational stability	Cutting iliotibial band too short will limit graft length
Anterior tibia bony bed preparation	Avoid use of permanent implants near the physes
Ensure hemostasis is achieved intra-articularly and extra-articularly prior to closure to decrease risk of arthrofibrosis	

Table 2. Advantages and Disadvantages of the Modified MacIntosh Technique for Anterior Cruciate Ligament Reconstruction

Advantages	Disadvantages
Intra- and extra-articular rotational constraint	Nonanatomic fixation
Physeal—sparing	Technically challenging
Autograft tissue	Narrow indication window
Well supported in literature	

royalties or financial or material support from Arthrex; has received financial or material support from O Foundation; is a paid presenter or speaker for Arthrex and Vericel; and is a paid consultant for Guidepoint Consulting. All other authors (L.M.M., D.R.W.) 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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