Technical Note

"Y" Graft Double Bundle Anterior Cruciate Ligament Reconstruction

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Abstract: Single-bundle (SB) anterior cruciate ligament (ACL) reconstruction has been a standard procedure. However, residual rotary instability in approximately 20% of the cases (irrespective of the graft choice and the surgical technique) forces the surgeon to improve the biomechanical quality of the reconstruction. In parallel, adjustable suspensory fixation (ASF) devices have arisen. Biomechanics has defined (both anatomical and functional) the anteromedial (AM) and posterolateral (PL) bundles that work synergistically. In the unsymmetrical "anatomic" SB ACL reconstruction, the distribution of the ACL graft fibers (for AM or PL behavior) is not under the control of the surgeon. Furthermore, different sizes of the original footprints (depending on height) suggest the need to customize the graft footprint. This customization is only possible if distances are measured during surgical procedures. We present an inside-out technique for DB ACL reconstruction ("all-inside" also possible). Semitendinosus is folded to obtain a Y-shaped trifurcate configuration graft, distributing their bundles in two different areas. Used as measuring instruments, we used the "offset" guides as measuring instruments, allowing the surgeon to know the distance between the centers of the AM and PL tunnels. It may be carried out by means of common "offset" guides and any marketed ASF devices, while generating customized footprints. **Classification:** I: knee; II: ACL

Introduction

Single-bundle (SB) anterior cruciate ligament (ACL) reconstruction has been a standard procedure. However, residual rotary instability in approximately 20% of the cases (irrespective of the graft choice and the surgical technique),[1] has led to the development of the "anatomic" SB ACL reconstruction (placing the tunnels in the center of the ACL footprint on the femur)[2].

With superior biomechanical profile double bundle (DB), ACL reconstruction (ACLR) has been proposed, assuming that ACL is composed of the anteromedial (AM) and the posterolateral (PL) bundle.[3,4] Both bundles work synergistically, stabilizing during knee motion.[4]

In parallel, after the dominance of the graft transfixing fixations and intratunnel fixations (screws), adjustable suspensory fixation (ASF) devices have arisen.[5] Then, the tunnels lengths can be customized, and ACLR can be performed using a single semitendinosus (ST) tendon as a graft.

We present an inside-out technique for DB ACLR ("all-inside" also possible). ST is folded to obtain a Y-shaped trifurcate configuration graft. It is carried out by means of common "offset" guides and any marketed ASF devices, while generating customized footprints (Fig 1).

Surgical Technique

Patient Setup

Patient is in a supine position, with a side post at the level of the proximal thigh and a foot support (Table 1).

Graft Harvest and Preparation

After ST harvesting, a surgical needle (with the 2 ends of a no. 2 absorbable thread) threefold is passed through each of the two ends of ST graft to obtain a herringbone shape graft end (Fig 2). After ST ends passing through the 2 femoral ASF loops, they are

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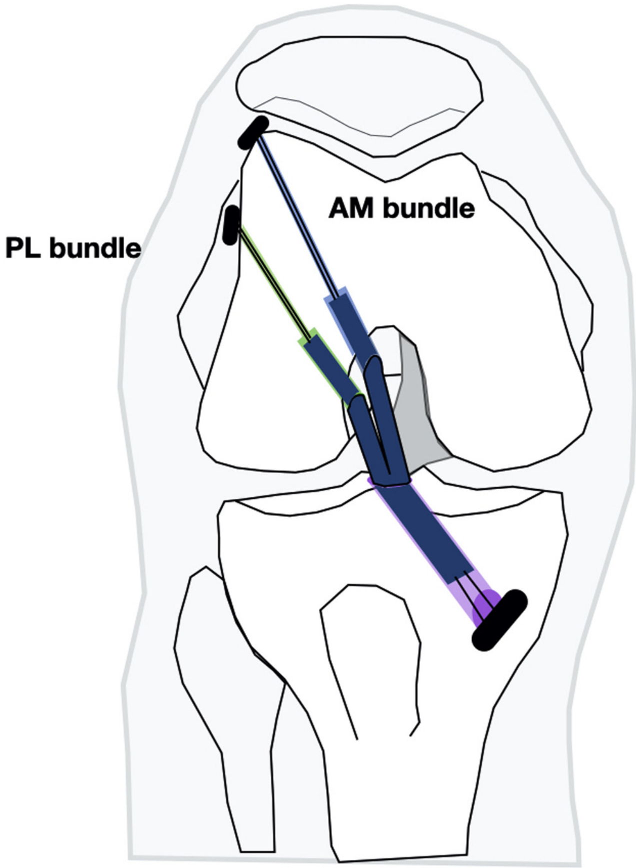

Fig 1. Double-bundle (Y-shaped trifurcate configuration graft) anterior cruciate ligament reconstruction.

closed together. One of the femoral loops is passed through the loop of tibial ASF, leaving this equidistant with respect to the femoral loops. Then, two limbs of the ST are tied (through the tibial ASF loop), yielding a secured end-to-end graft. Cross-sectional security stitches are added (all intratunnel) (Fig 3). Tibial side and femoral bundles grafts are measured. The longest will be the AM. Finally, static manual pretensioning is performed for 10 minutes[6] (Video 1).

Drilling Tunnels

Routine Portals Are Performed: A Transpatellar View Portal Can Be Useful.

Drilling AM Femoral Tunnel

After the posterior part of the lateral intercondylar notch was cleaned, the "capsular line reference" (CLR) must be identified as a bony landmark.[7] An "offset" femoral guide is introduced through the AM portal (in accordance with AM diameter) and leaned against the apex point of the posterior cartilage. The center of the AM femoral tunnel is placed in front of the CLR and higher (anteriorly) relative to the apex of the posterior cartilage (at the level of AM native ACL direct fiber attachment). A microfracture in the selected femoral AM tunnel entry point is performed. The guide is withdrawn, the knee is flexed completely and then, the guide pin is inserted until the lateral cortex of the lateral femoral condyle. A cannulated reamer (suitable for the fixation device) is passed over the guide pin. The length of the tunnel is measured. Using a guide pin, we created the femoral AM tunnel at a 20-mm depth using a drill bit of the same diameter as the AM graft (Fig 4).

Table 1. Step-by-Step Details of Technique

1. **Patient positioning**
   A. The patient is placed supine on an operative table with a lateral post just proximal to the knee, at the level of the padded tourniquet, and a foot roll to keep the knee flexion at 90°.
2. **Graft harvest and preparation**
   A. The ST alone is harvested in the standard fashion. The ST is passed through the 2 femoral loops and then the graft ends meet. One of the femoral loops is passed through the loop of the tibial device.
   B. The threads of the graft limbs are tied through the loop of the tibial ASF. Cross-sectional stitches are added.
3. **Drilling tunnels**
   A. Drilling the femoral AM tunnel
   - The "capsular line reference" is identified. An "offset" femoral guide is introduced through the AM portal (in accordance with AM diameter). The tip of the guide is leaned against the apex point of the posterior cartilage.
   - The center of AM femoral tunnel is selected at the level of AM native ACL direct fiber attachment.
   - A guide pin is placed in an inside-out manner to perform a microfracture in the selected entry point of the femoral AM tunnel.
   - The joint can be flexed completely, and a guide pin can be inserted until the lateral cortex of the lateral femoral condyle.
   - A cannulated reamer (suitable for the fixation device) is passed over the guide pin, and a tunnel is drilled up to and through the lateral cortex of the femur.
   - The femoral AM tunnel is created at a 20-mm depth using a drill bit of the same diameter as the AM graft.

   B. Drilling the femoral PL tunnel
   - A guide pin is inserted in an inside-out manner until the lateral cortex of the lateral femoral condyle.
   - A cannulated reamer (suitable for the fixation device) is passed over the guide pin and then, the femoral PL tunnel is created at a 15-mm depth using a drill bit of the same diameter as the PL graft.

   C. Drilling the tibial tunnel
   - A guide pin is inserted from the external cortex to the ACL insertion. Reaming is performed only on the tibial cortex.
   - By means of a bone trephine, a bone cylinder (for later autograft) is harvested
   - Final reaming is performed with increasing drill-bit diameters with single-anteromedial bundle biological augmentation (or SAMBBA) effect
4. **Graft passage and fixation**
   - Leaving the knee at 90° of flexion, two traction threads extend from the tibia to the femur, and the Y-graft is tracked from the tibia to the femur until each bundle is docked into its respective femoral tunnel.
   - With the knee flexed at 20°, the tensioning sutures are used to tighten the fixation loops until the large button of the tibial suspensory device is placed at the top of the tibial tunnel external aperture.
   - The knee is taken through 20 cycles of motion, and again, the graft is tensioned. Tibial tunnel is filled with the bone autograft.

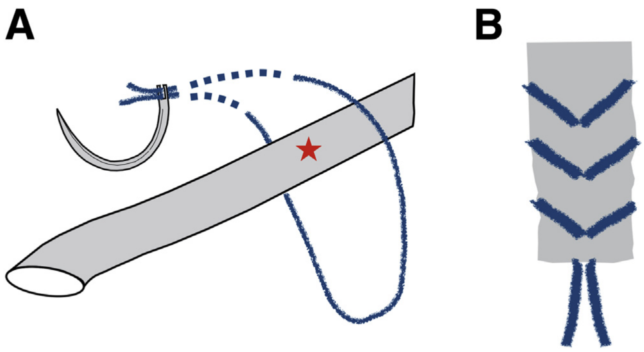

Fig 2. (A) A common surgical needle (with the 2 ends of a no. 2 absorbable thread) threefold is passed through each of the two ends of ST graft. (B) A herringbone shape graft end is obtained.

Drilling PL Femoral Tunnel

At 100° knee flexion, an "offset" femoral guide is introduced through the AM portal (in accordance with PL diameter) and is supported on the anterior perimeter of the AM tunnel and oriented toward PL footprint (preserving a 2-mm bone bridge between the femoral tunnels) (Fig 4). A guide pin is placed in an inside-out manner to perform a microfracture in the selected entry point of the PL femoral tunnel. The guide is withdrawn, and once the entry point is recognized, a guide pin is inserted until the lateral cortex of the lateral femoral condyle. A cannulated reamer (suitable for the fixation device) is passed over the guide pin. The length of the tunnel is measured. Using a guide pin, we created the PL femoral tunnel using a drill bit of the same diameter as the PL graft and 15-mm depth (Fig 5)

Drilling Tibial Tunnel

It is drilled with a 55° angled ACL guide. A guide pin is inserted from the external cortex to the ACL insertion. Reaming is performed only on the tibial cortex. By means of a bone trephine, a bone cylinder for later autograft is harvested (until subchondral bone). Final reaming is performed with increasing drill-bit diameters with the single-anteromedial bundle biological augmentation (or SAMBBA) effect.[8] To conserve residual tissue, we stop as soon as the bone of the tibial plateau is breached and is within the ACL remnant (Fig 6).

Graft Passage and Fixation

Two traction threads are passed from the tibia to the femur. Threads are individually attached to the loops of femoral suspensory devices until buttons are beyond the femoral cortex. The Y-graft is tracked from the tibia to the femur until each bundle is docked into its respective femoral tunnel. With the knee flexed at 20o, the tensioning sutures are used to shorten and tighten the fixation loops until the large button of the tibial suspensory device is placed at the top of the tibial tunnel external aperture (avoiding intratunnel ASF migration). The knee is taken through 20 cycles of motion,[9] and again, the graft is tensioned. Tibial tunnel is filled with the bone autograft.

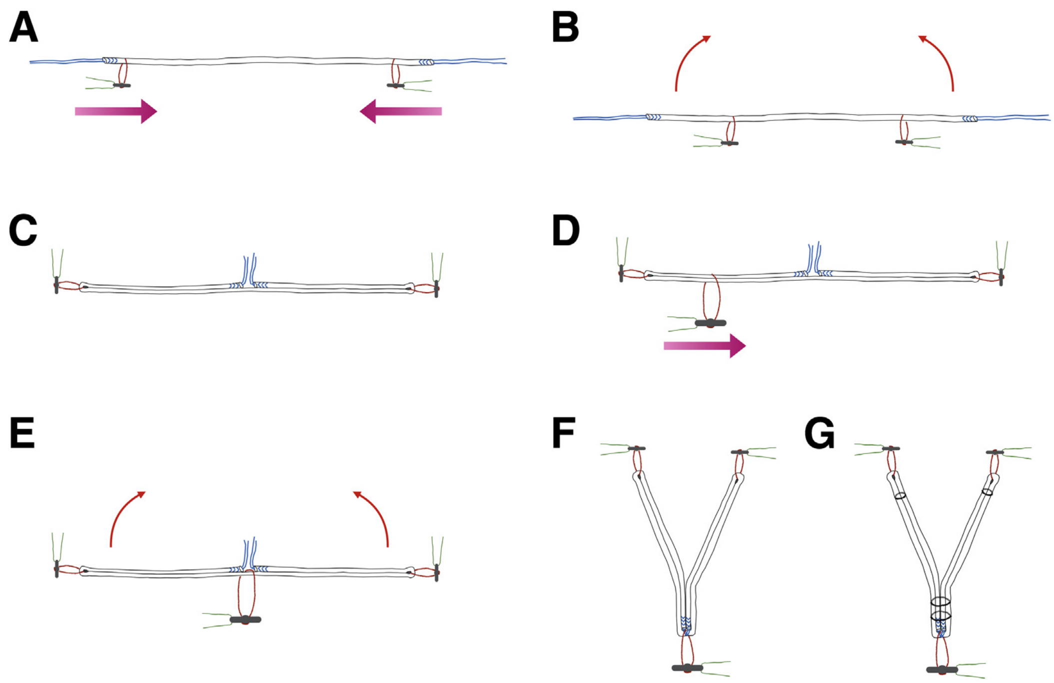

Fig 3. (A) ST ends are passed through the 2 femoral ASF loops. (B) ST ends are folded. (C) The limbs are approximated to the graft midpoint. (D) One of the femoral loops is passed through the loop of tibial ASF leaving this equidistant with respect to the femoral loops.(E) The graft is folded again. (F) The two limbs of the ST are tied (through the tibial ASF loop), yielding a secured end-to-end graft. (G) Cross-sectional security stitches are added (all intratunnel).

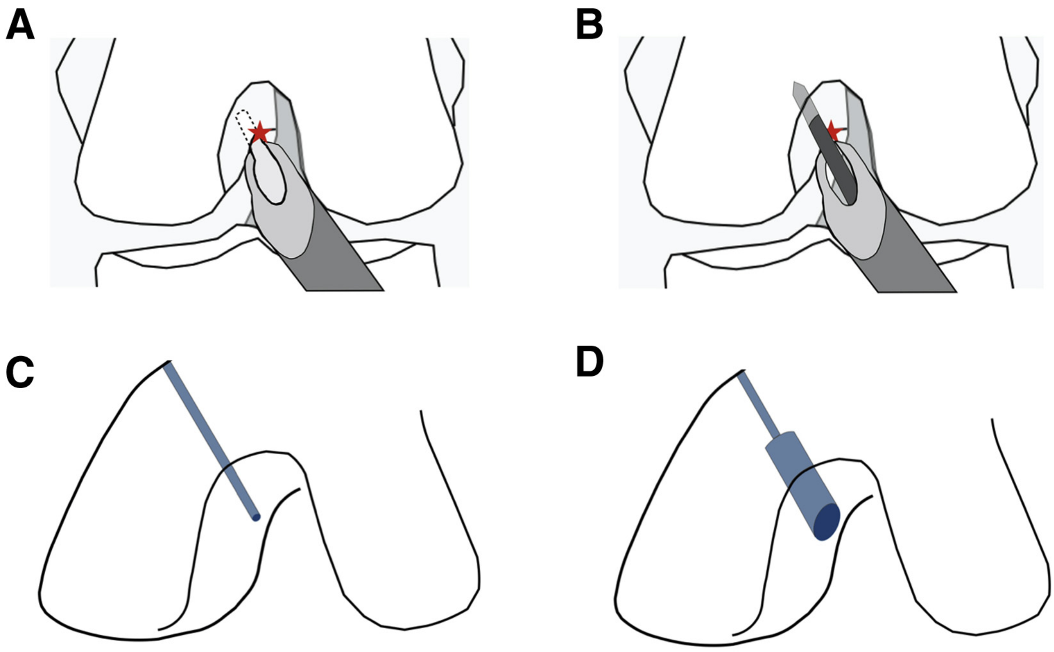

Fig 4. Drilling anteromedial (AM) femoral tunnel. (A) "Capsular line reference" is shown as a bony landmark (red star), An "offset" femoral guide is introduced through the AM portal in order to place the center of the tunnel. (B) After performing a microfracture in the selected point, we inserted the guide pin until the lateral cortex. (C) A cannulated reamer (suitable for the fixation device) is passed over the guide pin. (D) Femoral tunnel is created at a 20-mm depth using a drill bit of the same diameter as the AM graft.

Postoperative Course

A routine ACL rehabilitation program is carried out. Crutches for 3 to 4 weeks and an articulated brace for 4 to 6 weeks are recommended.

Discussion

We present an inside-out DB ACLR in which ST is folded to obtain a four-strand Y-shaped trifurcate configuration graft (DB "Y" ACLR).

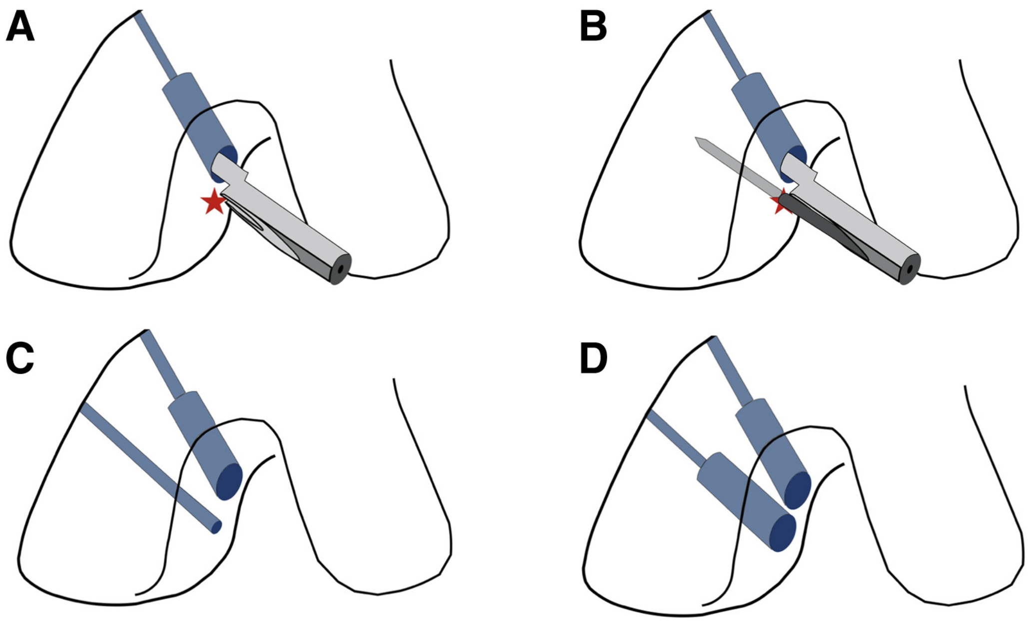

Fig 5. Drilling posteriolateral (PL) femoral tunnel. (A) An "offset" femoral guide is introduced through the anteromedial portal and supported on the anterior perimeter of the anteormedial tunnel and oriented toward the PL footprint. (B) A guide pin is placed in an inside-out manner to perform a microfracture in the selected entry point of the PL femoral tunnel. (C) A cannulated reamer (suitable for the fixation device) is passed over the guide pin. (D) The PL femoral tunnel is created using a drill bit of the same diameter as the PL graft and 15-mm depth.

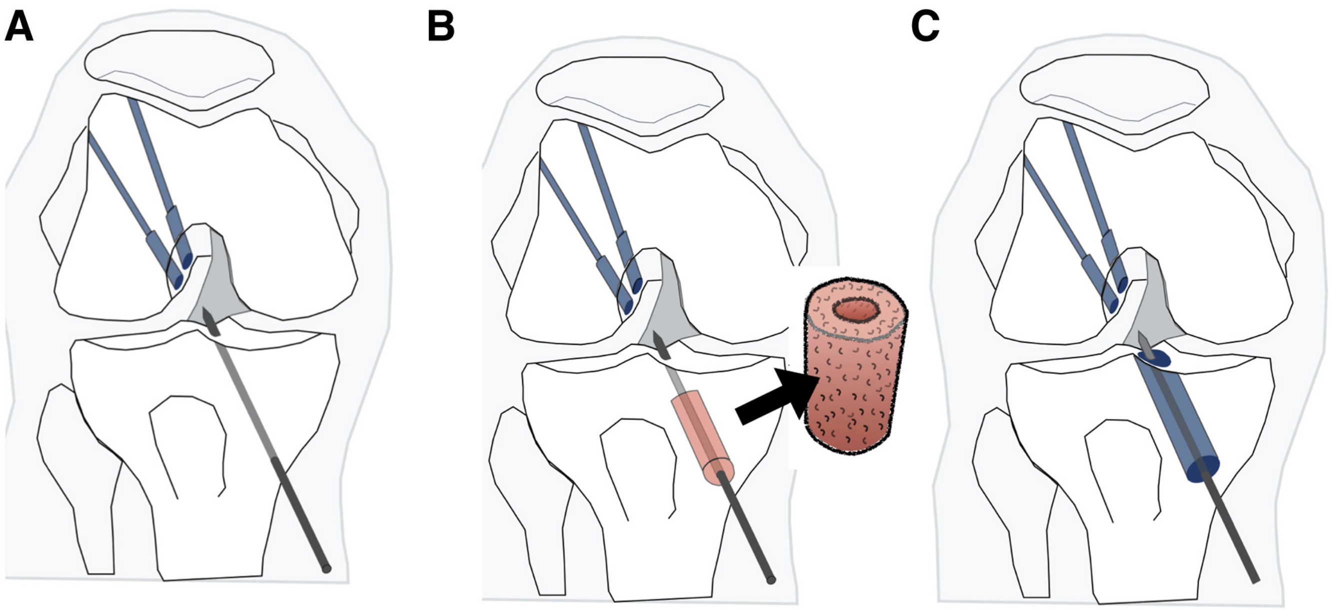

Fig 6. Drilling tibial tunnel. (A) A guide pin is inserted from the external cortex to the ACL insertion (reaming is performed only on the tibial cortex). (B) By means of a bone trephine, a bone cylinder for later autograft, is harvested (until subchondral bone). (C) Final reaming is performed with increasing drill-bit diameters with the single-anteromedial bundle biological augmentation (or SAMBBA) effect.

Firstly, DB "Y"ACLR is a reconstruction model by means of two stabilizers instead of just one. Biomechanics has defined (both anatomical and functional) the AM and PL bundles. The relative contribution of each bundle to the knee can be debated, but not their synergy. The PL bundle is taut in extension but slackens at higher flexion angles, with the AM bundle taking the majority of the load.[4,10] In the proposed DB "Y"ACLR, the fibers of graft have an aliquot distribution. 100% of AM fibers have AM behavior, and 100% of PL fibers have PL behavior.

In the unsymmetrical "anatomic" SB ACLR, the distribution of the ACL graft fibers (for AM or PL behavior) is not under the control of the surgeon. In order to increase rotational stability, the recruitment of PL fibers has been collected by reducing the percentage of AM fibers. Perhaps, they may be related with the larger number of revisions noticed in "anatomic" ACL reconstructions compared to DB[11] and even the transtibial single-bundle reconstruction model.[12]

In any SB-ACLR, the geometric attachment area of the graft is the entrance tunnel area itself. In DB "Y" ACLR, however, the geometric attachment area of the graft is an oval area that includes the AM and PL tunnels. The "functional" footprint is greater than the sum of the tunnel entrance surfaces. Better filling of native ACL footprint surface areas results in better control of

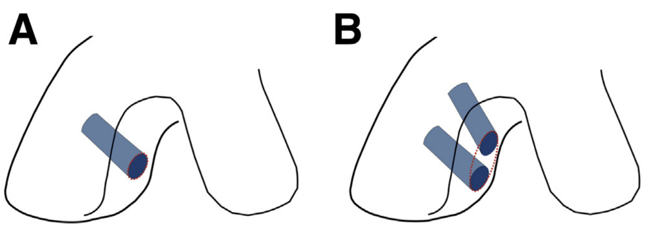

Fig 7. (A) In the single-bundle anterior cruciate ligament reconstruction, the tunnel and the functional footprint are the same. (B) In double-bundle anterior cruciate ligament reconstruction, the area of the oval functional footprint is larger than the sum of the areas of the tunnels.

Table 2. Advantages, Disadvantages, Indication, Risk and Limitations of the Double Bundle Anterior Cruciate Ligament With "Y" Graft

Advantages:
- Biomechanical qualities of DB-ACL reconstruction
- Surgical procedure by means of universal anatomic manners (inside-out) and tools (offset guides).
- Customization of the footprint is allowed according to patient size.
- Any marketed adjustable suspensory fixation (ASF) can be used. We have used ASF from both Zimmer-Biomet (femur: toggleloc with ziploop; tibia: toggleloc XL with ziploop inline) and ConMed (femur: Infinity Femoral Adjustable Lopo Button; tibia: Infinity Free Loop and Infinity Tibial Button Standard)
Disadvantages
- More complicated and expensive surgery
Indications
- Pivoting or high-demand patients
- Younger patients
- Sportswomen
Risk
- Overlap of tunnel apertures
- Insufficient length of the ST to obtain "Y" graft
Limitations
- Short stature (under 160 cm for males and 155 cm for females)

anteroposterior laxity.[13] This increases the biomechanical value of the available tissue graft.

We agree with the biomechanical principles of the proposed similar "TriLink" reconstruction.[14] But from the point of view of a surgical procedure, our group works with more universal anatomic concepts and tools.

In order to recreate accurately the original femoral footprint, "offset" guides can also be used as measuring instruments. From a starting point and sequentially, by means of different "offset" guides, the distance between the centers of the AM and PL tunnels can be known. It is possible to know exactly the oval area of the "functional" footprint performed (Fig 7). Then, different sizes of the original footprints can be carried out.[3,15] This customization allows us to generate functional graft footprint areas depending on the height of the patient.[5,16]

Preserving gracilis tendon reduces donor site morbidity and limits the loss in the knee flexion strength.[17] Quadrupling the ST provides an excellent graft diameter in most cases. But essentially, DB"Y"ACLR is a distribution of the graft fibers in two different areas. ASF devices allow one to customize each bundle. An AM bundle can be thicker and longer than the PL bundle. In fact, routinely, an intratunnel 20-mm and 15-mm graft lengths are generated, respectively, for AM and PL bundles.

ASF devices have shown less tunnel widening than resorbable interference screws.[18] To improve the graft-healing environment, the tibial tunnel is filled with the harvested bone autograft.

One of the limitations of the described procedure is the risk of tunnels overlapping. In cases of patients with relatively short stature, (<160 cm for men; <155 cm for women), this technique could be not recommended[19] (Table 2).

Another limitation is that at least in one of five patients, the length of ST tendon, may be inadequate to be used alone as a four-strand graft (especially in females).[20,21] In order to ensure more intratunnel graft length, tripling the ST and gracilis harvesting should be considered.

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