Anterior cruciate ligament reconstruction using the double bundle method

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ABSTRACT
Clinical results of our reconstruction technique for anterior cruciate ligament using the double bundle, i.e., the combination of bone-tendon-bone (BTB) from the patellar tendon and semitendinosus tendon (ST), were evaluated. BTB was fixed in the tunnels produced on the isometric points on the tibia and femur, and ST, on the tibial tunnel through the same route as BTB. Throughout the observation period, no patients developed pain, limited range of motion, and/or instability of the operated knee. All patients were able to return to previous sports activities within 12 months. No apparent changes occurred on the reconstructed ligament. In 4 of 14 patients, knee stability was quantitatively examined, and a good result was obtained. The double bundle was found to be a useful method for patients who require physiologically more durable reconstruction.

Key words: anterior cruciate ligament, double bundle, reconstruction

INTRODUCTION
Reconstruction of a ruptured anterior cruciate ligament (ACL) is essential for patients to return to previous physical activities. It is also important in order to prevent secondary osteoarthritis. With recent advances in arthroscopic techniques, reconstruction ligaments can be accurately grafted with a smaller surgical invasion.1–6 However, in our experience of ACL reconstruction in over 500 cases, the endurance of these ligament substitutes seems to be unsatisfactory in athletes or physical laborers, whose bodies are substantially bigger than ordinary persons. We developed a reconstruction method using a double bundle which consists of bone-tendon-bone from the patellar tendon (BTB) and the semitendinosus tendon (ST).7 The present study examined the clinical results of this method including post-operative changes of the reconstructed ligament.

MATERIALS AND METHODS
Fourteen knees of 14 patients (13 males, 1 female, age range, 17–37 years; mean age, 22.5 years) who received the ACL reconstruction using the double bundle were
examined. Informed consent was obtained from each patient, and the clinical application of this technique was approved by the Ethical Committee of Kyoto Prefectural University of Medicine.

Arthroscopy was performed before and immediately after the surgical treatment, in the period between 6 months and 2 years and 1 month (second post-operative arthroscopy, mean: 14.4 months) when the fixation implant (i.e., the end plate and ligament button) was removed, and changes of reconstructed ligaments were examined according to the tibial tunnel position evaluated by tomography.

Our technique is described in detail elsewhere. In short, bone tunnels are made on the isometric points of the femur and tibia, BTB is embedded in the tunnels, and ST is also fixed in the tunnel on the tibia and via the over-the-top-route on the femur by maintaining the adhesive position on the tibia. By retaining the ST end on the distal side, ST could receive blood supply (Fig. 1). BTB corresponds to the antero-medial bundle of the conventional methods, and ST corresponds to the posterolateral bundle, and these two realize physiologically more durable reconstruction. For fixation, ligament buttons (Kyocera Co., Kyoto, Japan), staples, and interference screws (Linvatec Co., FL) are used. Knee stability was quantitatively examined in terms of the forward-movement of the tibia at 20° flexion position and with 20 pounds forward-pulling, before and immediately after the surgery in all cases and at the second post-operative arthroscopy in 4 cases, under general anesthesia and by using a knee laxity tester (Stryker Inc., USA).

The tunnel position was classified into one of 4 types using the method of Muneta et al. (Fig. 2). In Type 1, the entire tunnel is located anterior to the Blumensaat line. In Type 2, the tunnel center is located anterior to the line. In Type 3, the tunnel center is located posterior to the line. In Type 4, the entire tunnel is located posterior to the line. Types 3 and 4 are good, functional positions.

Changes of the reconstructed ligament were evaluated into 3 levels, i.e., normal when the ligament was intact (Fig. 3), mild when changes were found only on the surface of the ligament (Fig. 4), and severe when changes were found in the entire ligament.

Range of motion (ROM) exercise was started 3 days after surgery and by using a Townsend-Rebel type brace (Townsend Inc., USA), partial weight-bearing was started from the 8th day, and full-weight bearing was allowed 4 weeks after the surgery. Muscular training was started 3 weeks after surgery using Cybex 350 (Lumex Inc., USA) for the extensors and flexors. Eight weeks after surgery, the brace was removed and changed to a supporter and jogging was allowed. Return to previous sports activities was allowed after 6 months.

**Figure 1** Positions of BTB and ST in the ACL reconstruction method. On the femur side, BTB is embedded into the tunnel, and ST runs through the over-the-top route lateral to the tunnel. On the tibia, BTB and ST are embedded into the same tunnel, and BTB is located anterior to ST.
Figure 2  Positions of tibial tunnel in tomography according to the classification method of Muneta et al. In Type 1, the entire tunnel is located anterior to the Blumensaat line. In Type 2, the tunnel center is located anterior to the line. In Type 3, the tunnel center is located posterior to the line. In Type 4, the entire tunnel is located posterior to the line. Types 3 and 4 are good, functional positions.

Figure 3  Normal condition. The reconstructed ligament was intact.

Figure 4  Mild changes. Changes were found only on the surface of the ligament.
RESULTS

Throughout the observation period, no patients developed pain, limited ROM, and/or instability of the operated knee. All 14 patients returned to their previous sports activities in 7 to 12 months (mean: 8.1 months).

There were no patients with Type 1 or 2 tibial tunnel positions, and all patients had good functioning positions, i.e., either Type 3 (n = 1) or Type 4 (n = 13) (Table 1).

At the second arthroscopy, the reconstructed ligament showed almost no changes in 11 patients (Fig. 3), while mild degenerative changes were found mainly on BTB surface in 3 patients (Fig. 4). No patients developed such a change as cyclops.

Knee stability was examined in 4 patients when the fixation implant was removed. One patient showed mild change at the second arthroscopy, while the other 3 had normal ligaments. In the 3 normal patients, the increase of knee instability at the removal of fixation implant was +1.48 mm, and that in the one mild-change patient was +0.5 mm (Table 2).

Table 1
| Tibial tunnel position and the changes of reconstructed ligament |
|----------------------|--------|--------|--------|--------|
| Position type        | 1      | 2      | 3      | 4      | Total  |
| Number of patients (A) | 0      | 0      | 1      | 13     | 14     |
| No. of patients who had changes on the reconstructed ligament (B) | 0      | 0      | 0      | 3      | 3      |
| Frequency of changes (%), B/A | –      | –      | 0      | 23     | 21     |

Type 1: the entire tunnel is located anterior to the Blumensaat line.
Type 2: the tunnel center is located anterior to the line.
Type 3: the tunnel center is located posterior to the line.
Type 4: the entire tunnel is located posterior to the line.

DISCUSSION

In our method, BTB as the substitute of the antero-medial bundle is fixed at a 20° flexion position and this makes tension of BTB increase with knee flexion, while ST as the substitute of the postero-lateral bundle is fixed via the over-the-top route at a 90° flexion position, which makes tension of ST increase with knee extension. The flexion and extension of BTB and ST were grossly confirmed with arthroscopy. Therefore, the combination of BTB and ST for ACL reconstruction would realize higher durability compared to the conventional technique using BTB or ST alone.7 In the 14 patients, no cases developed pain, limited ROM, and/or instability of the operated knee. All cases had clinically very stable knees, and they were able to return to their previous sports activities within 12 months after the surgery.

In the second arthroscopy, no severe changes such as cyclops were observed in the reconstructed ligaments. Cyclops is thought to be caused by inappropriate bone tunnel position.9,10 In the patients, the tunnels were produced in a good position, so there was no mechanical stress which causes cyclops. The reconstructed ligament is comprised of not only BTB but also ST. Among the 14 patients, changes as shown in Fig. 4 were found only in 3 patients. Though these changes were not as severe as those causing clinical problems, if they were severe, the ligament would be at a risk of rupture. Therefore, in our method, the tibial tunnel position would be more important than in other methods.

Stability of ligament was quantitatively examined in 4 patients. Though the number of cases examined was small, sufficient stability was obtained. Because the fixation position of BTB and ST was determined by considering physiological roles of the antero-medial

Table 2
| Data of 4 patients whose knee stability was quantitatively examined in terms of the forward-movement of the tibia at 20° flexion position and with 20 pounds forward-pulling |
|----------------------|--------|--------|--------|--------|
| Patient No.          | 1      | 2      | 3      | 4      |
| Sports               | baseball | rugby | basketball | soccer |
| Movements (mm):      |        |        |        |        |
| Immediately after surgery | 0.5 | 0.67 | –1.83 | 2.5 |
| At removal of fixation implant | 1.0 | 1.33 | 1.33 | 3.0 |
| Difference           | +0.5   | +2.0   | +3.16 | +0.5 |
| Changes in reconstructed ligament | none | none | none | mild |
| Postoperative time when patient returned to sports activity | 7 months | 8 months | 8 months | 7 months |
| Clinical problems    | none   | none   | none   | none   |
and postero-lateral bundle, BTB and ST are assumed to mimic the tension forces of the corresponding ligament. In addition, blood circulation obtained from one side of ST would contribute to early recovery.

Our method with the double bundle results in physiologically more durable reconstruction and would be a useful treatment method for patients who require high durability of the reconstructed ACL.

REFERENCES