

Anatomic Oblong Double Bundle Anterior Cruciate Ligament Reconstruction

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Summary: Double-bundle anterior cruciate ligament (ACL) reconstruction using hamstring tendon grafts is a standard procedure for ACL injury. However, its clinical effectiveness is not always satisfactory. One cause of this was problems with the graft-tunnel healing of the posterolateral bundle (PLB) on the femur. To solve this problem, we devised a new anatomic ACL reconstruction technique to improve the graft-tunnel healing of the femoral PLB by using a single-bundle with one bone tunnel on the femoral side and a double-bundle on the tibial side. We have performed 40 procedures with excellent results and no cases of intra- or postoperative complication. This procedure can help improve the graft-tunnel healing around the femoral bone tunnel aperture for the PLB.

Key words anterior cruciate ligament, anatomic double-bundle reconstruction, hamstring tendon autograft, graft-tunnel healing

INTRODUCTION

Arthroscopic anatomic anterior cruciate ligament (ACL) reconstruction with a hamstring tendon graft is the standard procedure for ACL injury [7,17]. Conventionally, single-bundle (SB) ACL reconstruction is performed, in which two bone tunnels are made in the center of the footprints on the femur and tibia, and a semitendinosus tendon consisting of a single massive multistrand bundle (4-6 double bundles) is transplanted. However, a recent anatomical study has shown that the ACL actually consists of two func-

tionally different bundles—the anteromedial bundle (AMB) and the posterolateral bundle (PLB) [5]. To more closely mimic this normal structure, a double-bundle (DB) ACL reconstruction was developed, in which bone tunnels for both the AMB and PLB are created within the femoral and tibial footprints (4 tunnels in total), and a multistrand bundle is divided into two ST (2-3 double bundles each for AMB and PLB) for transplanting.

Randomized controlled trials [6,12] and a meta-analysis [4] have suggested that the clinical outcomes of DB ACL reconstruction are better than those of SB

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Abbreviations: ACL, anterior cruciate ligament; AMB, anteromedial bundle; DB, double-bundle; FAM, far anteromedial; MIR, medial intercondylar ridge; PLB, posterolateral bundle; SB, single-bundle; ST, Semi Tendinosus Tendon.

ACL reconstruction as measured with a KT-1000 arthrometer (anterior stability) and the pivot shift test (rotational stability). However, other reports have not found clear differences between the two methods [2,13]. Theoretically, anatomic DB ACL reconstruction should restore the physiological functions of the knee; however, its clinical effectiveness has not yet been sufficiently verified. Several studies have found problems with the PLB graft, which is the most important factor in DB ACL reconstruction. According to previous studies of second-look arthroscopic examinations, Otsubo et al. [7] reported poor synovial coverage of the PLB in 16% of cases and 11% of the PLB grafts showed substantial damage around the femoral tunnel aperture. Similarly, Asagumo et al. [1] reported PLB graft rupture in 7% (5 of 71) of cases. These studies indicated that one cause of this was problems with the graft-tunnel healing of the PLB on the femur. In previous MRI studies, Taketomi et al. [14] reported poor graft-tunnel healing of the femoral footprint on the PLB side, which they thought was due to large changes in the tension of the PLB graft inside the bone tunnel. Furthermore, Tanaka et al. [15,17] reported high signal-intensity lesions were frequently observed around the femoral tunnel aperture in PLB images of DB grafts compared to SB grafts, suggesting that SB grafts had more favorable graft-tunnel healing at the femoral side.

From these studies, we surmised that one reason DB ACL reconstruction failed to show clearly better results than SB ACL reconstruction was a certain probability of damage occurring to the PLB graft in the femoral bone tunnel. In other words, if healing of the PLB on the femoral side could be improved and the mechanical strength could be increased, a DB ACL reconstruction could better restore the original functions and produce superior results in more patients. Therefore, we devised a new technique of anatomic ACL reconstruction to improve the graft-tunnel healing of the femoral PLB by using an SB with one bone tunnel on the femoral side and a DB on the tibial side. To preserve the original advantage of anatomic DB ACL reconstruction, we did not use a simple circle for the single femoral bone tunnel but employed an oblong shape to better reproduce the anatomical footprint of the ACL.

In this article, we describe in detail the surgical technique, which we call “anatomic oblong double-bundle ACL reconstruction.”

SURGICAL TECHNIQUE

Scoping Technique

The knee is held at 90° of flexion on the operating table. In addition to the two standard anteromedial and anterolateral portals, a far anteromedial (FAM) portal is created 1.5 cm medially to the anteromedial portal. First, an arthroscopic evaluation was performed through the two standard portals. If the need arises, meniscal surgery and chondroplasty and so on were performed before the ACL reconstruction.

Graft Harvesting and Preparation

A small longitudinal skin incision about 3 cm long was made at the pes anserinus, and a semitendinous muscle tendon was harvested by the commonly used procedure. As the muscle belly is removed, the harvested semitendinosus tendon has two portions, distal tendinous and proximal membranous (Fig. 1-A). In the anatomic double-bundle ACL reconstruction which is commonly performed, the AMB and the PLB grafts mainly consist of a tendinous and membranous part, respectively, and quality of the PLB graft is predicted to be poor compared to the AMB, despite the fact that the excursion of the PLB graft is reported to be larger

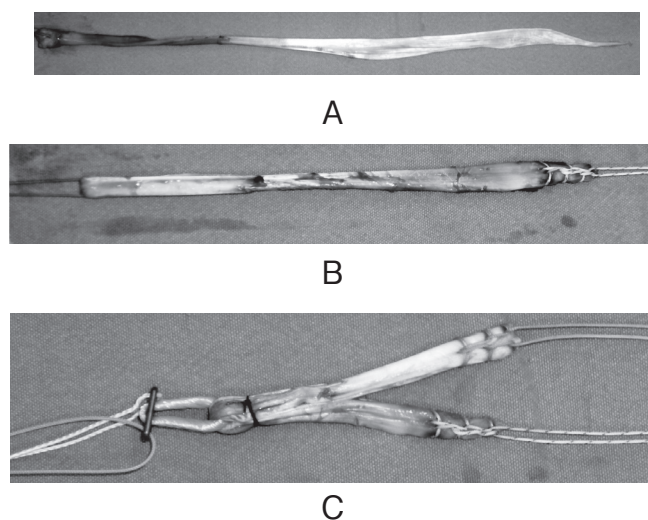


Fig. 1. Graft preparation. (A) The tendinous (left end) and membranous parts (right end) of the graft are exposed after removing the muscle belly. (B) The semitendinosus tendon is folded in half at its middle, and the ends are connected with a strong suture. (C) After passing it through the loop of an Endobutton-CL, the anteromedial bundle (AMB) is folded again so that it is 5-7 mm longer than the posterolateral bundle (PLB). Thereafter, the AMB is formed from one-half of the semitendinosus tendon, and the PLB from the tendinous portion and membranous portion of both ends.

than that of the AMB. In our procedure, to compensate for the possible weakness of the PLB graft, the graft is prepared in consideration of the following two points. One is that the graft is prepared in a V-shape, with one limb on the femoral side and two limbs on the tibial side. The other is that the PLB graft is made of both the tendinous and membranous parts, which improves the properties of the PLB.

In brief, the harvested semitendinosus tendon is looped through #3 non-absorbable suture, and a Krackow suture with #2 Fiber wire is applied at each end. The #3 non-absorbable suture is left alone until the graft passage (Fig. 1-B).

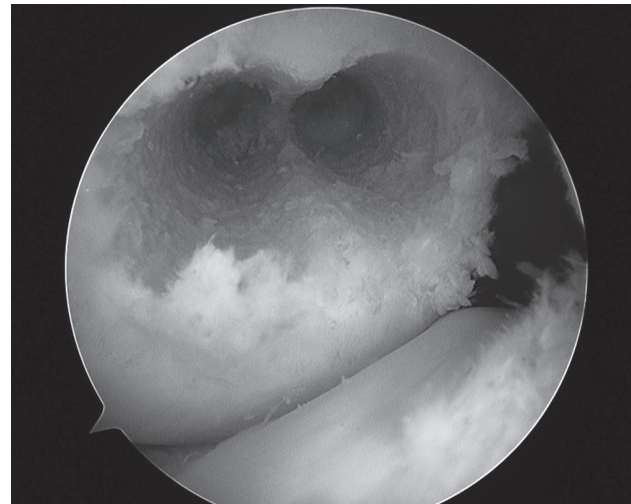
After the total channel length of the femoral tunnel is measured, the doubled tendon is looped through an Endobutton-CL (Smith & Nephew Endoscopy, MA). In consideration of difference in length of the AMB and the PLB in the native ACL, we create 5 to 7 mm of length difference between the AMB and the PLB (Fig. 1-C).

Femoral Socket Creation

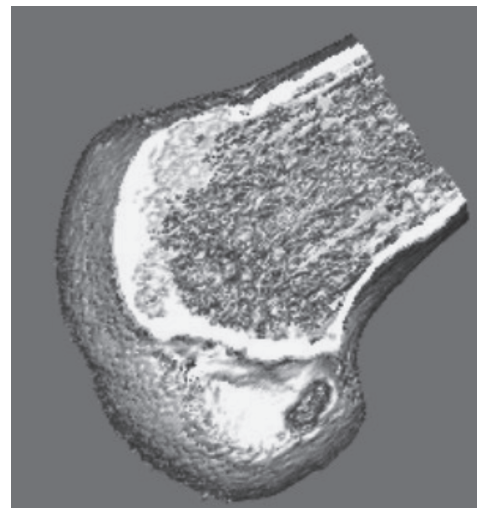
Under arthroscopic viewing through the antero-medial portal, the femoral socket is made through the FAM portal, which enables a perpendicular approach to the femoral footprint of the ACL. First, the ACL remnant over the footprint is removed completely but meticulously using a punch and an electric shaver to expose the resident's ridge and the posterior cartilage margin. Next, the knee is held in full flexion and 2.4-mm two guide pins are placed parallel to each other within the footprint, spaced about 2.5-3.5 mm apart, and followed by overdrilling with a cannulated drill. Then the remaining projection within the femoral socket is completely removed with a punch and/or an electric shaver to make an oblong socket, followed by creation of a 4.5-mm-diameter femoral tunnel to introduce the Endobutton (Fig. 2).

Tibial Tunnel Preparation

For the tibia, after obtaining a view of the face of the medial intercondylar ridge (MIR) [15], a 2.4-mm wire was inserted into the posterolateral fiber at an angle of approximately 55° to the sagittal plane and 10° to the tibial axis using a guide, and another 2.4-mm wire was inserted into the anteromedial fiber at an angle of approximately 45° to the sagittal plane and 15° to the tibial axis using the same guide. As the dense fibers of the natural ACL are reported to be concentrated on the medial side of the MIR [12,15], care is taken to introduce each wire near the apex of the MIR. Each wire is overdrilled with a 5-6 mm-diameter drill bit. Purnell et



A



B

Fig. 2. An oblong-shaped femoral socket for right-knee anterior cruciate ligament reconstruction. (A) Arthroscopic image. The bone tunnel is created starting from the far anteromedial portal during deep flexion. Two sockets are overlapped so that there is no division between them, creating an oblong shape. A single bone tunnel is created from the bottom of the socket to the cortical plate using an Endobutton drill. (B) Three-dimensional computed tomography image. The oblong femoral bone tunnel is in the anatomical footprint.

al. [8] has reported that the average length of the tibial footprint was 10.7 ± 1.3 mm and we don't insist on retaining the bone bridge between the two tunnels.

Graft Passage and Fixation

After introduction of a leading suture through the

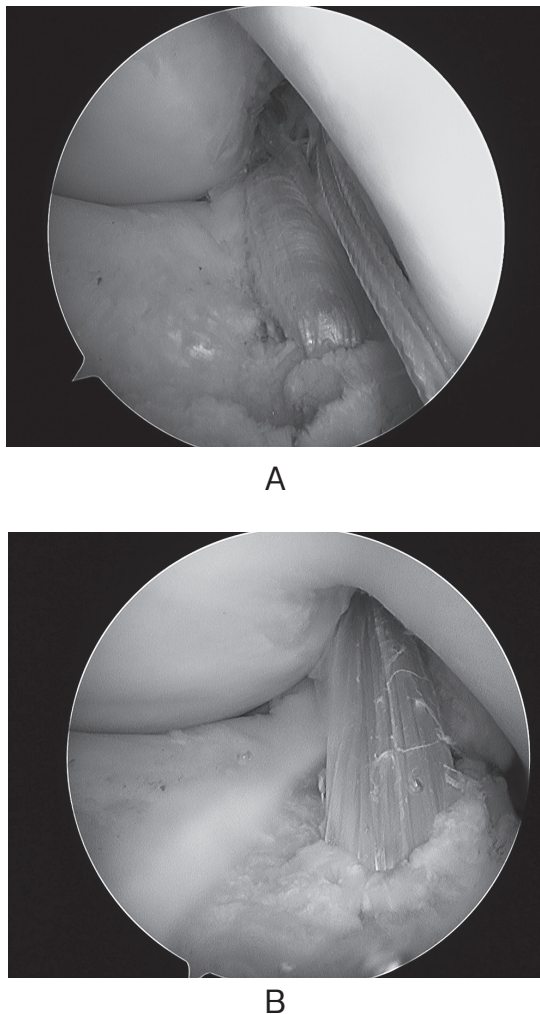


Fig. 3. The graft is inserted from the far anteromedial portal and fixed to the femur with an Endobutton. (A) First, the posterolateral bundle is inserted into the bone tunnel in a inside-out fashion. (B) Then, the anteromedial bundle is inserted and fixed with a double spike plate.

FAM portal to the femoral tunnel, the graft is passed and fixed with the Endobutton to the femur. Next, each free end of the graft is passed into the tibial tunnel in inside-out fashion. After the AM and PL graft sutures were tied to the double spike plate (DSP; MEIRA Corp., Nagoya, JAPAN), the grafts were fixed at 15-20° of knee flexion under 30N of initial tension (Fig. 3).

Preliminary clinical results

We performed preliminary evaluations on 40 knees of 40 patients (9 men, 31 women; mean age, 22 years [range, 13-45 years]). The average side-to-side difference was 0.74 ± 0.81 mm ranging from 0 to 2 mm as measured using a KT-2000 arthrometer (MEDmetric,

San Diego, CA, USA). We have yet to experience an intra- or postoperative complication with this surgical technique.

DISCUSSION

The widely used procedures of anatomic DB ACL reconstruction with the hamstring tendon do not add a completely new PLB graft to the SB ACL reconstruction, but divides the same graft into two—one for the AMB and the other for the PLB—which are grafted onto bone tunnels created within the footprints on the femur and tibia. In other words, the individual AMB and PLB grafts are thin and weak, which can increase the risk of re-rupture, or lead to poor graft-tunnel healing at the PLB [9], which has a greater graft excursion. To solve these problems and improve the clinical results with DB ACL reconstruction, we developed a new surgical technique—anatomic oblong double-bundle ACL reconstruction with hamstrings.

In this procedure, the following three modifications were made to promote healing of the PLB on the femoral side, which are the characteristic advantages of this surgical technique. The first modification was creating one bone tunnel on the femoral side. Previous reports have indicated that one reason for the poor graft-tunnel healing in DB reconstruction is the larger length-change of the PLB graft compared with that of the AMB graft [7,9,14]. In our procedure, the graft excursion still differs between the AMB and PLB; however, because both bundles are fixed together in the bone tunnel with a single Endobutton, there is less excursion of the PLB graft in the femoral bone tunnel. This is expected to reduce the bungee-cord effect on the PLB that is seen in conventional DB ACL reconstruction, and improve the graft-tunnel healing of the PLB footprint area in the single oblong bone tunnel. Moreover, the “killer turn” at the femoral bone tunnel is dealt with by fixing both bundles together, which should reduce the stress concentration in the area of the PLB footprint. The second modification was making the femoral bone tunnel oblong shaped. This enabled the SB graft to be inserted into the anatomical footprint. An anatomical study by Iwahashi et al. [3] reported that the femoral footprints of a normal ACL are directly inserted between the resident’s ridge and the posterior cartilage margin, with a width of 8.0 ± 0.5 mm. Similarly, Purnell et al. [8] reported the width of femoral footprints of normal ACL to be 7.6 ± 1.4 mm. In SB ACL reconstruction, the femoral bone tunnel is often 8 mm or larger [17]; thus, it can be difficult to create a circular bone tunnel in the anatomical footprint

between the AMB and PLB, as is done in conventional SB ACL reconstruction. The oblong femoral bone tunnel used in our procedure more accurately reproduces the anatomical femoral footprint, which is difficult to accomplish with conventional SB reconstruction. Thus, although an SB is used on the femoral side, the differences between the AMB and PLB can be maintained. Furthermore, creating a bone tunnel at the accurate anatomical footprint can lower the risk of graft impingement by the posterior cruciate ligament or lateral condylar notch [11], which not only improves the graft-tunnel healing of the PLB in the femoral bone tunnel but could also lead to less substantive graft damage. The third modification involved changes when creating the graft to create a PLB with both tendinous and membranous parts, which is expected to improve the quality of the PLB graft. A biomechanical study by Seon et al. [9] found that PLB grafts for DB ACL reconstruction experienced greater stress than did normal PLB. Our procedure increases the cross sectional area of the PLB graft, which is expected to increase its resistance to breakage; this should prevent ruptures at both the femoral tunnel aperture and of the graft itself.

Our method has some limitations. As stated above, no biomechanical study has been done to verify the reasoning behind this procedure. In addition, the course of the graft does not precisely match the normal ACL. However, although an SB is used on the femoral side, as this procedure creates an oblong bone tunnel at the precise anatomical footprint, better graft-tunnel healing could lead to improved results from ACL reconstruction.

CONCLUSION

We developed a new surgical technique that creates an oblong bone tunnel at the anatomical footprint on the femur. This procedure can help improve graft-tunnel healing around the femoral bone tunnel aperture for the PLB, which is a weak point of anatomic DB ACL reconstruction with hamstring tendon.

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