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# Evaluation of a behind-remnant approach for femoral tunnel creation in remnant-preserving double-bundle anterior cruciate ligament reconstruction — Comparison with a standard approach

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ABSTRACT

*Purpose:* To evaluate a novel approach for femoral tunnel creation, a behind-remnant approach, in remnant-preserving double-bundle anterior cruciate ligament (ACL) reconstruction through comparison with a standard approach.
*Methods:* Sixty patients who underwent remnant-preserving double-bundle ACL reconstruction were included. Thirty patients with a standard approach were classified as the standard group, and 30 patients with a behind-remnant approach as the behind-remnant (BR) group. The anteromedial bundle (AMB) and posterolateral bundle (PLB) were provisionally fixed at 20° and 45° of flexion to a graft tensioning system during surgery. Bundle tension was recorded during knee flexion–extension and in response to anterior or rotatory loads. Femoral tunnel positions were then assessed using the quadrant method.
*Results:* During flexion–extension, the BR group showed equivalent tension curves between AMB and PLB, while the standard group showed reciprocal tension curves. The tension on the PLB was lower than the AMB in response to anterior or rotatory loads in the BR group, while the AMB and PLB shared equivalent loads in the standard group. Tunnel position of the AMB in the BR group was lower and deeper, with smaller variances, than that in the standard group. Tunnel position of the PLB in the BR group was lower than that in the standard group.
*Conclusions:* In remnant-preserving double-bundle ACL reconstruction, a behind-remnant approach can be achieved without any removal of the remnant tissue, and could create a deeper and lower AMB tunnel and a lower PLB tunnel with higher reproducibility, showing equivalent tension curves between the AMB and PLB.


## 1. Introduction

The anterior cruciate ligament (ACL) can be morphologically divided into two bundles: the anteromedial bundle (AMB) and the posterolateral bundle (PLB); recent trends in ACL reconstruction have been toward anatomic double-bundle ACL reconstruction that replicates both the AMB and the PLB of the native ligament. Recent comparative studies between traditional single-bundle and anatomic double-bundle reconstructions have demonstrated that anatomic double-bundle ACL reconstruction has some advantages in clinical settings with regard to both anterior and rotational stability [1–5], and restores more normal knee biomechanics than traditional single-bundle reconstructions [6,7]. In particular, tunnel positions, especially femoral tunnel position, were considered one of the main factors that influences knee kinematics and clinical results in double-bundle reconstruction. However, controversy still exists regarding where to create the femoral tunnels of the AMB and PLB.

Several studies have been reported with regard to the anatomic femoral insertion and femoral tunnel creation. It is widely accepted that the ACL attaches posteriorly to the lateral intercondylar ridge [8–11], and several studies have described a large femoral insertion area that extends backward to the articular cartilage margin, consisting of the combined portions of direct and indirect insertion [10,12–14]. However, one of the main reasons for the controversy could be that some consider only direct insertion to be the normal attachment site [15–17], while others consider indirect insertion (attachment of the fan-like extension fibers) to be the main attachment site [8,18]. This difference might confuse surgeons as to where in the anatomical insertion site the femoral tunnels should be placed during ACL reconstruction. In particular, it has been a matter of controversy as to where the femoral tunnels should be placed in the large area behind the lateral intercondylar ridge, or what should be used as landmarks in the cases with the ridge located extremely anterior or without obvious ridge [19].

Recently, the remnant preserving technique has been recommended based on the theoretical advantages such as proprioceptive function preservation [20–23], stability preservation [24,25], and graft healing [26–29]. A recent study also showed that the remnant tissue

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can be used for a landmark of anatomic positioning of the tunnels, not only for the tibial side but also for the femoral side [30]. Muneta et al. reported that, with arthroscopic observation behind the femoral remnant tissue from the anteromedial portal, the majority of the ACL injured knees kept the direct insertion of the proximal portion of the injured ACL, whereas fan-like extension fibers attached to the indirect insertion site were covered with synovial tissue differently case by case. These findings could be observed even when the midsubstance fibers, which were attached to the direct insertion site, showed lack of integrity to the midsubstance of the ACL remnant. They developed a new approach for femoral tunnel creation, called a behind-remnant approach, in which femoral tunnels were created behind the ACL remnant using the posterior border of the direct insertion at the ACL femoral attachment as a landmark, without any removal of the remnant tissue.

The purpose of this study was to evaluate the behind-remnant approach in remnant-preserving double-bundle ACL reconstruction during surgery, through comparison with a standard approach. We specifically assessed graft tensions during knee flexion–extension and in response to anterior or rotatory loads, as well as femoral tunnel positions, of the AMB and PLB. The hypotheses underlying this study were that the behind-remnant approach could create lower and deeper femoral tunnels with higher reproducibility, and would show different tension patterns compared to the standard approach.

## 2. Materials and methods

### 2.1. Subjects

Between March 2011 and December 2012, 157 consecutive patients received anatomic double-bundle ACL reconstruction with an autologous semitendinosus tendon in our institution. During this period, we performed remnant-preserving double-bundle ACL reconstruction by the standard approach between March 2011 and January 2012 in all cases, and performed remnant-preserving double-bundle ACL reconstruction by the behind-remnant approach between February 2012 and December 2012 in all cases. Exclusion criteria included revision surgery, knees with osteoarthritis, concomitant ligament tears, history of injuries in the ipsilateral knee, and history of ligamentous injuries in the contralateral knee; seventeen patients were excluded. Among these, 60 patients agreed to be included in this study. The main reasons for the low percentage of participation were that patients were reluctant to have a longer scar (1 cm longer to place a graft tensioning system) and a longer operation time, or did not agree to take computed tomography. They comprised 39 male and 21 female patients with a mean age of 23 years (range, 14–42 years) at the time of surgery. All patients had an ACL-deficient knee with a mean period of 13 months (range, 1–96 months) from injury to surgery. Patients were then divided into two groups; 30 patients who underwent remnant-preserving double-bundle ACL reconstruction by the standard approach were classified as the standard group, and 30 patients who underwent remnant-preserving double-bundle ACL reconstruction by the behind-remnant approach were classified as the behind-remnant (BR) group. There were no significant differences in the demographic data and in preoperative laxity data between the two groups, as can be seen in Table 1. With regard to combined complete meniscus injury, 10 knees had medial meniscus injuries (three repaired and two partially removed), five had lateral meniscus injuries (all repaired) and one had both medial and lateral meniscus injuries (both repaired) in the standard group, whereas nine had medial meniscus injuries (seven repaired and two partially removed), six had lateral meniscus injuries (four repaired and two partially removed) and one had both medial and lateral meniscus injuries (both repaired) in the BR group. This study was approved by our institutional review board, and all the patients provided informed written consent.

**Table 1**
Patients' demographic data.

| | Standard | BR | P value |
|---|---|---|---|
| No. of patients | 30 | 30 | |
| Mean age, y (range) | 23.5 (15–40) | 21.6 (14–42) | 0.18 |
| Sex, male/female | 21/9 | 18/12 | 0.59 |
| Preoperative period, mo (range) | 16.1 (1–96) | 10.2 (1–53) | 0.88 |
| Combined meniscus injuries, no. | 11 | 16 | 0.30 |
| Mean KT measurements, mm (SD) | 6.5 (2.8) | 7.2 (2.8) | 0.18 |
| Pivot shift test, no. | | | >0.99 |
| 1+ | 2 | 2 | |
| 2+ | 18 | 18 | |
| 3+ | 10 | 10 | |

BR, behind-remnant.

### 2.2. Surgical technique

The ACL reconstruction procedure was performed by two attending surgeons (Surgeon one, two) or under their supervision. A standard arthroscopic examination was performed via anteromedial and anterolateral portals. A ruptured ACL was confirmed arthroscopically, and meniscal injury was managed according to the injury status. An oblique 3 cm incision was made on the anteromedial tibial surface at the level of the pes anserinus. Only the semitendinosus tendon was harvested with an open-loop tendon stripper (Smith & Nephew Endoscopy, Andover, MA, USA). The harvested tendon was cut into halves and folded, creating two double-stranded bundles of 5.5 cm or more in length looped with EndoButton CL-BTB (Smith & Nephew Endoscopy). The open end of each graft was closed with two Krackow sutures and a Kessler suture using . Prior to graft passage, the grafts were pretensioned by Suture Vise with Tensiometer (Smith & Nephew Endoscopy) for at least 10 min on Graftmaster (Smith & Nephew Endoscopy).

The remnant tissue of the ruptured ACL at the tibial side was not removed at all. Two tibial guide wires were inserted from the anteromedial surface of the tibia at approximately 10 mm above the tibia tubercle level with anatomical landmarks of the ruptured ACL remnant and medial intercondylar eminence. The guide wire for the AMB was aimed 4 mm posterior to the anterior margin of the ACL remnant and just lateral to the medial intercondylar eminence at an angle of 60° from the joint line in the anterior–posterior radiographic view. The guide wire for the PLB was aimed just anterior and lateral to the spine of the medial intercondylar eminence at an angle of 40° from the joint line in the anterior–posterior radiographic view. Thereafter, tibial tunnels for the AMB and PLB with a diameter matched with the graft diameter were created. The directions of the tibial tunnels were extremely critical for achieving the anatomic femoral position using the transtibial technique.

In the standard group (Fig. 1), only residual tissue of the normal femoral attachment area was peeled off using a monopolar radiofrequency probe as little as possible but enough to detect the intercondylar ridge and the lateral bifurcate ridge [10]. Guide wires for the femoral drill holes were inserted via the transtibial tunnel approach in the figure-of-four position [31] with arthroscopic observation of the frontside of the remnant tissue from the anteromedial portal. The center of the femoral drill hole for the AMB and PLB was aimed at each center of the original AMB and PLB on the basis of bony landmarks. First, the guide wire for the PLB was inserted through the tibial drill hole for the PLB. The center of the femoral drill hole for the PLB was aimed distal to the lateral bifurcate ridge and posterior to the intercondylar ridge in flexion position. A 4.5-mm-diameter tunnel was created to the lateral cortex of the femur using an EndoDrill (Smith & Nephew Endoscopy). A second guide wire for the AMB was then inserted through the tibial drill hole for the AMB. The center of the femoral drill hole for the AMB was aimed proximal to the lateral bifurcate ridge and posterior to the intercondylar ridge in flexion position. A 4.5-mm-diameter tunnel was created from the lateral wall to the lateral cortex of the femur using