



## The modified bone-patellar tendon-bone allograft in single-bundle anterior cruciate ligament reconstruction

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**Bone-patellar tendon-bone graft has been an attractive option for single-bundle anterior cruciate ligament reconstruction in clinical practice. However, the graft-tunnel mismatch in the proximal part of the tibial tunnel and the ultimate strength after postoperative ligamentization process have been potential problems for the traditional 10-mm wide graft. We modified the traditional bone-patellar tendon-bone allograft to make it double-layer, as an ideal substitute graft for single-bundle anterior cruciate ligament reconstruction with better graft-tunnel match and higher initial graft strength.**

**Keywords :** anterior cruciate ligament reconstruction ; bone-patellar tendon-bone ; allograft ; double-layer.

### INTRODUCTION

Bone-patellar tendon-bone (BPTB) graft has been an attractive option for single-bundle anterior cruciate ligament (ACL) reconstruction in clinical practice, because of bone plugs both on femur and tibia allowing for an early and rapid rehabilitation. However, the graft-tunnel mismatch in the proximal part of the tibial tunnel and the ultimate strength after the postoperative ligamentization process have been potential problems for the traditional 10-mm wide graft.

The graft-tunnel mismatch results in a “dead space” proximal to the bone plug in the tibial tunnel (Fig. 1A). The synovial fluid may flow into this dead space (5). Moreover, motion in the sagittal

plane can occur more theoretically during flexion and extension in the early postoperative period, which was believed to be “windshield wiper effect” (6). These factors were thought to interfere with tendon-to-bone healing and to lead to postoperative bone tunnel enlargement. Various methods have been proposed to address this problem, without however eliminating this adverse effect.

In the traditional method for 10-mm BPTB graft, patellar tendon tissue was fashioned into a rectangle in cross-sectional view, with 10 mm in width, approximately 4 mm in thickness (3) (Fig. 1b). The initial strength of such a graft is comparable to the native ACL. However, it is known that all grafts have to go through the postoperative “ligamentization” process, during which initial graft strength is significantly lost and the ultimate strength becomes inferior to the native ACL (2,9,10). In spite of no measurement of ultimate strength *in vivo*, many postoperative laxity failures and graft ruptures in clinical follow-up suggest that a traditional 10-mm

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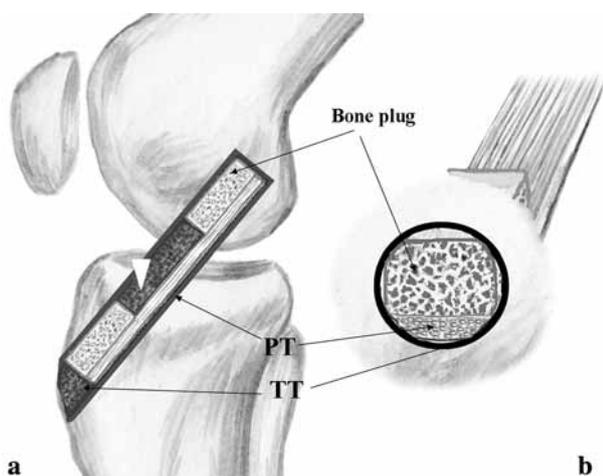
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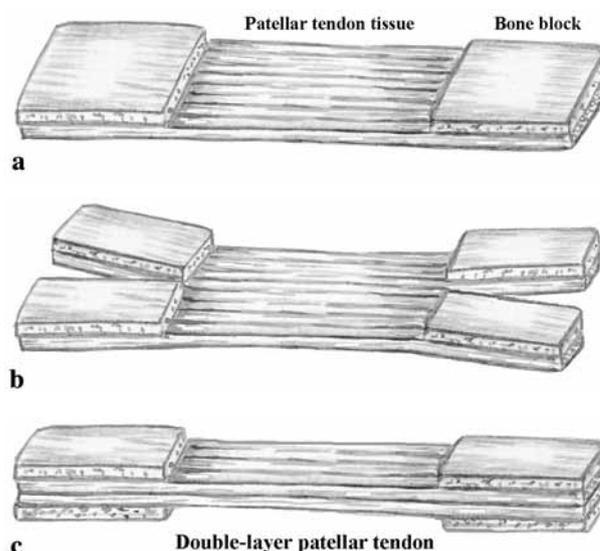
**Fig. 1.** — Illustration of the anterior cruciate ligament reconstruction with traditional bone-patellar tendon-bone allograft. Lateral view of tibial tunnel (a) shows the “dead space” (white triangle) between the patellar tendon graft and proximal tibial bone tunnel. Cross-sectional view (b) shows that patellar tendon tissue is like a rectangle, with 10 mm in width, approximately 4 mm in thickness. PT : patellar tendon, TT : tibial tunnel.

BPTB graft can be problematic after ligamentization changes.

Clinically, allografts have been widely used because they avoid donor-site morbidity and offer other advantages such as larger and predictable graft size (8). We present here a technique to modify the BPTB allograft to make it double-layer for use in single-bundle ACL reconstruction. This modified procedure would make full use of the larger size of BPTB allograft and preserve more patellar tendon tissue, with the aim to better match the graft with the bone tunnel and to increase the initial strength of the graft.

### SURGICAL TECHNIQUE

BPTB allografts from a qualified Tissue Bank in our country, usually wider than 20 mm, were used. The modification procedure was simple (Fig. 2), the bone block on each side of the graft was split into two similar fragments on the midline along its long axis and folded to make the cortices face each other. The ligament tissue was folded and the cancellous bone in excess was resected to make each small fragment 10 mm wide, 5 mm thick and



**Fig. 2.** — Illustration of the modified procedure for double-layer bone-patellar tendon-bone allograft. a : the wide bone-patellar tendon-bone allograft. b : bone blocks on two sides of the graft are split into two similar fragments on the midline along their long axis with patellar tendon tissue left intact. c : the graft is folded to make the cortices face each other, with a double-layer 10 mm wide patellar tendon preserved.

25 mm long. Then the two small bone fragments were fixed together, shaped like a column 25 mm in length and 10 mm in diameter, and the bone block was perforated transversely with drill holes and armed with No. 2 Ethibond suture (Ethicon, Somerville, NJ). The bone plug on each side was fashioned to pass through the 10-mm-diameter gauge. The ligament should be kept as thick as possible to allow a good contact for the graft with the cancellous bone of the tunnel.

The other surgical procedures like bone tunnel position and the fixation method were similar to the traditional technique as described by Kim *et al* for BPTB graft ACL reconstruction (7). The tibial tunnel point was located posterior to the center of the native ACL insertion and 7 mm anterior to the posterior cruciate ligament. The tibial tunnel was created with a cannulated reamer 10-mm in diameter. The femoral tunnel was located at 6 mm anterior to over-the-top point at 10 o'clock position on the right knee or the 2 o'clock position on the left knee at 90° knee flexion. The femoral tunnel was reamed



**Fig. 3.** — Postoperative radiographs of a 20-year-old man after single-bundle anterior cruciate ligament reconstruction with a double-layer bone-patellar tendon-bone allograft. a : antero-posterior view, b : lateral view.

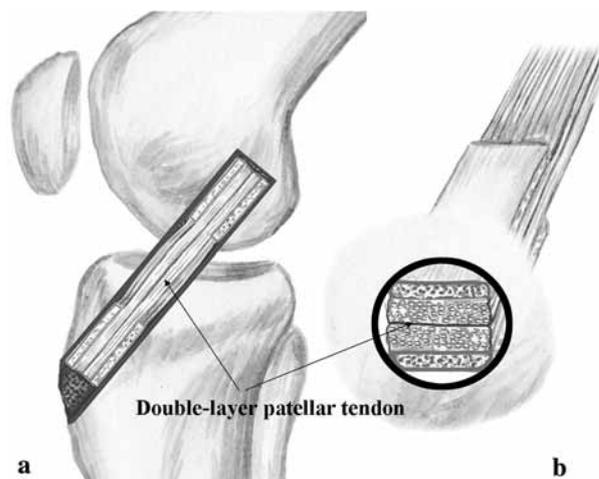
with the 10-mm cannulated reamer to 25 mm in depth. The graft was fixed within the femoral tunnel with use of an 8-mm bioabsorbable interference screw with the knee in 90° of flexion. After pre-tensioning, the graft was fixed within the tibial tunnel with a 9-mm bioabsorbable interference screw in 10° to 15° of knee flexion (Fig. 3).

Each patient was placed in a hinged brace in 0° of flexion for one week, then with gradual increase from 0° to 60° of flexion until 90° was achieved at the fourth week. All patients were permitted immediate partial weight-bearing using crutches. Patients were allowed to bear their full weight approximately four weeks after surgery. By the twelfth week, jogging, swimming, and cycling were permitted. Return to sports involving jumping, pivoting, or sidestepping was allowed after six months.

## DISCUSSION

The double-layer procedure as described here was the first to successfully introduce the 20-mm BPTB allograft in the clinical practice. Based on the wide 20-mm allograft, this modified procedure will match the graft with the bone tunnel better and simultaneously increase the initial graft strength.

For the double-layer BPTB allograft, approximately 8 mm in thickness of patellar tendon tissue will make a better match with the bone tunnel (Fig. 4). We can roughly estimate the cross-section-



**Fig. 4.** — Illustration of the anterior cruciate ligament reconstruction with double-layer bone-patellar tendon-bone allograft. a : lateral view of tibial tunnel, b : cross-sectional view.

al area of the tunnel and the graft : the cross-sectional area of the bone tunnel 10 mm in diameter is 78 mm<sup>2</sup> and is virtually similar for the 10-mm wide double-layer patellar tendon. This will achieve a good contact for the tendon tissue with the cancellous bone around the tunnel. Therefore, the inner opening of the tibial tunnel is blocked and synovial fluid will not reflux into the bone tunnel. Moreover, the good match will reduce the interspace between the graft and tunnel and the adverse “windshield wiper effect” will be decreased. These factors will create favourable conditions to promote tendon-to-bone healing.

In the traditional preparation procedure, much bone and ligament tissue was resected uselessly, as the BPTB allograft was trimmed to be 10 mm in width to match the bone tunnel. However, a wider patellar tendon was found preferable. Barber *et al* suggested to preserve the patellar tendon as wide as possible, even up to 15 mm in their BPTB allograft reconstruction (1). A cadaver study compared the mean ultimate load of 7-mm-wide, 10-mm and 15-mm BPTB composites, and showed that the wider BPTB grafts had the higher ultimate load (4). In the present study, we used the double-layer technique to match 20-mm wide patellar tendon into the bone tunnel of 10 mm in diameter. For the double-layer BPTB allograft, the patellar tendon attached

to the bone cortex will be 20 mm in width, the initial strength will be significantly increased and the ultimate load will be high enough to meet the demand on the native ACL even after the ligamentation process.

Compared to the traditional method, it is a simple modification without additional difficulty for surgeons ; and it is an economic procedure to make full use of the wide allograft and reserve 20 mm wide patellar tendon without additional cost for patients. In our clinical experience with 48 patients, knee stability was restored and knee function was improved without special complications.

Nevertheless, wide grafts, wider than 20 mm, are required for application of this double-layer technique, so this procedure only applies to allografts. One more reason is that the ultimate load of allograft needs to be strengthened because it is reduced in the process of sterilization and preservation and the slow tendon-bone healing process. Second, the needs extra width was easily provided with allografts.

#### Acknowledgment

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