Single-Tunnel Double-Bundle Anterior Cruciate Ligament Reconstruction

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Abstract: The anterior cruciate ligament (ACL) is composed of 2 bundles: the anteromedial (AM) bundle and the posterolateral bundle. Traditional reconstructions of the ACL reconstruct the location and the trajectory of the AM bundle. Although this may control tibial translation, the isolated AM bundle reconstruction may not restore rotational stability. Recently, authors have studied and recommended anatomic reconstruction of both bundles of the ACL. Recent in vitro studies have suggested that this better restores rotational stability. Double-bundle ACL reconstruction, however, has not shown clear, clinical postoperative in vivo superiority to date. Furthermore, there are potential complications of ACL reconstruction that are magnified in double-bundle techniques. In addition, many patients' native tibial ACL footprints are smaller than the size requirements for 2-tunnel drilling.

We present a novel technique using a new device for producing a double-bundle ACL construct while creating only 1 tibial tunnel and 1 femoral socket. The aim of this technique is to create a 2-bundle construct while eliminating the increased potential operative complications associated with the creation of 2 tibial tunnels and 2 femoral sockets.

Keywords: ACL reconstruction, double bundle, knee, arthroscopy

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HISTORICAL PERSPECTIVE

The anterior cruciate ligament (ACL) is composed of 2 bundles: the anteromedial (AM) bundle and the posterolateral (PL) bundle.[1–3] The traditional transtibial ACL reconstruction recreates only the AM bundle. Recent data have shown that this may not restore normal rotational knee kinematics.[4–6]

To address this deficiency in rotational stability, surgeons have developed various techniques to reconstruct both bundles of the ACL. These include the low single-bundle reconstruction, the hybrid reconstruction, and the anatomic double-bundle reconstruction. The low single-bundle reconstruction recreates parts of both the AM and the PL bundles at a more anatomic femoral position, which is lower on the "clock face" of the intercondylar notch (commonly, the 10-o'clock position for a right knee and the 2-o'clock position for a left knee).[7] This can be facilitated by establishing the femoral socket through the AM portal. Biomechanical studies have suggested that this may improve rotational stability.[8–10]

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The anatomic double-bundle ACL (DB ACL) reconstruction creates 2 separate femoral and tibial tunnels to recreate the normal anatomy of the ACL. Although in vivo level 1 data have shown that DB ACL reconstruction has similar subjective results to single-bundle ACL reconstruction, DB ACL reconstruction demonstrates improved rotational control over the single-bundle technique.[11–14] However, the DB ACL technique is not applicable to all patients. Recent authors have demonstrated that the size of the tibial footprint may be prohibitively small in some patients to create 2 anatomic tunnels.[15] In addition, 4-tunnel reconstruction has been shown to be associated with increased tunnel widening, which may create a deficiency of cancellous bone stock during revision procedure.[16] These increased risks must be taken into consideration until clinical studies prove that the 4-tunnel double-bundle reconstruction is superior to the traditional techniques.

We propose a technique using a new implant to reconstruct the ACL: the single-tunnel DB ACL reconstruction. This involves the use of a single femoral and tibial tunnel and a new implant that separates and positions 2 distinct bundles. This allows for the surgeon to create a more anatomic reconstruction with a procedure that is technically less demanding, minimizes tunnel widening, and decreases operative time.

INDICATIONS

Our technique is indicated for primary and revision reconstructions in patients with ACL deficiency. There are no contraindications for primary ACL reconstructions. In situations of revision reconstruction where femoral or tibial bone stock is not sufficient to provide for stable fixation, a 2-stage procedure with initial bone grafting of bony defects is recommended.

SURGICAL TECHNIQUE

Arthroscopy and Preparation

The patient is positioned supine on the operating table. A leg holder may be used; however, it is imperative that the knee can be flexed to a minimum of 120 degrees. Alternatively, a lateral thigh post may be used. A diagnostic arthroscopy is performed, and concomitant pathology is addressed. The diagnosis of ACL rupture is confirmed, and the ACL remnant is debrided from the notch. The center of both the tibial and the femoral footprints of the ACL are identified and marked with a thermal device before complete removal. These locations will serve as the center for the femoral socket and the tibial tunnel. The femoral origin of the ACL is best viewed through a medial viewing portal.

Tibial Tunnel Placement

The tibial tunnel is placed in the center of the tibial footprint, as previously indicated with a thermal device. This is medial to the posterior aspect of the anterior horn of the lateral meniscus. The reference point for creating the tibial tunnel is an area on the tibia medial to the tibial tubercle, at a minimum of 3 cm distal to the joint line. To allow for a transtibial technique,

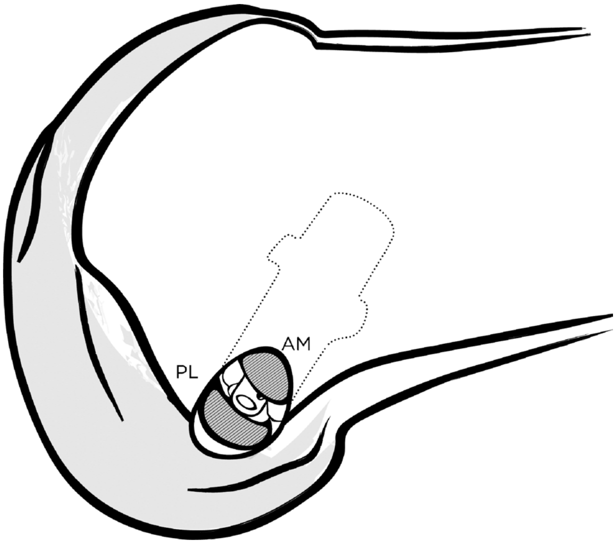

FIGURE 1. Sagittal illustration of the distal femur, demonstrating the graft-bundle orientation in the single-tunnel double-bundle technique.

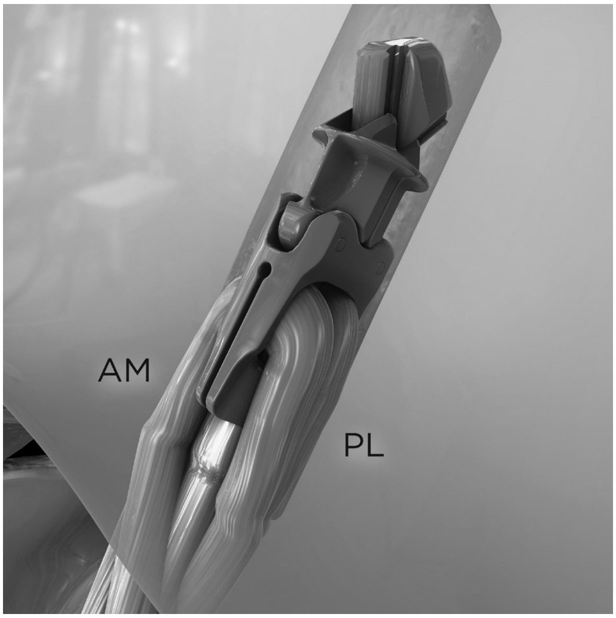

FIGURE 2. Intraosseous position in the femoral socket of the Aperfix device, depicting graft-bundle position and rotation with aperture compression of each bundle.

this point should be immediately anterior to the tibial insertion of the superficial fibers of the medial collateral ligament. If hamstring autograft is used, this location is exposed during graft harvest. If allograft is used, the proper position of the tibial entry point is indicated by drill sleeve placement and exposed through a 2-cm longitudinal incision. A 3.2-mm guide pin is drilled from this point to the center of the ACL tibial footprint using an ACL drill guide set at a 55-degree angle. This guide pin is then overdrilled with the appropriate-sized cannulated reamer, typically 9 or 10 mm.

Femoral Tunnel Placement

The femoral tunnel is positioned in the center of the femoral origin, as previously indicated. The proper position of the tunnel should be located inferior to the intercondylar ridge, immediately posterior to the lateral bifurcate ridge. If this location is accessible with an ACL over-the-top guide through the tibial tunnel, a transtibial technique may be used. By keeping the entry site of the tibial tunnel adjacent to the medial collateral ligament, the approach to the femoral tunnel can be brought down the wall toward the 10- and the 2-o'clock positions. Alternatively, if this point is not accessible through the tibial tunnel, a low AM accessory portal is used. The guide pin for the femoral fixation device should be inserted to the cortex of the femur. Depth marks on the guide pin can help predict the length of the femoral tunnel. After insertion of the guide pin, the pin is overreamed with the appropriate-sized reamer, usually 10 mm, to a depth of 30 mm and a minimum of 27 mm. If a tunnel of less than 27 mm is present, we recommend performing a traditional reconstruction with a single-bundle technique.

Graft Preparation

Hamstring autograft or allograft is recommended. Alternatively, a tibialis allograft (anterior or posterior) may be used, but one half of the graft must be divided into 2 segments, each with an approximate width of 6 mm. Both ends of both graft strands are secured with a strong, no. 2 nonabsorbable suture in a whipstitch fashion. Each graft strand is then independently passed through the appropriate position in the Aperfix femoral fixation device (Cayenne Medical, Scottsdale, Ariz).

Graft Placement and Fixation

The femoral fixation device with the graft properly positioned is gently inserted into place through the tibial tunnel or through the AM portal if this is the way the femoral tunnel was

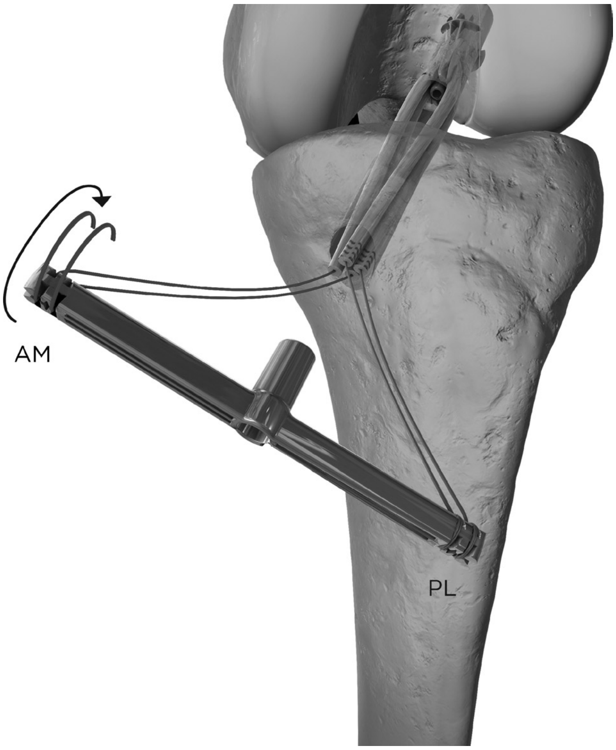

FIGURE 3. The graft limbs are secured to the 1-handed manual-tensioning T-handle device.

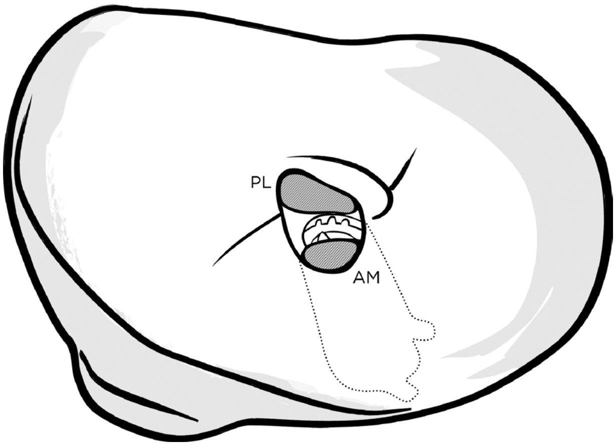

FIGURE 4. Axial illustration of the tibial tunnel aperture and proper graft position for the single-tunnel double-bundle construct.

established. The device should be oriented so that 1 graft is positioned superiorly (posterior in the 90-degree flexed position) and the other is positioned inferiorly (anterior in the 90-degree flexed position) to approximate anatomic orientation until the implant is seated (Fig. 1). In the left knee, the bundles would be positioned at the 11- and 5-o'clock positions in the femoral tunnel. The device is then deployed, providing for aperture femoral fixation (Fig. 2). If the AM portal is used for femoral tunnel instrumentation, then the sutures of each limb are individually retrieved through the tibial tunnel with a suture grasper, and the

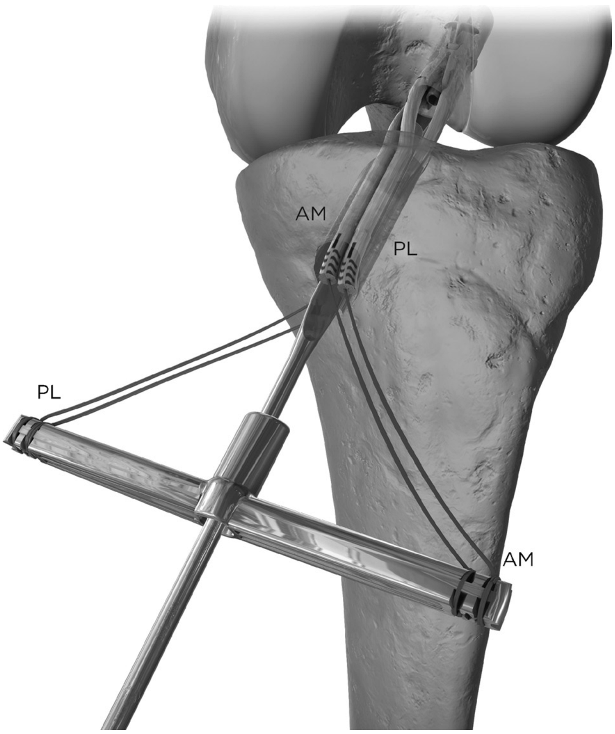

FIGURE 5. The grafts are rotated in the tibial tunnel to position the AM and the PL bundles in their correct orientation. This can be facilitated by the use of a Freer elevator.

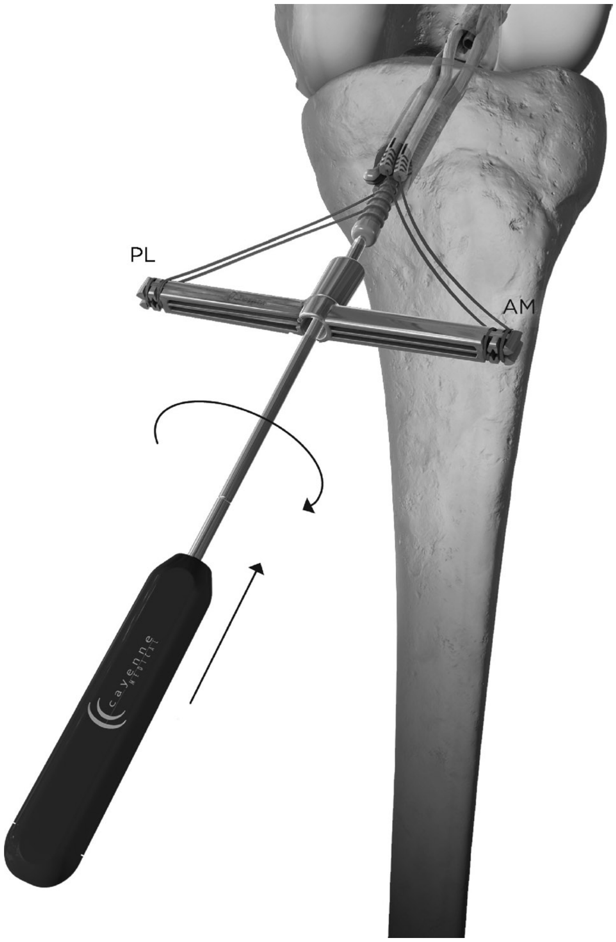

FIGURE 6. The tibial fixation is applied with a screw sheath placed between the 2 bundles. As the screw is inserted, the sheath spreads each bundle against the tibial tunnel, providing for compressive fixation of each limb.

limbs of each graft are pulled into the tibial insertion. The sutures of each limb are then firmly secured to the tibial guide independently so that 1 limb of each graft is firmly secured to each side of the T-handle graft-tensioning device (Fig. 3). This allows for equal tension to be applied to each graft with a 1-handed device. The T-handle is then rotated with visualization of the tibial footprint so that 1 graft is passing through the AM portion of the tunnel and the other through the PL portion of the tunnel (Fig. 4). This process is facilitated by inserting a flat device, such as a Freer elevator, into the tibial tunnel between the bundles to rotate the graft at the internal aperture to position 1 bundle at the PL position and the other at the AM position (Fig. 5). Holding the bundles in the desired orientation, the knee is then cycled, with tension applied to the graft. Next, the tibial sleeve is inserted between the limbs of the graft, and the central screw is placed with the knee in full extension (Fig. 6). Care is taken to maintain tension on the graft with the T-handle to prevent loss of graft tension.

If the surgeon desires, each graft bundle may be individually tensioned. With the knee in full extension, the PL bundle may be cycled and provisionally fixed with a staple or screw. The knee is then placed in the desired position of flexion (30–60 degrees) and cycled, and the screw/sleeve is applied while maintaining tension on the AM bundle. The provisional

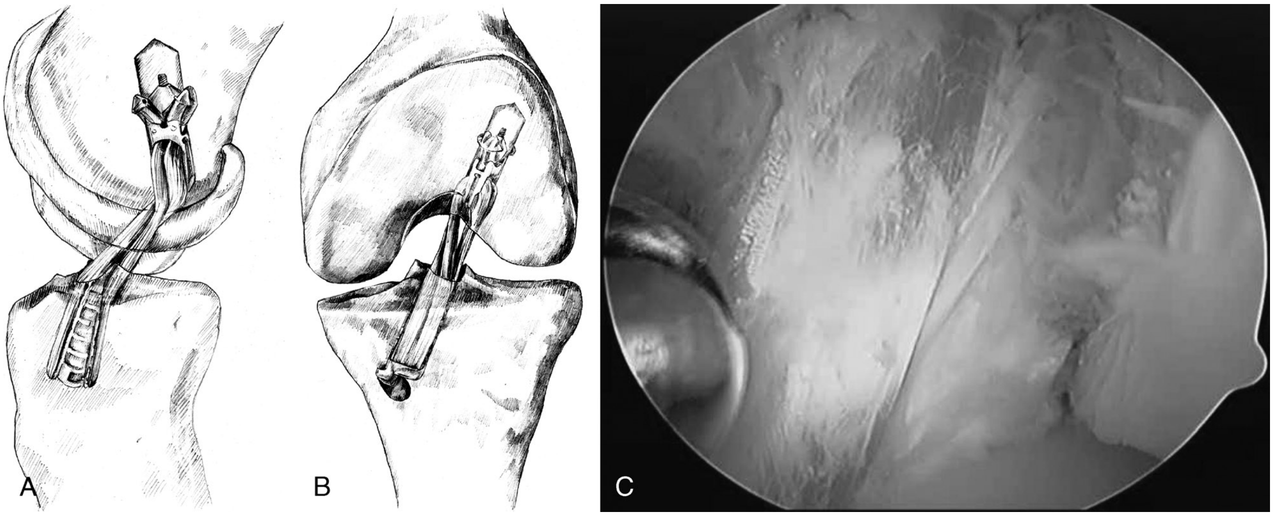

FIGURE 7. Sagittal (**A**) and coronal (**B**) illustrations of the final single-tunnel double-bundle construct. (**C**) An intraoperative photograph of the final construct in a left knee.

fixation device is then removed. Alternatively, the Linvatec ACL tensioning device (ConMed Linvatec, Utica, NY) can be used to differentially tension each graft limb at the desired degree of knee flexion before applying the tibial fixation. This completes the final construct (Figs. 7A–C).

The remaining prominent limbs of the grafts are then removed sharply after inspecting the intraarticular portion of the graft for adequate tension and absence of impingement.

The wounds are then irrigated and closed, and a postoperative dressing is applied. The leg is then placed in a postoperative brace in full extension.

Postoperative Management

The patient is allowed to bear weight as tolerated, with crutches as needed, with the brace locked in extension for 2 weeks, or until adequate quadriceps tone is achieved. Protected weight bearing in the brace allowing for flexion is then continued for 2 more weeks. At 4 weeks, the brace is discontinued if the patient is able to obtain full active extension without a lag. Range of motion, edema control, and isometric quadriceps/hamstring/hip abductor/hip adductor isometric exercises are begun immediately. Low/no resistance cycling is then started at 2 to 4 weeks. Short arc closed chain exercises are begun at 4 to 6 weeks. Jogging and open chain exercises are begun at 10 to 12 weeks. Plyometric exercises and sport-specific drills are begun at 12 to 16 weeks. Return to sport is recommended at 4 to 6 months. The specific protocol should be slightly delayed if allograft is used.

Complications and Concerns

There are several potential pitfalls to this procedure. Although posterior wall blowout is a potential concern, we have not encountered this to date. This danger is inherent to using the low AM portal. Proper guide-pin orientation must be ensured, and the knee must be positioned in adequate flexion to avoid this event. In addition, adequate tension must be maintained during tibial fixation to prevent driving the graft in an intra-articular direction, leading to poor graft tension. Although our construct separates the graft centers by 8 to 9 mm (depending on femoral implant size), the true "ideal" amount of graft separation required for true double-bundle kinematics is unknown. The senior author has shown that this technique closely restore normal knee translational kinematics more closely than a traditional single-bundle reconstruction.[17]

One possible concern of this technique is that the surgeon may choose to tension both grafts simultaneously at the same flexion angle (15–20 degrees). The issue of "ideal" graft-tensioning parameters remains to be determined. Prior authors have recommended a differential tensioning pattern, with the AM bundle typically tensioned in greater degrees of flexion (45–60 degrees), whereas the PL bundle is tensioned at or near full extension.[18,19] However, recent biomechanical studies have suggested that this may be capturing the knee.[20,21] Cuomo et al[20] reported that tensioning the AM bundle in flexion overconstrained the anteroposterior laxity and recommended tensioning both bundles at 20 degrees of knee flexion. Miura et al[21] studied the response to a 134-N anterior tibial load and knee kinematics after DB ACL reconstructions with various tensioning strategies. They found that fixation of the AM bundle in 60 degrees of flexion overloaded the anterior graft. These data may be supported by recent arthroscopic second-look studies of individual graft integrity, demonstrating compromise (rupture or laxity) of up to 20%.[22,23] These high rates may be the sequelae of overconstraining the grafts by tensioning them in excessive tension, although the absolute cause remains to be seen.

The follow-up data on our new technique remain to be seen, although early results are promising. Biomechanical data on our reconstruction technique are pending. However, the clinical understanding and application of the true anatomy of the ACL continue to evolve. As further understanding of kinematic patterns improves, that data can be applied to patient care. Furthermore, technical advances will be made to perform the ACL reconstruction with improved biomechanics, kinematics, and surgical results.

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