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Technical notes

# Remnant-preserving, selective single-bundle augmentation of the anterior cruciate ligament using a bone–patellar tendon–bone autograft: A technical note

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ABSTRACT

*Background:* To the best of our knowledge, there has been no detailed study on bone–patellar tendon–bone (BTB) grafts for remnant-preserving, selective-bundle anterior cruciate ligament (ACL) augmentation. Therefore, we aimed to develop such a technique using a BTB graft.
*Method:* A total of five patients underwent surgery using the presented procedure. These patients were young, male, and with high body mass index, and hence required very high durability of reconstructed ACL. A femoral bone tunnel was created using the inside-out technique via an accessory far-medial portal, protecting the remnant using a probe, regardless of the presence of an anteromedial (AM) or posterolateral (PL) tunnel. A single tibial tunnel was drilled at the center of the AM or PL attachment and two transverse skin incisions were made in the ipsilateral knee. The central third of the patellar tendon attached to a patellar and tibial bone plug autograft with a width of seven millimeters was harvested by subcutaneous tunneling. The femoral side was fixed using a cortical fixation device for BTB and the tibial bone plug was fixed using an interference screw with the knee at an angle of 20° of flexion by applying maximal manual traction.
*Results:* Bone tunnel enlargement, which was measured by computed digital radiography, was not observed in all cases. A BTB autograft for remnant-preserving, selective-bundle ACL augmentation offers reduced risk of tunnel enlargement.
*Conclusion:* The presented procedure might be considered one of the potentially available options for patients with ACL partial tear who require very high durability of reconstructed ACL.
*Level of evidence:* 5



## 1. Introduction

Anatomical and biomechanical studies conducted in the last decade have shown that restoration of normal knee biomechanics with double-bundle anterior cruciate ligament (ACL) reconstruction is more efficient than that with single-bundle ACL reconstruction. This is because an altered rotational axis results in a significantly higher translation of the lateral compartment in single-bundle ACL reconstruction [1]. On the contrary, Crain et al. reported that arthroscopic evaluation of ACL reconstruction often reveals several types of ACL remnants in the intercondylar notch [2], and a recent ACL reconstruction with preservation of the original remnant or selective-bundle reconstruction has resulted in good clinical outcomes [3–8]. Almost all of these procedures used hamstring grafts. However, potential complications are associated with tunnel enlargement using grafts with soft tissues such as hamstrings [9–11]. One of the popular grafts for ACL reconstruction is a bone–patellar tendon–bone (BTB), which exhibits high strength. To the best of our knowledge, there has been no detailed study on BTB grafts for remnant-preserving, selective-bundle ACL augmentation. Therefore, this study aimed to develop such a technique using a BTB graft for patients requiring very high durability of reconstructed ACL.

## 2. Surgical procedures

### 2.1. Arthroscopic evaluation

Surgery was conducted in patients with supine position under general anesthesia. An arthroscope was inserted into the joint cavity through the medial and lateral portals with the knee flexed at an angle of 90°. The status of the ACL remnant, meniscus, and articular cartilage was determined. An ACL remnant bridging the femur and tibia

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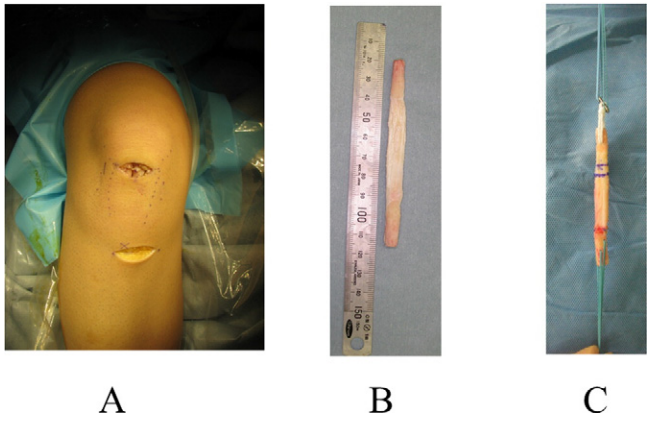


**Fig. 1.** Incisions and graft harvesting. A. Two transverse skin incisions and harvested bone–patellar tendon–bone (BTB) graft. A proximal incision (length two to three centimeters) is made in the distal side of the patella, and a distal incision (length four centimeters) is made in the tibial tuberosity to the medial side. B. Harvested BTB graft with a diameter of seven millimeters. C. The extra-cortical flipped button device is attached to the femoral side and two FiberWires are attached to the tibial side.

was considered to be a good indication for remnant-preserving, selective-bundle augmentation.

### 2.2. Graft harvesting and preparation

Two transverse skin incisions were made in the ipsilateral knee. A proximal incision (length two to three centimeters) was made in the distal side of the patella and distal incision (length four centimeters) in the tibial tuberosity of the medial side (Fig. 1A). The central third of the patellar tendon attached to a patellar and tibial bone plug autograft was harvested by subcutaneous tunneling to avoid damage to the infrapatellar nerve and leave the major portion of the paratenon without incision, as described by Kartus [12]. The tendon was harvested as a rectangular bone plug on the patella of dimensions 7 (W) × 15 (L) × 7 (D) mm (Fig. 1B) and the defect in the tendon was left exposed. Both sides of the tissue sample were trimmed and prepared for easy passage through a diameter of seven millimeters. An EndoButton-CL-BTB (Smith & Nephew, Andover, MA, USA) or BTB TightRope (Arthrex, Naples, FL, USA) was attached to the femoral side through a hole (diameter 1.8 mm for EndoButton CL-BTB; 1.2-mm hole for BTB TightRope) created on the bone plug, and two FiberWires (Arthrex) were attached to the tibial side (Fig. 1C). The width of the BTB graft was seven millimeters, as 10-mm grafts are sometimes unsuitable for Asian and female patients for whom 10 mm is larger than one-third of the width of the patellar tendon.

### 2.3. Notch preparation

An anteromedial (AM) portal and an additional accessory far from the portal were constructed. Soft tissues in the notch were roughly excised using punch or mechanical instruments. Care was taken to avoid damage to the remnant. The remaining fibrous tissues on the lateral notch wall were delicately pared down to a minimum. Notchplasty was not routinely performed.

### 2.4. Tunnel preparation

A guide pin was inserted using the ACL guide system into the joint from the far-medial portal to prepare a femoral tunnel. A femoral bone socket and tunnel were created using the inside-out technique with the knee flexed beyond an angle of 135°, regardless of the AM and posterolateral (PL) tunnels. The probing technique can be used carefully to avoid damage to the remnant. After drilling a tunnel using a cannulated reamer (3.5 mm for BTB TightRope or 4.5 mm for EndoButton CL-BTB) along the guide pin, a tunnel (width seven millimeters) was created using a transportal technique (Fig. 2A and B, Fig. 3A and B). A tunnel for AM bundle-selective augmentation was set at the 1:30- or 10:30-o'clock position for the left or right knee, respectively [13]. A tunnel for PL bundle-selective augmentation was set at the 2:30- or 9:30-o'clock position for the left or right knee, respectively [13]. When using EndoButton CL-BTB, the tunnel length was measured by a scaled probe to determine a suitable fixation device size.

A tibial aimer (Smith & Nephew) was used to insert a guidewire for tibial tunnel preparation. The tip of the aimer was introduced into the joint cavity through the medial infrapatellar portal with the knee flexed at an angle of 90°. The tip was placed at the center of the AM remnant attachment on the tibia for AM bundle-selective augmentation (Fig. 2C), and immediately behind the AM bundle remnant using a probing technique for PL bundle-selective augmentation (Fig. 3C and D). A guidewire (diameter two millimeters) was then drilled into the tibia. The correct position of the guidewire and the absence of medial collateral ligament penetration were then visually confirmed. Finally, a tibial bone tunnel (width seven millimeters) was created (Fig. 3).

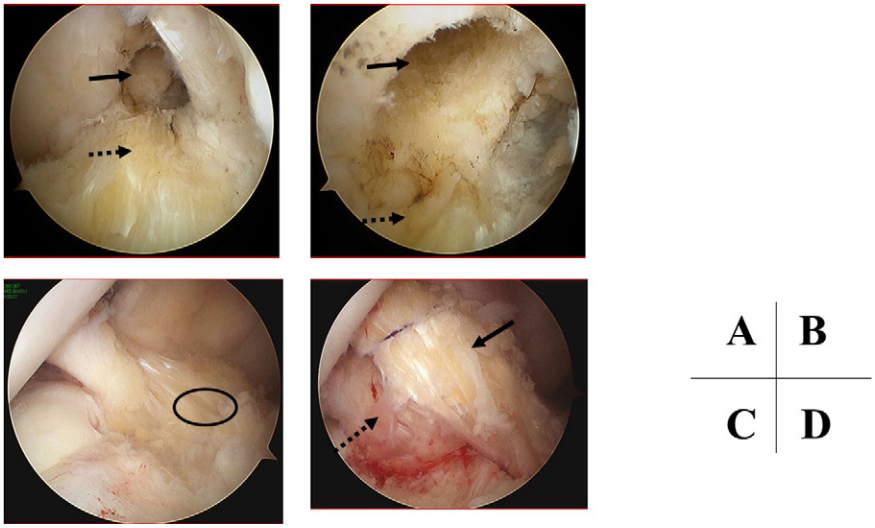


**Fig. 2.** Anteromedial bundle-selective augmentation with remnant preservation. A and B. Arthroscopic findings of the femoral tunnel position (arrow) with remnant (dotted arrow). C. A tibial bone tunnel is created at the center of the anteromedial remnant attachment on the tibia (circle). D. Arthroscopic findings of the reconstructed anteromedial bundle with the BTB graft (arrow) and the preserved remnant (dotted arrow).