Technical Note

Anatomical Double-Bundle Anterior Cruciate Ligament Reconstruction With Suture Augmentation

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Abstract: Ultra-high molecular weight polyethylene sutures are used for repair and reconstruction of extra-articular ligaments in the knee, elbow, and ankle joints. In recent years, the use of these sutures has become popular in a suture augmentation technique and has been applied for use in the reconstruction of the anterior cruciate ligament, which is an intra-articular ligament. Although several surgical techniques have been described in Technical Notes, all reports have been for single-bundle reconstruction, and none have applied the technique to double-bundle reconstruction. This Technical Note provides a detailed description of an anatomical double-bundle anterior cruciate ligament reconstruction combined with the suture augmentation technique.

Anterior cruciate ligament (ACL) reconstruction has been reported to have good clinical results; however, unresolved problems remain, such as the difficulty in early return to sports, re-rupture, and residual instability caused by poor initial strength of the tendon graft and the long time required for remodeling.[1,2] In recent years, the suture augmentation (SA) technique, which uses ultra-high molecular weight polyethylene (UHMWPE) sutures as augmentation in extra-articular ligament reconstruction, has become popular. This augmentation technique has also been used in ACL reconstruction with the aim of overcoming the above-mentioned problems and has attracted much attention for its versatility.[3-7] The SA technique can potentially resolve various problems in ACL reconstruction by protecting the tendon graft during the initial revascularization phase when the strength of the grafted tendon is reduced.[8-11] The purpose of this Technical Note is to describe in detail the SA technique using UHMWPE in combination with anatomical double-bundle ACL reconstruction.

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This work was financially supported in part by the Grants-in-Aid for Scientific Research of Japan Society for the Promotion of Science, Grant Number JP 20K17996 from the Ministry of Education, Culture, Sports, Science and Technology, Japan

The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received November 26, 2022; accepted February 12, 2023.

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2212-6287/221541

https://doi.org/10.1016/j.eats.2023.02.029

Surgical Technique

A detailed demonstration of the technique is shown in Video 1. The surgical pearls and pitfalls are provided in Table 1. The advantages, risks, and limitations of this procedure are summarized in Table 2.

Graft Preparation

The harvested ipsilateral semitendinosus tendon is cut into 2 pieces, one for the anteromedial (AM) bundle (13-14 mm long) and another for the posterolateral (PL) bundle (11-12 mm long). The diameter of each graft should be approximately 6 mm when doubled, and the gracilis tendon is also needed if their length or thickness is insufficient. The tendon for the AM bundle is doubled through the loop of a TightRope RT (Arthrex, Naples, FL), and the tibial end of the graft is sutured using No. 2 FiberLoop with FiberTag whipstitch (Arthrex). A No. 5 FiberWire (Arthrex) is used as suture augmentation (SA) and is doubled by passing through a loop of the TightRope RT inside the graft. Both ends of the SA suture are passed through the inside of the area stitched with FiberLoop on the tibial side of the graft, and the final pass should subsequently

Table 1. Surgical Pearls and Pitfalls

Pearls
Pass the SA inside the tendon graft and FiberLoop during preparation of the graft tendon, so that the SA is completely covered by the tendon graft while in the joint.
Tension the tendon grafts on the graft preparation station before introducing them to prevent their loosening after introduction.
Use the tensioning boot system when fixing the tibial side of the tendon graft, and flex and extend the knee to remove the laxity of the tendon grafts and to apply adequate tension to the AM and PL bundles simultaneously. Confirm that the tendon grafts are slightly lax arthroscopically.
Before fixation of the tendon grafts, check that they have a length pattern in which they are tight in knee extension and lax in knee flexion. The tendon grafts are fixed in 30° knee flexion, and the SAs are fixed to DSPs over a blunt hook in full knee extension. SAs should be fixed in independent tension with particular care taken to not make them tighter than the tendon grafts.
Pitfalls
Fixing the SAs too tightly may cause a stress shield effect on the tendon grafts, which may adversely affect their remodeling.
If the SAs are fixed too loosely, the SAs may not be able to protect the tendon grafts.

SA, suture augmentation.

exit from the tibial side of the graft (Fig 1). The 10 mm from the femoral end and the central portion of the graft are sutured together with polyglycolic acid suture (Vicryl; Ethicon Inc., Somerville, NJ) so that the SA is covered by the graft intraarticularly. The graft is then tensioned on a graft preparation station (GraftPro; Arthrex) (Fig 2). The graft tendon of the PL bundle is prepared in the same way.

ACL Reconstruction

The femoral bone tunnels are created in the anatomical position using the outside-in method, and the tibial bone tunnels are created according to the method using the anatomical/bony landmarks.[12,13] This method uses a quadrilateral surrounded by 4 landmarks (medial intercondylar ridge, anterior border of the medial and lateral intercondylar tubercles, anterior horn of the lateral meniscus, and Parsons' knob) to create 2 tibial bone tunnels. An Acufex Director Drill Guide (Smith & Nephew Endoscopy, Andover, MA) is placed at a position one-half the diameter of the AM graft away from the L-shaped ridge (combination of medial intercondylar ridge and Parsons' knob), and the guide pin of the AM bundle is inserted. To prevent coalition of the AM and PL tunnels and to place them within the quadrangle, the guide is placed 5 mm posterior to the AM guide pin and the guide pin of the PL bundle is inserted anterior to the anterior border of the medial and lateral intercondylar tubercles. If the guide pins are determined to be well positioned, drilling and dilating are performed to create the tibial bone tunnels (Fig 3). After the creation of the bone tunnels, each tendon graft is introduced into the tunnel using a guide

Table 2. The Advantages, Risks, and Limitation of Anatomic Double-Bundle ACL Reconstruction With SA

Advantages
A simple and familiar procedure for surgeons performing ACL reconstruction.
FiberWire is thin and flexible for easy intraoperative handling.
SA protects the tendon graft during the initial revascularization phase.
SA promotes early rehabilitation.
Possibility of superior stability with double-bundle reconstruction
Risks and Limitation
Possible foreign body reaction caused by SA
SA may cause stress shielding and delayed remodeling in tendon grafts.
If the SA is too tight, it may over-constrain the joint.

ACL, anterior cruciate ligament; SA, suture augmentation.

suture in the order of the PL bundle and AM bundle, and the TightRope RT is flipped to fix the femoral side of the tendon grafts. The position of the tendon grafts is then adjusted until the proximal and distal ends of the grafts are inserted into the femur and tibia by 10 and 15 mm, respectively. The FiberLoop sutured to the tibial side of the tendon grafts are tied to two Double Spike Plates (DSP; Meira Co., Aichi, Japan). After removing the graft laxity and looseness of the suture strands by flexing and extending the knee while tensioning both the AM and PL bundle grafts using the tensioning boot system (Meira Co.), the length pattern of the grafts is checked to ensure they are tight in knee extension and lax in flexion. The DSPs are fixed with screws at 30° of knee flexion by applying an initial tension of 10 N to each tendon graft (Fig 4).

Fixation of the SA

The No. 5 FiberWires used as SA are fixed in an independent tension from the tendon graft, taking particular care not to over-tension the SAs more than grafts. After fixation of the tendon grafts, the knee is placed in full extension, and the SAs are sutured to DSPs over a blunt hook to fix the SAs slightly looser than the tendon grafts (Fig 5). Finally, the knee is flexed and extended to confirm arthroscopically that the range of motion of the knee is not restricted and that there is no impingement of the graft into the intercondylar notch.

Rehabilitation

After surgery, partial loading with crutches and unrestricted range of motion exercises are permitted. Full loading begins 4 weeks after surgery. Running is allowed at 3 months, and return to sports activities are allowed at 8 to 9 months after surgery.

Discussion

This Technical Note describes an anatomical double-bundle ACL reconstruction with SA augmentation. This technique combines augmentation with UHMWPE

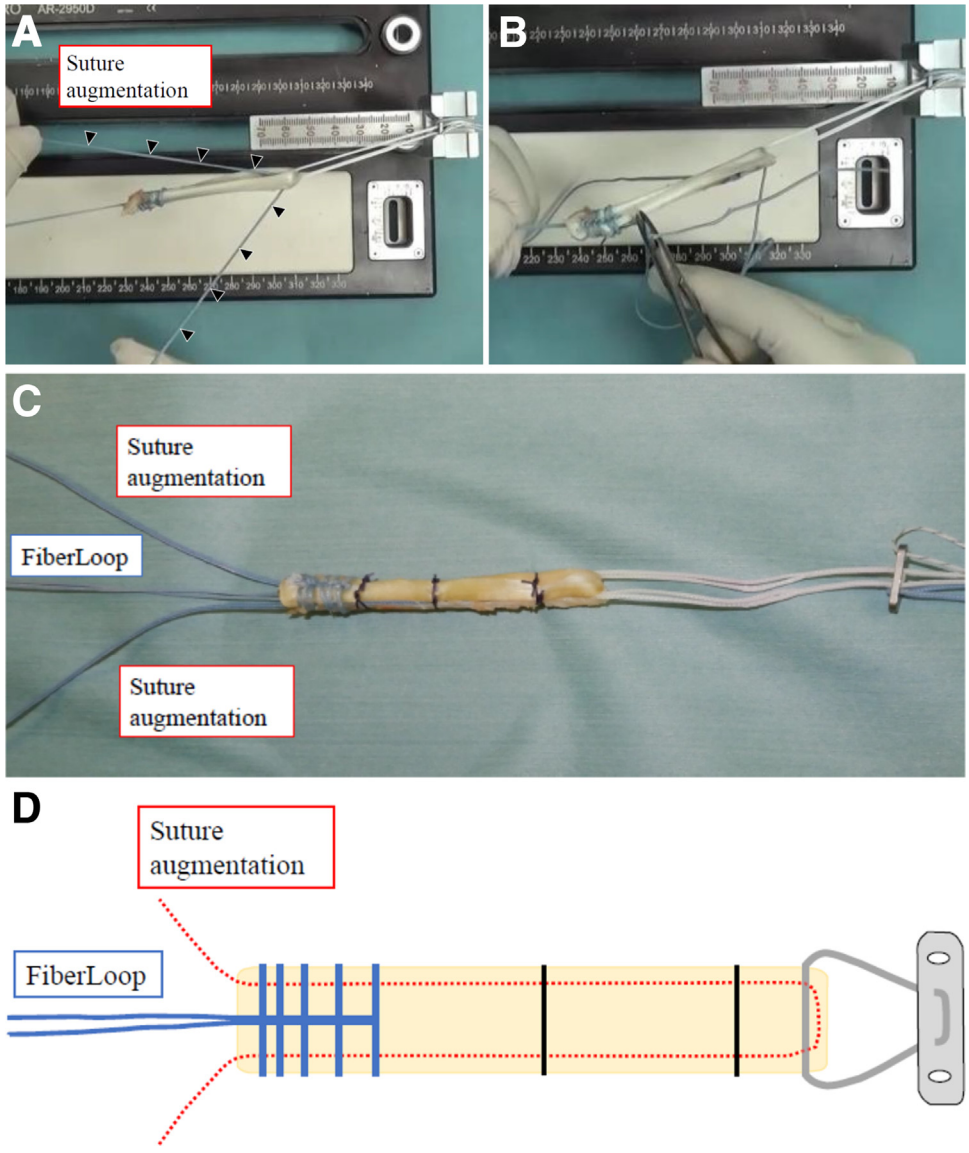

Fig 1. Preparation of the graft with SA. (A) A no. 5 FiberWire (Arthrex, Naples, FL) is used as SA (black arrowheads) and is doubled by passing through a loop of the TightRope RT (Arthrex) inside the graft. (B) Both ends of the SA suture are passed through the inside of the area stitched with FiberLoop (Arthrex) on the tibial side of the graft. (C) The SA should be completely covered by the tendon graft while in the joint. (D) The illustration of the prepared graft with SA. The red dot line indicates SA. SA, suture augmentation.

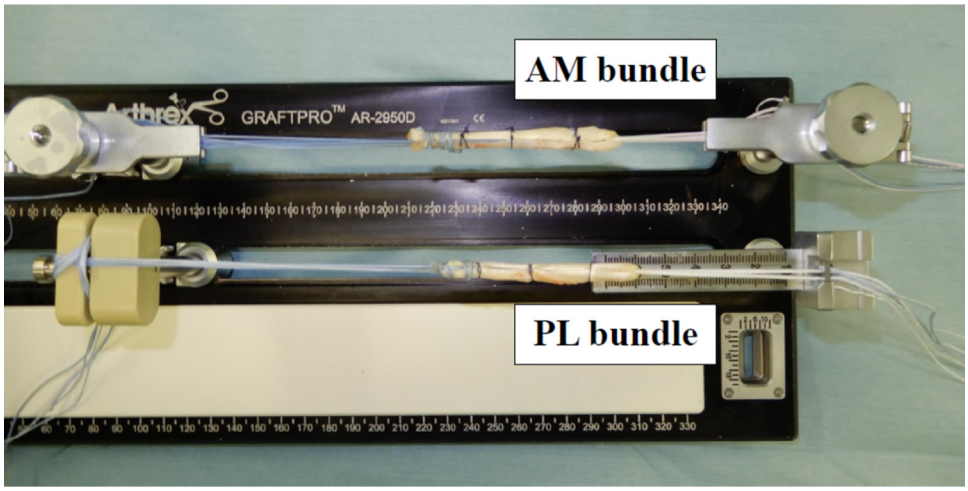

Fig 2. AM and PL bundle grafts being tensioned on the graft preparation station. The grafts are tensioned on the graft preparation station before insertion to prevent loosening after fixation.

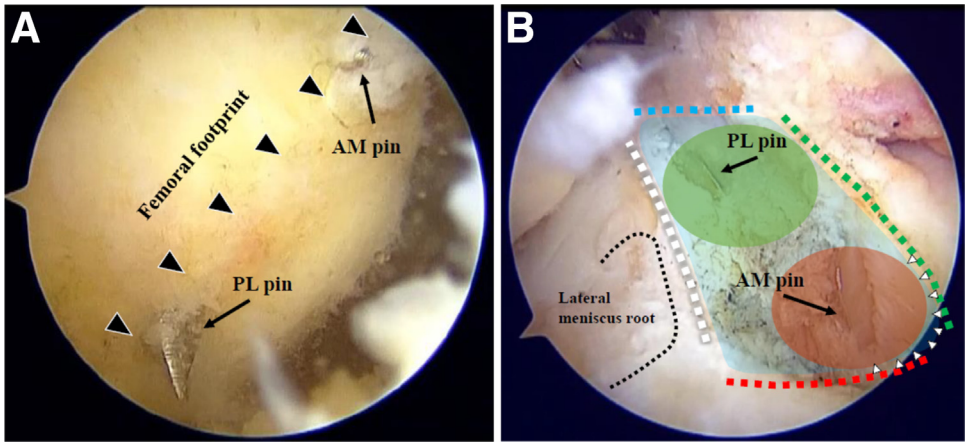

Fig 3. (A) Arthroscopic view of the lateral condyle of the right knee from the anteromedial portal. AM/PL pins are inserted in an appropriate position. Black arrowheads indicate the femoral anatomical footprint of the ACL. (B) Arthroscopic view of the intercondylar notch of the right knee from the anterolateral portal. The AM/PL bone tunnel is located anteroposteriorly within a square formed by four landmarks: anterior: Parsons' knob (red dotted line); medial: medial intercondylar ridge (green dotted line); lateral: anterior horn of lateral meniscus (white dotted line); posterior: anterior border of medial/lateral intercondylar tubercle (blue dotted line). Parsons' knob and medial intercondylar ridge join at the anterior medial margin to form an L-shaped ridge (white arrowhead). ACL, anterior cruciate ligament; AM, anteromedial; PL, posterolateral.

sutures to protect the tendon graft during the initial revascularization phase when the strength of the tendon graft is reduced, and anatomical double-bundle reconstruction for superior anterior and rotational stability. The aim of the technique is to allow an early return to sports and reduce the possibility of re-rupture.

The use of artificial ligaments in combination with autograft tendons in ACL reconstruction has been attempted in the past. However, the use of artificial ligaments for ACL reconstruction was discouraged due to reports of decreased strength of the grafted tendon in animal studies,[14] in addition to slow remodeling of the grafted tendon and frequent synovitis and rupture of the grafted tendon due to foreign body reaction in clinical studies.[15,16] In recent years, the SA method was developed to address these problems.[6,7,17-21] The method uses UHMWPE suture or tape, which is smaller in diameter and stronger than conventional artificial ligaments, in combination with an implanted tendon for reinforcement. Whereas artificial ligaments in the past expected permanent strength of the artificial ligament and ingrowth of tissue into the artificial ligament, the concept of the SA technique is to protect the tendon graft during the initial revascularization period, when the strength of the tendon graft is reduced.[17]

Mechanical studies on the SA technique have reported a reduced load on the tendon graft,[8,10,11] and in vivo studies have reported that SA protects the ligaments[9] and does not adversely affect the remodeling of the tendon graft or cause inflammation resulting from foreign body reaction.[22] Clinical studies have reported that the SA technique results in a higher rate of earlier return to pre-injury activity levels[20] and

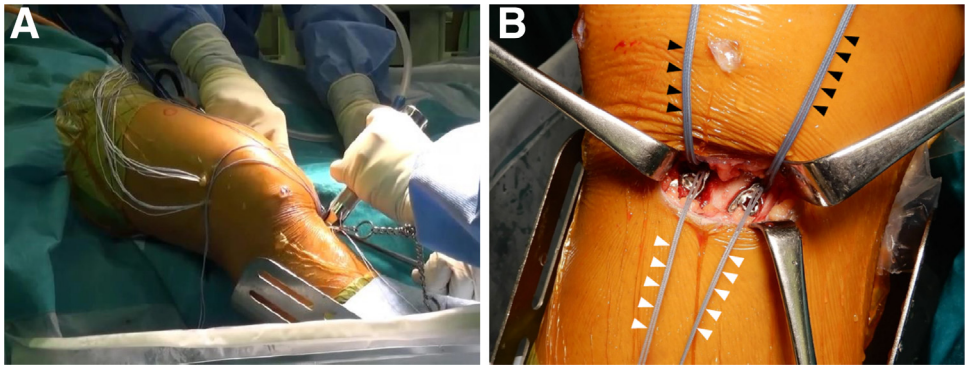

Fig 4. (A) Lateral view of the right knee during tendon graft fixation. Initial tension of 10 N is applied to each graft tendon using a tension boot, and both grafts are fixed using DSPs at 30° of knee flexion. (B) Magnified view of the right knee after fixation of the tendon graft. The tendon grafts (white arrowheads) are fixed using DSPs, but the SAs (black arrowheads) are not yet tied to DSPs. DSP, double spike plate.

Fig 5. (A) Lateral view of right knee during SA fixation. (B) Magnified view of the right knee during fixation of the SAs. The SAs (black arrowheads) are fixed to DSPs over a blunt hook in full knee extension, ensuring that the SAs are not tighter than the tendon grafts. (C) Magnified view of the right knee after fixation of the SAs. The SAs (black arrowheads) are fixed to DSPs under tension independent of the tendon grafts (white arrowheads). DSP, double spike plate; SA, suture augmentation.

improved postoperative Tegner activity scale[18,21] without increasing complications, including joint fibrosis. On the other hand, several studies reported limitations of the SA technique, with no significant improvement in anterior stability[18,19] or re-rupture.[18,20,21] However, most of these clinical studies of the SA technique have used single-bundle reconstruction with hamstrings,[18-21] and our method of combining anatomical double-bundle reconstruction with the SA technique is expected to further improve clinical outcomes because of the advantages of both.

Anatomical double-bundle ACL reconstruction is a surgical technique that mimics the anatomy and function of the native ACL with an AM and PL bundle. Several cadaver studies and systematic reviews have reported better anterior and rotational stability using anatomical double-bundle reconstruction compared to a single-bundle reconstruction.[23,24] We believe that the improvement in stability with anatomical double-bundle reconstruction could overcome the limitations of the SA method described above.

However, there are still several problems with this technique. First, in double-bundle reconstruction, the effect of the SAs of the AM and PL bundles on graft remodeling remains unclear, and there is no established method for the tensioning, limb positioning, and device selection of SA fixation. In this procedure, the SAs were fixed to DSPs over a blunt hook in knee extension to make sure that the SAs are slightly looser than the tendon grafts; however, further mechanical and histological studies are warranted to determine the effect of the SAs and its fixation method on the remodeling of the tendon grafts. Second, the extent to which early rehabilitation is possible when using this method is not yet fully understood. This may be clarified by in vivo studies of the effect of this procedure on the remodeling of tendon grafts and by clinical studies on the safety of earlier return to sports.

In conclusion, we have described the anatomical double-bundle ACL reconstruction combined with the SA technique. This method can potentially resolve the difficulty of early return to sports and re-rupture in ACL reconstruction. Future biomechanical and histological studies are needed on the effects of this method on tendon grafts and clinical studies to verify its clinical benefits.

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