Technical Note

A Hybrid Repair Technique Combining Single-Bundle Reconstruction and Primary Repair With Internal Brace Augmentation for Anterior Cruciate Ligament Injury

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Abstract: Recently, favorable outcomes of primary anterior cruciate ligament (ACL) repair have been reported in patients with proximal tears and good tissue quality. If the tear involves the midsubstance of the ACL fibers or Sherman type II or III injury, independent primary repair will cause a higher failure rate at long-term follow-up. For these cases, we conduct primary repair and apply an internal brace and single-bundle reconstruction as hybrid augmentation. This hybrid repair technique encourages natural healing of the primary ligament by the internal brace and single-bundle graft as a provisional scaffold during the healing phase, as well as early mobilization. We describe our ACL hybrid repair technique, using a video and illustrations.

Anterior cruciate ligament (ACL) injury is a common orthopaedic injury. ACL reconstruction has been the standard treatment for an ACL rupture to restore the gross stability of the knee. However, the outcomes of ACL reconstruction can be limited by some complications, such as muscle weakness and graft rupture. Moreover, only 65% of patients return to their preinjury level and 55% return to competitive sports.[1] The secondary ACL injury rate in patients younger than 25 years is 21%. The secondary ACL injury rate in athletes who return to sport is 20%.[2] Approximately 20% to 50% of patients will have evidence of osteoarthritis within 10 to 20 years.[3]

Therefore, there has been a renewed interest in the concept of primary repair of the ACL. However, strict patient selection has been applied in modern studies by only performing repairs in patients with proximal tears (Sherman type I injury).[4,5] Primary repair failure rates reported in the literature are 7% to 11%.[6] If the tear involves the midsubstance of the ACL fibers or Sherman type II or III injury, independent primary repair will cause a higher failure rate at long-term follow-up. Commonly, these patients will receive ACL reconstruction instead. For these cases, we conduct primary

Table 1. Indications and Contraindications for Hybrid Repair Technique Combining Single-Bundle Reconstruction and Primary Repair With Internal Brace Augmentation for Anterior Cruciate Ligament Injury

Indications
Acute midsubstance ACL injury of Sherman type II or III not suitable for independent primary repair
Chronic ACL injury with enough remnant for suturing
Contraindications
Rerupture of repaired ligament
Acute ACL injury of Sherman type IV with poor remnant quality
Partial ACL tear of Sherman type I suitable for independent primary repair

ACL, anterior cruciate ligament.

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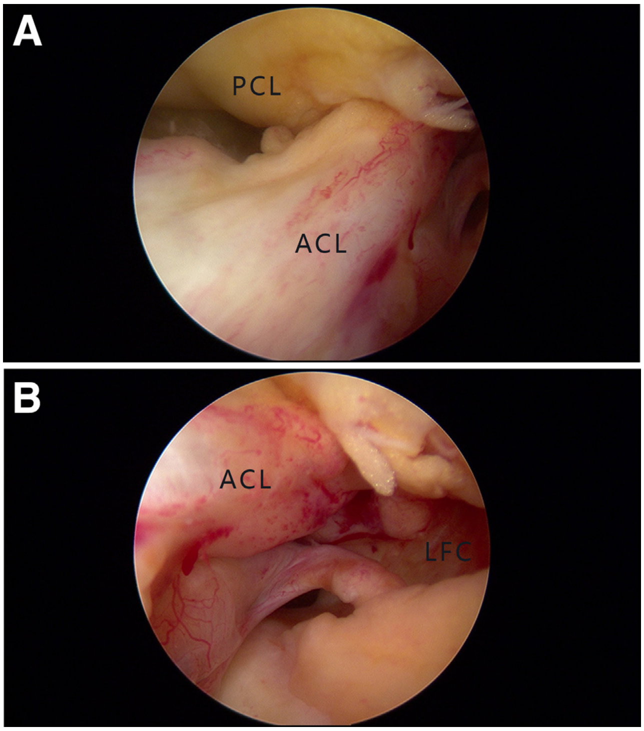

Fig 1. Frontal view of left knee. (A) Sherman type II injury. (B) Arthroscopic inspection of Sherman type II injury through anterolateral portal. (ACL, anterior cruciate ligament; LFC, lateral femoral condyle; PCL, posterior cruciate ligament.)

repair and apply an internal brace and single-bundle reconstruction as hybrid augmentation. This hybrid repair technique encourages natural healing of the primary ligament by the internal brace and single-bundle graft as a provisional scaffold during the healing phase, as well as early mobilization.

Surgical Technique

Indication

In the case of ACL injury, we start with an arthroscopic inspection of the ruptured ACL. We classify injuries according to the Sherman method.[7] If remnant tissue is classified as Sherman type II or III injury, hybrid repair is performed. Sherman type I injury receives an independent internal brace—augmented primary repair. For Sherman type IV injury, we perform a single-bundle ACL reconstruction (Table 1). These procedures were approved by the ethics committee of our hospital. Written consent forms were signed by all participants. The clinical trial approval number is MRCTA, ECFAH of FMU [2018]138, and the file number is IEC-FOM-013-2.0.

Positioning

The patient is placed in the supine position, and a tourniquet is placed on the upper thigh.

ACL Inspection

Standard anterolateral and anteromedial portals are created, and arthroscopic inspection of the knee is performed. If necessary, meniscal or cartilage surgery is performed. The ACL is inspected. ACL injuries of Sherman type II and III are repaired with the hybrid technique (Fig 1, Video 1). The ACL remnant is left intact and not shaved. Regardless of whether the tear location is midsubstance or distal

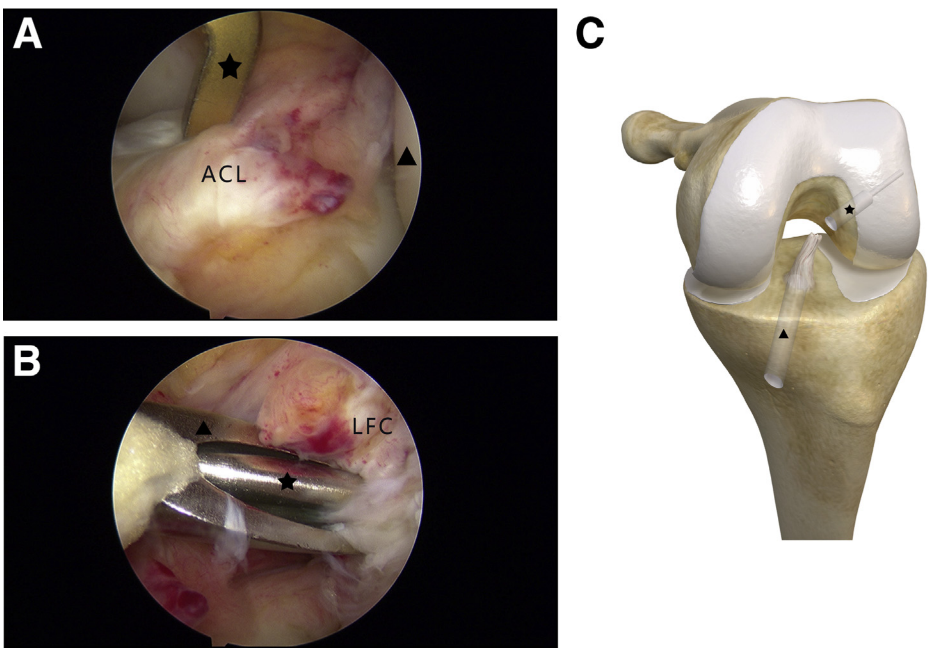

Fig 2. (A) Frontal view of left knee through anterolateral portal showing the location of the tibial tunnel. The tibial guide (Smith & Nephew) (star) points to the anterior cruciate ligament (ACL) footprint. The triangle indicates the wall of the lateral femoral condyle. (B) Frontal view of left knee through anterolateral portal showing the location of the femoral tunnel. The triangle indicates the 7-mm offset femoral guide (Smith & Nephew). The star indicates the K-wire with a diameter of 2 mm. (C) Frontal view of left knee showing preparation of bone tunnels. The star indicates the femoral tunnel; triangle, tibial tunnel.

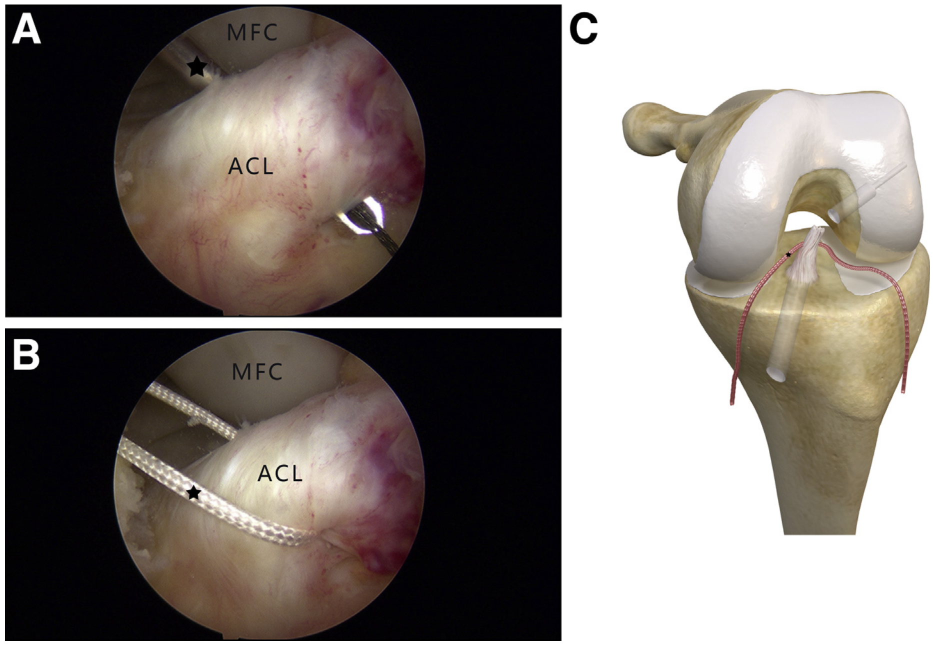

Fig 3. (A) Frontal view of left knee through anterolateral portal showing the first suture of the anterior cruciate ligament (ACL) using a lasso. The star indicates the SutureLasso SD with a perforating needle cannula and a nitinol wire loop. (B) Frontal view of left knee through anterolateral portal showing high-strength tape (Ultrabraid, star) passing through the ACL stump. (C) Frontal view of left knee showing high-strength tape (star) passing through the ACL. (MFC, medial femoral condyle.)

and regardless of the poor quality of the ACL remnant, we can still use the technique to restore as many ACL fibers as possible.

Graft Preparation

The semitendinosus and gracilis tendons are harvested and prepared as a 6-strand hamstring autograft.

Tibial and Femoral Tunnel Preparation

A tibial ACL guide with a tip aimer (Smith & Nephew) is placed at 50° at the center of the ACL footprint. A skin incision is made above the pes anserinus. A K-wire is placed first; the tibial tunnel is then drilled. The drill size is judged by the diameter of the 6-strand graft. Caution is especially taken to protect the remnant of the ACL fibers (Fig 2A).

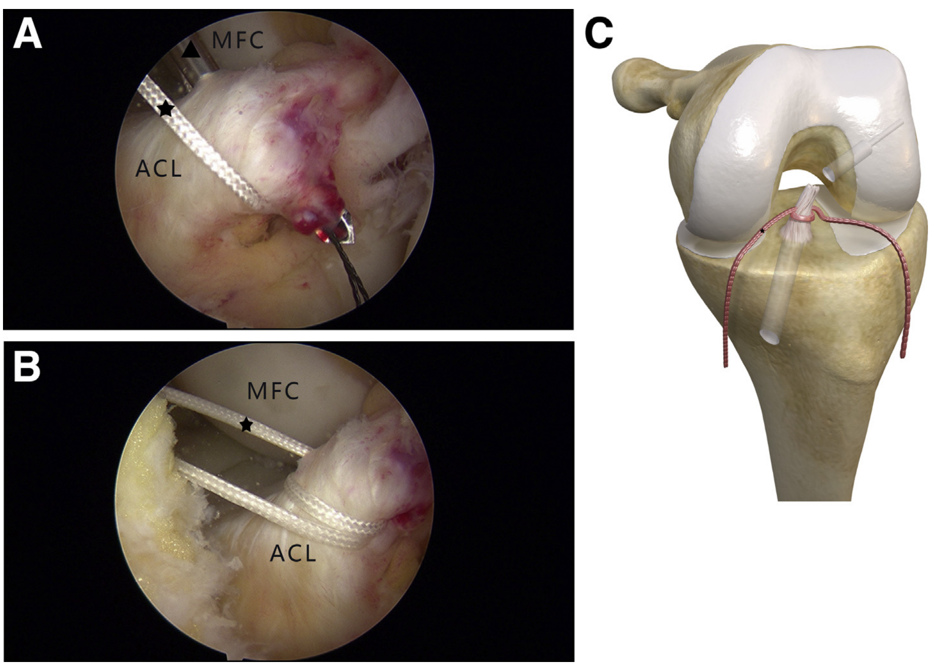

Fig 4. (A) Frontal view of left knee through anterolateral portal showing the second suture of the anterior cruciate ligament (ACL) fibers with the SutureLasso (triangle) and Ultrabraid (star). (B) Frontal view of left knee through anterolateral portal. The medial free end of Ultrabraid (star) is passed through the ACL stump with the wire loop of the SutureLasso. A loop is formed in the ACL stump. (C) Frontal view of left knee showing the loop formed in the ACL stump with Ultrabraid (star). (MFC, medial femoral condyle.)

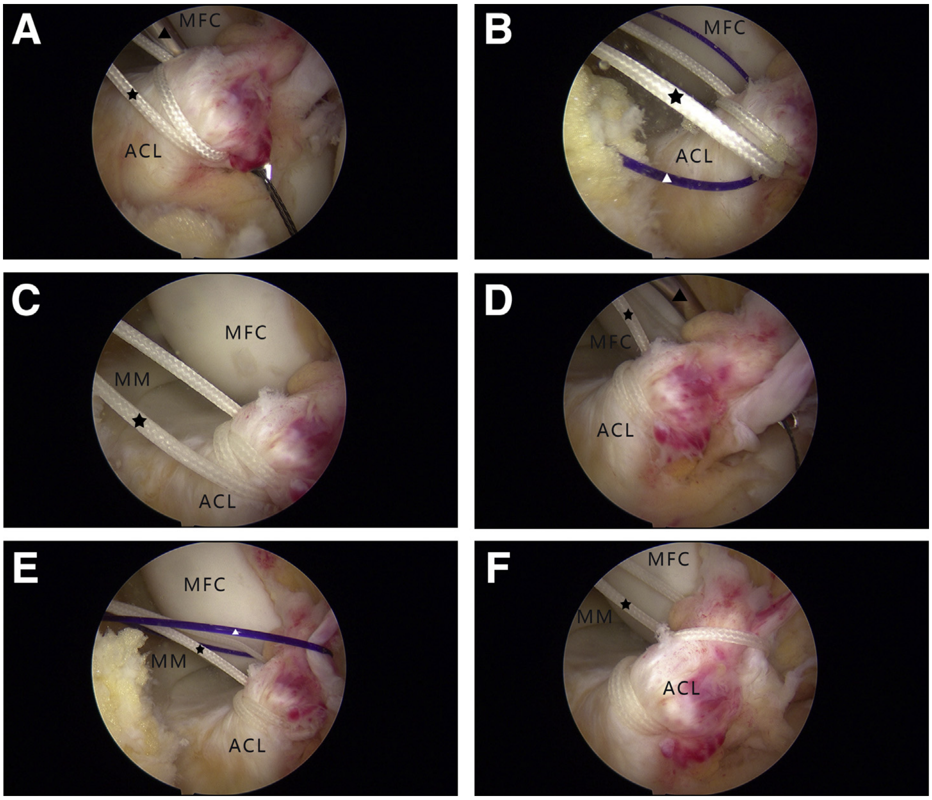

Fig 5. Frontal view of left knee through anterolateral portal. (A) A third suture crosses the anterior cruciate ligament (ACL) fibers with the SutureLasso (triangle). The star indicates the Ultrabraid loop in the ACL stump. (B) A No. 0 PDS II suture (Ethicon) (triangle) is passed through the ACL stump as the passing wire with the nitinol wire loop of SutureLasso. The star indicates the Ultrabraid loop in the ACL stump. (C) The lateral free end of Ultrabraid (star) is pulled into the ACL stump by the medial end of the PDS suture, and a second loop is formed in the ACL stump. (D) A fourth suture of the ACL stump is performed from distal to proximal with SutureLasso (triangle). The star indicates the 2 Ultrabraid loops in the ACL stump. (E) A No. 0 PDS suture (triangle) is passed through as the passing wire with the nitinol wire loop of SutureLasso. The star indicates the 2 Ultrabraid loops in the ACL stump. (F) The distal end of the Ultrabraid (star) is passed from distal to proximal. A third loop is formed more proximally. (MFC, medial femoral condyle; MM, medial meniscus.)

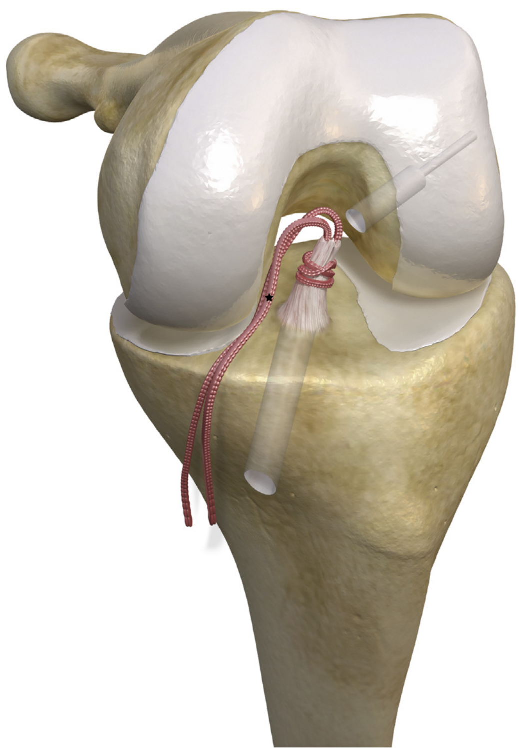

Fig 6. Frontal view of left knee showing the anterior cruciate ligament suture (star) using a suture method similar to the Kessler technique for flexor tendon repair.

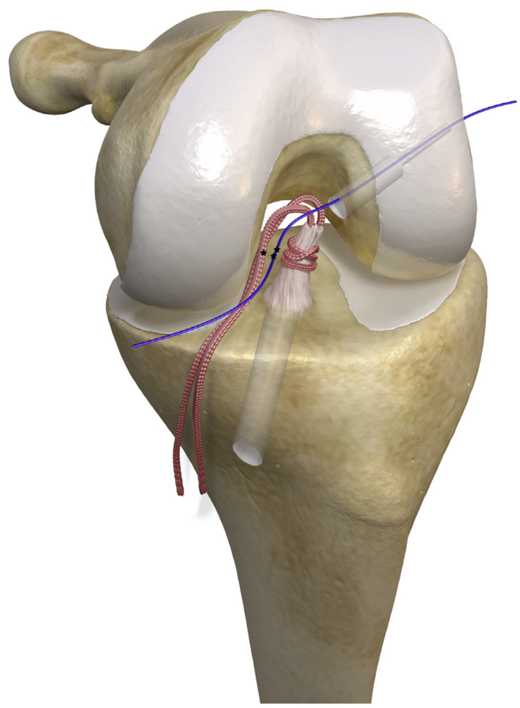

Fig 7. Frontal view of left knee. A passing wire is passed from the medial portal through the femoral tunnel outside the lateral skin (2 stars). The single star indicates the anterior cruciate ligament suture with Ultrabraid (1 star).

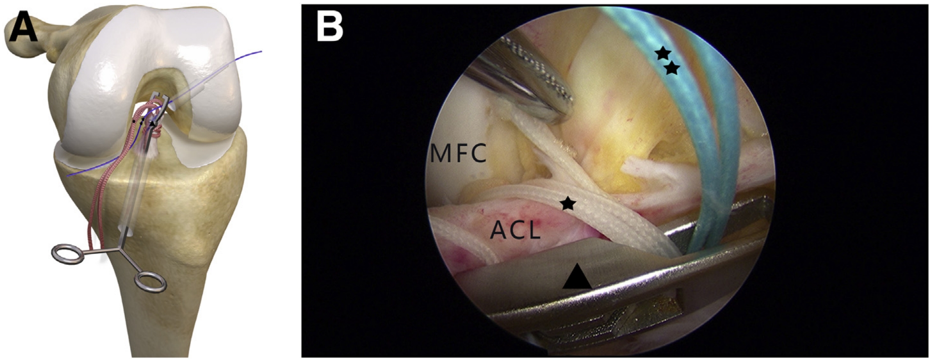

Fig 8. (A) Frontal view of left knee. A grasper (triangle) is placed through the tibial tunnel into the joint to hold the passing wire (2 stars) and the free end of Ultrabraid (1 star). (B) Frontal view of left knee through anterolateral portal showing the grasper (triangle) hold the passing wire (2 stars) and the free end of Ultrabraid (1 star). (MFC, medial femoral condyle.)

At the femoral attachment, a 7-mm offset guide (Smith & Nephew) is placed against the posterior wall of the lateral femoral condyle, and a K-wire is drilled from the center of the femoral footprint inside out, with the knee fully flexed. A 4.5-mm tunnel is drilled first, and a socket of the desired depth and diameter is then created. The same caution is taken to protect the remnant of the ACL fibers (Fig 2 B and C).

ACL Suture

A repair method similar to the Kessler technique for flexor tendon repair is performed with a SutureLasso SD (Arthrex) and Ultrabraid (Smith & Nephew). The SutureLasso SD is a curved, perforating needle cannula with a nitinol wire loop. The Ultrabraid is a kind of No. 2 high-strength wire with co-braid suture. The critical point is to grasp as many ACL fibers as possible. Two or more loops are formed around the distal ACL stump (Figs 3-6).

Passage and Fixation of Graft and High-Strength Wire

Step 1. A long guide pin with a passing wire is inserted into the femoral tunnel from the anteromedial portal (Fig 7). With the knee flexed, the pin is passed

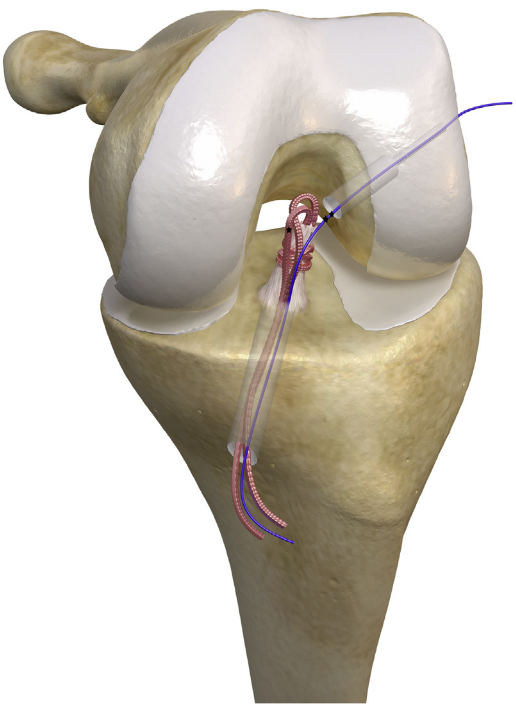

Fig 9. Frontal view of left knee. The passing wire (stars) and the free end of Ultrabraid (triangle) are grasped outside the tibial tunnel.

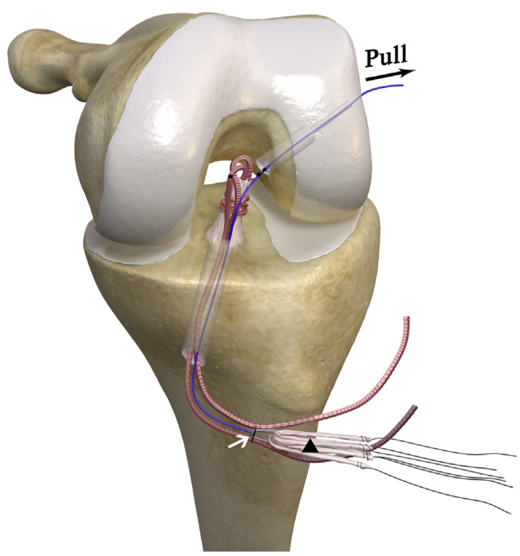

Fig 10. Frontal view of left knee. The 6-strand graft (triangle) is prepared and connected to the TightRope RT (white arrow). The 2 free ends of Ultrabraid (1 star) are each passed through the eyeholes of the TightRope RT, which is connected to a passing wire (2 stars).

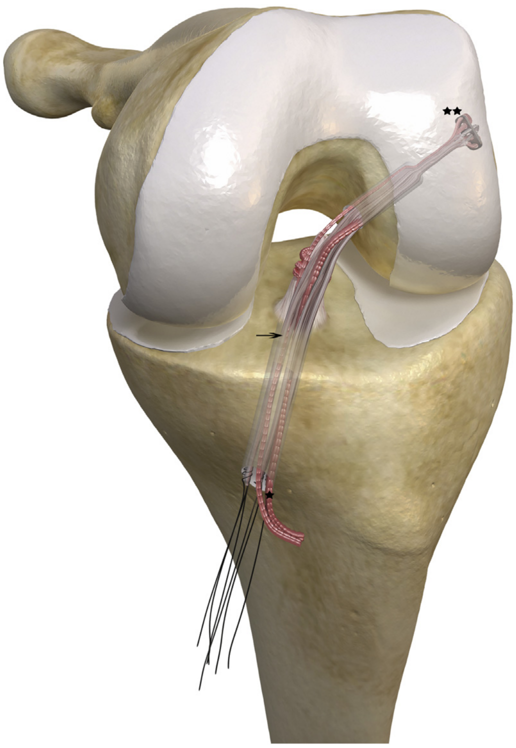

Fig 11. Frontal view of left knee. The graft (arrow) and the Ultrabraid (1 star) are passed through the femoral tunnel. The TightRope (2 stars) is flipped on the femoral cortex.

proximally out through a puncture in the soft tissue, where it is pulled free of the passing suture.

Step 2. The passing wire and the free end of Ultrabraid are retrieved through the tibial tunnel (Figs 8 and 9).

Step 3. The 6-strand graft is prepared and connected to a TightRope RT (Arthrex). The 2 free ends of Ultrabraid are each passed through the eyeholes of the TightRope RT (Fig 10).

Step 4. The graft and the Ultrabraid are pulled into the bone tunnels along with the passing wire. The TightRope is pulled out of the femoral tunnel and seated on the femoral cortex (Fig 11).

Step 5. Proper retrograde tension should be applied to the graft and Ultrabraid while the knee is flexed and extended 20 times to make sure the TightRope RT has been properly seated and has eliminated slack from the graft.

Step 6. With the knee flexed at 30°, tibial fixation of the graft is performed with Biosure Sync (Smith & Nephew). A 5.5-mm Footprint PK suture anchor (Smith & Nephew) is used to stabilize all the suture ends dangling out of the tibial incision (Fig 12).

Rehabilitation

The patient is allowed to fully bear weight with crutches during the first week. Physical therapy focuses on early range of movement, muscle control, and restoration of function. The rehabilitation protocol can be compared with the accelerated ACL reconstruction protocol described by Irrgang.[8] Use of a brace is required for 6 weeks.

Discussion

Compared with other ACL primary repair techniques, one of the critical features of the hybrid technique is using graft as a provisional scaffold, which forms a “bridge” between the 2 torn liment ends. The pathology and mechanism behind the failure of the ACL to heal have been identified as missing a provisional scaffold at the ACL wound site.[9] Without a provisional scaffold, if a gap forms between the torn ends of the ACL fibers, the synovial fluid hampers the formation of a stable fibrin-platelet clot. For most ACL repair techniques, patient selection is restricted to patients with proximal tears of good quality, described as Sherman type I tears.[7] Proximal ACL ruptures (Sherman type I tears), with good tissue quality and good contact between the ruptured ends, have the best outcomes. However, after proximal

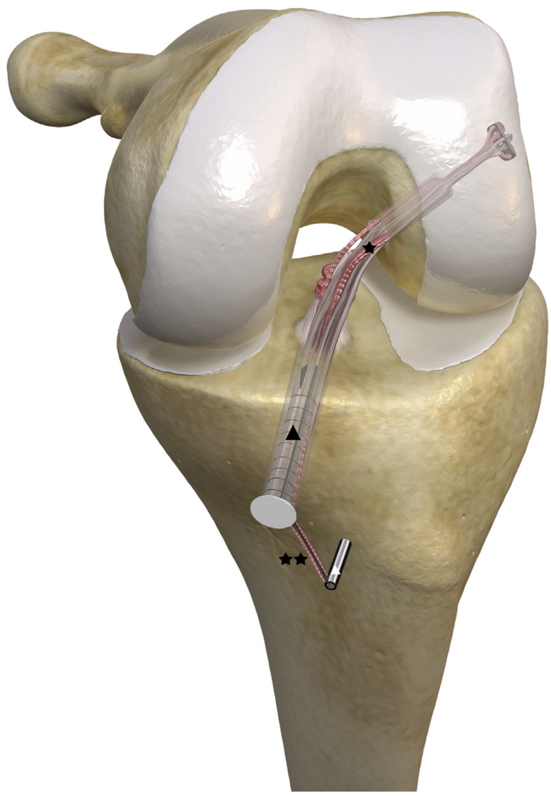

Fig 12. Frontal view of left knee. Tibial fixation of the graft is performed with Biosure Sync (black triangle). A 5.5-mm Footprint PK suture anchor (white triangle) is used to stabilize all the suture ends (stars) dangling out of the tibial incision.

Table 2. Advantages and Disadvantages of Hybrid Repair Technique Combining Single-Bundle Reconstruction and Primary Repair With Internal Brace Augmentation for Anterior Cruciate Ligament Injury

Advantages
The native ACL is carefully sutured with high-strength wire, and the tension is restored.
The remnant can reattach to the femoral footprint of the ACL with proper fixation.
The 6-strand hamstring graft provides a provisional scaffold to eliminate gap formation.
The graft scaffold contributes to the formation of a stable fibrin-platelet clot, which can make the ruptured ends of the ACL heal.
Disadvantages
Hamstring harvesting comorbidity can occur with the 6-strand graft as the provisional scaffold.
The native ACL is spared, which hinders the precise location of bone tunnels, especially the femoral tunnel.

ACL, anterior cruciate ligament.

ACL repair, gap formation of approximately 1 mm was measured after repetitious knee cycling with a mean maximum failure load of 243 N.[10] Sherman type II and III tears affect more ACL fibers distally, where more gap formation will be noted. The outcome of midsubstance primary repairs is significantly worse than that of proximal ruptures.[11] For these cases, the hybrid technique is more suitable than independent ACL repair, including primary repair, repair with static augmentation, and repair with dynamic augmentation. The hybrid technique combined repair with internal brace augmentation and single-bundle reconstruction. The 6-strand hamstring graft provides a provisional scaffold to eliminate gap formation. The graft scaffold will contribute to the creation of a stable fibrin-platelet clot, which can make the ruptured ends of the ACL heal.[9]

Crain et al.[12] described 4 types of ACL remnant and found that the remnant that reattached to the notch wall made the highest contribution to anterior-posterior translation. The remnant-preserving operative methods focus on less remnant debridement. During remnant-preserving ACL reconstruction, the remnant is left untreated without reattachment to the notch wall, which is different from the hybrid repair. During the hybrid repair, the ACL remnant is preserved with caution during tunnel preparation initially. The ACL suture, similar to the Kessler technique for flexor tendon repair,[13] is performed to hold as many ACL fibers as possible with high-strength wire. Then, the whole distal stump of the ACL is brought to its femoral origin on the lateral notch wall with a provisional scaffold and static augmentation of the internal brace. The hybrid technique is different from remnant-preserving ACL reconstruction, as mentioned earlier, for 2 reasons: (1) The remnant is carefully sutured with high-strength wire, and the tension is restored. (2) The remnant can reattach to the femoral footprint of the ACL with proper fixation.

There are 2 limitations to the hybrid technique. Hamstring harvesting comorbidity can occur with the 6-strand graft as the provisional scaffold. The native ACL is spared, which hinders the precise location of bone tunnels, especially the femoral tunnel (Table 2).

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