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이중 다발 전방십자인대 재건술의 임상적 결과 및 이차적 관절경 소견

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목적: 본 연구는 이중 다발 전방십자인대 재건술 후의 단기 임상결과와 이차적 관절경 소견을 알아보았다.

대상 및 방법: 이중 다발 전방십자인대 재건술 후에 최소 24개월 이상 추시가 가능하였던 49 예(환자)를 대상으로 하였다. 임상적 결과로 Lysholm 슬관절 점수, Tegner 활동 점수, 도수 및 기계적 전방 안정성 검사를 시행하였다. 15 예에서 스테플 제거와 함께 이차적 관절경 수술을 시행하여, 재건된 전방십자인대의 파열 유무와 이식건의 주관적인 긴장 정도 및 활액막 형성 정도를 검사하였다.

결과: Lysholm 슬관절 및 Tegner 활동 점수는 각각 술전 67.4, 2.0에서 최종 추시에 96.1, 6.1로 호전되었다 ($p<0.01$). Lachman 및 pivot-shift 검사에서 39예, 36예가 정상범위로 호전되었다. 스트레스 방사선 검사의 양측 차이 정도는 10.8 mm에서 3.3 mm로 의미있게 호전되었다 ($p<0.01$). 이차적 관절경 소견상 모든 환자에서 전내측 다발이 정상 및 정상에 가까운 소견이 관찰되었으나, 8예 (53.3%) 에서 후외측 다발의 부분 및 완전 파열이 관찰되었다.

결론: 이중 다발 전방십자인대 재건술이 임상적으로 슬관절의 회전 및 전, 후방 안정성을 복원하는 효과적인 수술법이라도, 이차적 관절경 수술을 시행한 증례의 몇 예에서 후 외측 다발의 파열이 관찰되었다.

색인 단어: 이중 다발, 전방 십자인대 재건술, 임상적 결과, 이차적 관절경

Introduction

The anterior cruciate ligament (ACL) has been considered to consist of two distinct functional bundles since at least 1938, that is, the anteromedial (AM) and posterolateral (PL) bundles[8], but reconstruction techniques have traditionally focused on re-creating one ACL bundle, to effectively act as a checkrein to anterior tibial translation and tibial rotation.

Recently, interest has been shown in double-bundle (DB) ACL reconstruction with the aim of producing better clinical control of rotational stability than that achieved by single-bundle (SB) reconstruction. Biomechanical data also suggested that the DB ACL reconstruction has some advantages over SB ACL reconstruction, such as, improved anteroposterior laxities and tibial rotations, due to the addition of a PL graft[4,13,15]. However, there is concern that these procedures may lead to larger graft-length changes during the full range of knee motion, and that this could compromise graft healing or lead to excessive graft stretching during postoperative rehabilitation[6].

We hypothesized that the anatomy of ACLs reconstructed using double bundle technique may be similarly restored to the anatomy of normal ACLs. Accordingly, we undertook this study to analyze clinical outcomes and to assess the usefulness of DB ACL reconstruction using tibialis anterior allografts by second-look arthroscopy.

Materials and Methods

From December 2004 to July 2007, 67 patients underwent DB ACL reconstruction in our institute. Only those patients who received unilateral primary ACL reconstruction without combined ligamentous surgery were included. Patients with objectively detectable lateral, medial, or posterior instability, and thus, suspected of having multiple ligament injuries, were excluded. We also excluded patients that had previously undergone open or arthroscopic surgery, and those with radiologic degenerative changes of more than Kellgren-Lawrence grade III in either knee. Two patients were excluded due to re-rupture of the reconstructed ACL during sports activity. Of the remaining patients, 49 were followed for more than

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two years, and these patients constituted the study cohort. The mean follow up period was 35.8 months (range, 24.1~54), and mean time from injury to reconstruction was 7.4 months (range, 0.1~8.9). The study subjects were 40 men and 9 women of average age 31.2 years at surgery (range, 14.3~58 years) (Table 1). In terms of combined meniscal injuries, 25 patients had a medial meniscal injury (13 were repaired using the inside-out technique and 12 underwent partial meniscectomy) and 9 lateral meniscal injuries (one was repaired and remaining 8 underwent partial meniscectomy). This study was approved by the institutional review board of our hospital, and written informed consent was obtained from all patients.

1. Clinical outcomes assessments

Patients were evaluated preoperatively and at least 2 years postoperatively. Clinical results were evaluated using ranges of motion, Lysholm knee scores, Tegner activity scores, and the Lachman and pivot-shift tests. Radiologic stabilities were evaluated by performing an instrumented laxity test using a Telos device (Telos stress device, Austin & Associates, Fallston, Maryland) at 30° of knee flexion and with a 20 lb anterior tibial load applied to the proximal tibia. Normal, contralateral sides were used as controls. Differences in anterior translations between reconstructed knees and normal contralateral knees were used to evaluate the restoration of normal laxity after ACL reconstruction.

2. Surgical technique

One senior surgeon performed all reconstructions. An EndoButton CL (Smith & Nephew, Andover, Massachusetts) was used for femoral side fixation and a bioabsorbable interference screw (Linvatec, Largo, Florida) and staples were used for tibial side fixation. After routine diagnostic arthroscopy, meniscal repair or meniscectomy was performed when concomitant meniscal injuries were present. Tibialis anterior allografts were prepared to make two double-looped grafts of 5 to 6 mm diameter for the posterolateral bundle (PLB) and of 7 mm diameter for the anteromedial bundle (AMB). Both graft loop ends were connected to an EndoButton loop and the free ends were prepared with whipstitch sutures. In each knee, the PLB tibial tunnel was placed at the center of the PLB footprint on the tibia (5 mm anterior to the PCL) using a tibial drill guide set at an angle of 45° to the horizontal plane with a starting point just anterior to the superficial medial collateral ligament. On the other hand, the AMB tunnel was positioned in a more anteromedial position on the tibial footprint (7 mm anterior and 5 mm medial from the PLB tunnel) using a tibial drill guide set at an angle of 55° to the horizontal plane. The femoral AMB tunnel was prepared through an anteromedial portal at the 1:00-o'clock position for left knees or at the 11:00-o'clock position for right knees[5,9]. Femoral PLB tunnel locations were prepared through an accessory anteromedial portal at 5 to 8 mm from the anterior lateral femoral condyle cartilage, and 3 to 5 mm from the inferior lateral femoral condyle cartilage with knees in 90° of flexion. Knees were cycled approximately 10 times through a full range of motion. PLB and AMB grafts were fixed at 10° to 20° of flexion and at 60° to 70° of flexion, respectively, using bioabsorbable interference screws under 40 N of tension. Additional fixation on the tibial side was performed using a single staple.

3. Postoperative Rehabilitation

Postoperatively, all patients wore a hinged brace that no motion limits were set. At 24 hours postoperatively, patients were placed on a rehabilitation regimen that included quadriceps muscle strengthening and straight leg raising exercises. Patients were not allowed partial weight bearing ambulation until week 8. Knee braces were fully removed at 8 weeks postoperatively when full weight bearing ambulation was allowed. At 4 months, patients were allowed low impact sports, such as, jogging. Sports

Table 1. Patient demographics

Age (mean, range)	31.2 (14.3~58)
Sex (male/female)	40/9
Time to 2nd look arthroscopy (mean, range) (month)	24.9 (10~51)
Follow-up duration (mean, range) (month)	35.8 (24.1~54)

that required jumping, pivoting, or sidestepping were permitted after 6 months.

4. Second-Look Arthroscopy

Fifteen of the 45 study subjects underwent second-look arthroscopy at the time of hardware removal. No patient showed clinical laxity or subjective instability at this time. The major cause of hardware removal was pain or discomfort because of bursitis around the staple. We explained the purpose of second-look arthroscopy to all patients prior to surgery and received a written permission. One senior surgeon performed all second-look arthroscopies.

The average period from DB ACL reconstruction to second-look arthroscopy was 24.9 months, with a range of 10 to 51 months. Mean age, gender, time to surgery, and mean follow-up duration were determined using medical records. For clinical evaluations were performed using the Lachman test and the pivot-shift test, and arthrometric evaluations using the Telos device. Lysholm Knee Scores and Tegner activity scores were obtained using a self-administered questionnaire and scores were determined at the time of second-look arthroscopy and at last follow-up to assess knee functional abilities.

During second look arthroscopy, we subjectively evaluated morphology, extent of synovial coverage, and graft tension (using a probe). Reconstructed ACL morphologies were classified as intact or as partial or total tears. Intact was defined as no discernable graft injury or abnormal change. A partial tear was defined as one of less than 50% of the graft thickness. The presence of small bundles that preserved graft continuity, but which were elongated, is referred to as parallel fragmentation. Partial tears and parallel fragmentation were categorized as partial injuries. A total tear was defined as complete tear of the graft tendon (Fig. 1). Graft tension was evaluated by pulling the graft with a probe at 20 to 900 of knee flexion and was

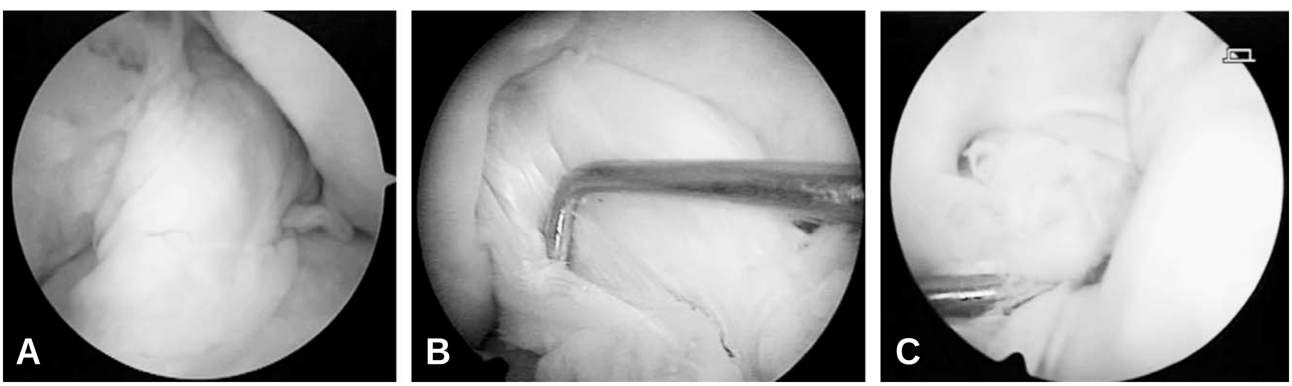

Fig. 1. Arthroscopic classification of transplanted grafts based on the morphology of graft, (**A**) no rupture in both AM and PL bundle, (**B**) partial rupture with fragmentation of fibers in the PL bundle, (**C**) complete rupture in the PL bundle.

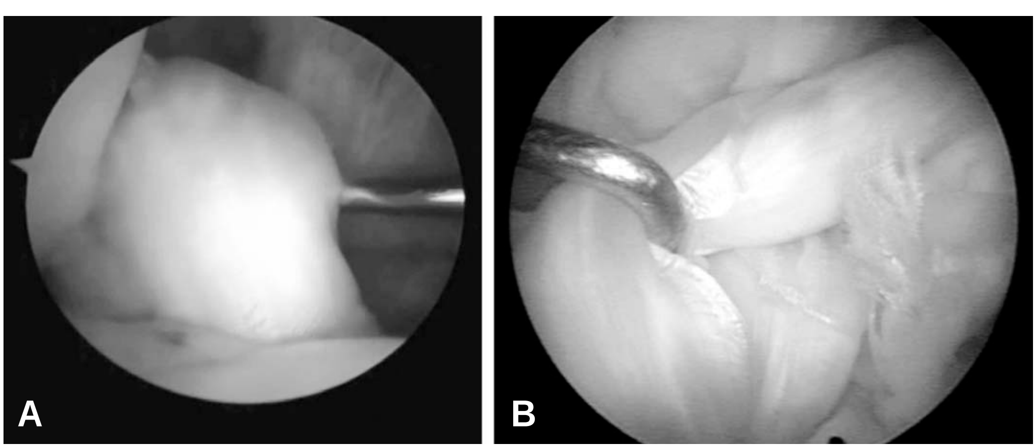

Fig. 2. Manual examination of the tension on the reconstructed ACL with a probe: (**A**) The AMB and PLB show nearly normal tension on manual probing, which is classified as "taut". (**B**) The grafts show slight laxity on probing, which is classified as "lax".

categorized as taught or lax. When evaluating the PLB, we checked its tension in the 'figure of four' position. Grafts that were as taught as normal ACLs throughout the 20 to 900 range of knee flexion were considered 'taught'; those with less tension, that is, showed redundancy or an obvious loss of tension, were considered 'lax' (Fig. 2). Synovial coverage was evaluated after tourniquet deflation. Grafts that were entirely covered with synovium and showed good vascularity are referred to as having good synovial coverage, and grafts partially covered with synovium are referred to as having poor synovial coverage (Fig. 3).

5. Statistical analysis

The paired-samples t-test in SPSS version 17.0 was used to analyze pre- and postoperative differences (such as Tegner activity scores, Lysholm knee scores, and instrumented laxity test results). Statistical significance was accepted for p values of <0.05.

Results

No postoperative complications, such as, iatrogenic cartilage injury, serious tunnel malposition, graft fixation failure, infection, fracture, or deep vein thrombosis were observed during or after surgery. Mean limitation of knees in extension was $0.1^{\circ} \pm 0.7^{\circ}$ (range, 0~5) at last follow-up. No problematic loss of flexion or extension (>10°) was observed at last follow-ups. The preoperative average Lysholm knee score was 67.4 (range, 30~80), and significantly improved at last follow-ups to 96.4 (range, 85~100). Average activity levels as determined by Tegner scores were restored to preinjury levels last follow-ups, and increased from 2.0 to 6.1. The Lachman testing at last follow-up indicated grade II laxity in one patient, but no patient had grade II laxity by the pivot-shift test (Table 2). Average side-to-side difference by the arthrometric test was 10.8 mm (range, 7-18) before reconstruction and this improved to 3.33 mm (range, 0-6.8) at last follow-ups ($p<0.01$).

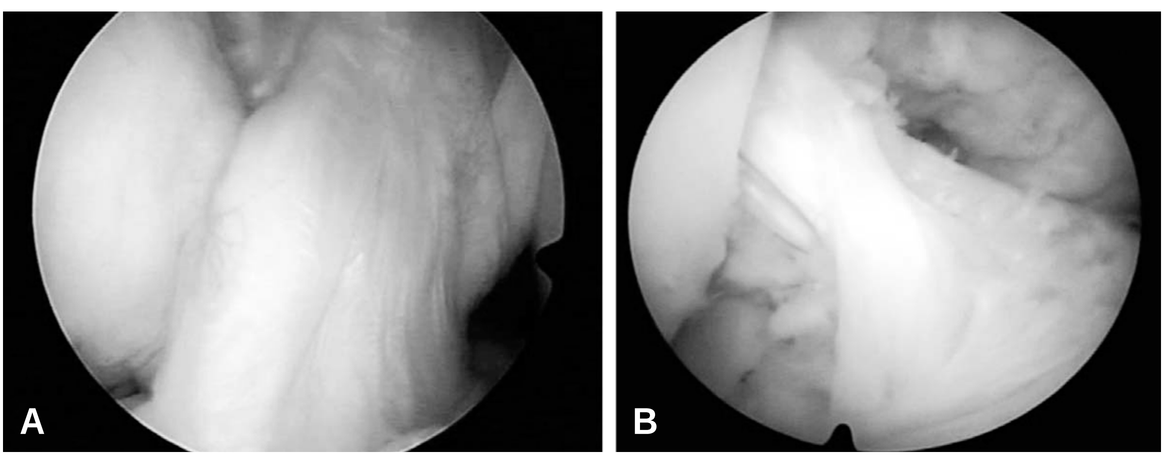

Fig. 3. Arthroscopic classification based on the synovial coverage over the grafts. (**A**) The AM bundles are covered with synovium over its entire length including femoral tunnel aperture and classified as "good". (**B**) The PL bundles are not fullly covered with synovium and classified as "poor".

Table 2. Clinical results of DB ACL reconstruction

		DB ACL (n=49)			
	Grade	0	1	2	3
Lachman test	Preop.	-	10	24	15
	Last follow-up	39	9	1	-
Pivot-shift test	Preop.	9	25	12	3
	Last follow-up	36	13	-	-
Lysholm knee score (mean±SD)	Preop.	67.4±15.1			
	Last follow-up	96.4±4.1			

1. Second-look arthroscopy

Second-look arthroscopy revealed no total tear case in the AMB. On the other hand, the PLB showed total or partial injury in 8 knees. In terms of synovial coverage, AM bundle coverage was good in 11 cases (73.3%), and poor in 4 (26.7%), but synovial coverage of the PLB was poor in 6 (40.0%). In particular, poor synovial coverage was usually observed at the femoral tunnel aperture combined with a partial graft tear. With regard to graft tension on probing, more laxity was found for the PLB than the AMB; PLBs were lax in 9 knees (60%) and AMBs in 2 knees (Table 3).

During clinical evaluations conducted before the second-look arthroscopy, no complaints of subjective instability were noted. Lachman test was grade 0 in 12 knees (80.0%) and grade 1 in 3 knees (20.0%), and the pivot-shift test was grade 0 in 10 knees (66.7%) and grade 1 in 5 knees (33.3%). Mean Lysholm knee score was 97.4. Telos stress radiography showed that side-to-side anterior laxity differences decreased at last follow-up to mean difference of 2.2 mm (range, −1.0~4.3) from 9.8 mm (range, 6.2~14.3). In terms of AMB graft tension before the second-look arthroscopy, the side-to-side difference in anterior laxity was 2.3±1.2 mm for patients with a taut graft (n=28) and 3.1±2 .0 mm for patients with a lax graft (n=10), which was not significantly different (p=0.480).

Discussion

The present study shows that PLBs in 5 knees (33.3%) after DB ACL reconstruction were total tear at the femoral tunnel aperture although they were clinically stable. Furthermore, poor synovial coverage over the graft around the femoral tunnel aperture was observed even in patients without apparent graft rupture. In particular, synovial coverage of PL grafts was poorer than that of AM grafts. Several authors have reported similar findings. Otsubo et al[7]. reported that 11% of PLBs were partially or completely damaged at the femoral tunnel aperture, and suggested that in such cases, graft tunnel incorporation was inadequate. Toritsuka et al[12]. commented that 11% of hamstring ACL grafts showed looseness and that 34% of clinically successful knees had a partial tear during second-look arthroscopy. It has been suggested that PL bundle failure is due the PL graft being exposed to excessive stress at the femoral tunnel because of the wind-shield wiper and/or bungee cord effect[11]. Furthermore, other studies have reported that PLB strain is significantly higher than AMB strain, especially in near extension in normal ACL and DB ACL reconstructed knees[1,10].

Yonetani et al[16]. also reported that PL graft length change over range of motion is greater than that of AM grafts. Markolf et al[5]. reported that occasionally PL grafts fail due to markedly higher forces in these grafts near 0° during internal torque or anterior tibial force tests. These findings led to the suggestion these biomechanical characteristics might be responsible for PL graft damage or poor synovial coverage around the tunnel aperture of PL grafts[7].

Although no significant correlation was found between graft morphology and clinical outcome, loss of tension and/or partial graft rupture could lead to total graft failure. Therefore, to establish the clinical utility of DB ACL

Table 3. Comparison of the two bundles with respect to second-look arthroscopic findings

		DB ACL (n=15)	
		AMB	PLB
Morphology	Intact	10 (66.7%)	7 (46.6%)
	Partial injury	5 (33.3%)	3 (20.0%)
	Total tear	0	5 (33.3%)
Synovial coverage	Good	11 (73.3%)	9 (60.0%)
	Poor	4 (26.7%)	6 (40.0%)
Tension	Normal	13 (86.7%)	6 (40.0%)
	Lax	2 (13.3%)	9 (60.0%)

reconstruction in ACL-deficient knees, further advancements in operative procedure, especially regarding the PLB graft, are required to improve results after DB ACL reconstruction.

In this series, second-look arthroscopic findings showed that the anatomy of the normal ACL was not restored due to PLB failure. Accordingly, our hypothesis that the anatomy of ACLs reconstructed using double bundle technique may be similarly restored to the anatomy of normal ACLs was not proven by the data obtained during this study.

Some limitations of this study require consideration. First, the number of that patients underwent second-look arthroscopy was statistically inadequate, because we did not routinely perform second-look arthroscopy. Second, graft tensions and synovial coverage were assessed subjectively. That could be the reasons why higher rate of graft laxity and poor synovial coverage was recorded than other reports[7,12] in this study. But still this result (26.7% in AM bundle group, 40% in PM bundle group) showed the similar outcomes with previous reports like Chun et al[2]. showed in single bundle reconstruction using fresh-frozen Achilles allograft (19 of 85 cases, which were 22% of poor synovial coverage). Third, we only evaluated DB ACL reconstructions performed with an allograft. But Yamagishi et al[14]. reported same amount of bloodstream with normal ligament can be seen in allograft side at postoperative 6 month, and Chun et al[3]. reported revascularization of allograft can be seen at around postoperative 6 weeks and same result with autograft at postoperative 12 months.

In conclusion, nevertheless we had relative good clinical results and stabilities after DB ACL reconstruction, second-look arthroscopic findings showed that reconstructed DB ACL was not similarly restored to the anatomy of the normal ACL due to PLB failure.

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= ABSTRACT =

Clinical Outcome and Arthroscopic Evaluation of Double-Bundle Anterior Cruciate Ligament Reconstruction

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Purpose: The aim of this study was to evaluate short-term clinical results and second-look arthroscopic findings after double-bundle anterior cruciate ligament (DB ACL) reconstruction.

Materials and Methods: Forty-nine patients, who were followed up for at least 24 months after DB ACL reconstruction, were included. Clinical results, such as, Lysholm knee and Tegner activity scores, and manual laxity and instrumented anterior laxity test results were evaluated. In fifteen patients (15 knees), second-look arthroscopy with staple removal was performed. At second-look arthroscopy, the authors assessed about reconstructed ACL rupture, subjective graft tension and extent of synovial coverage.

Results: Lysholm knee scores significantly improved from 67.4 preoperatively to 96.1 at last follow-up ($p<0.01$). Tegner activity scale improved from 2.0 to 6.1. The Lachman test, at last follow-up, showed normal laxity in 39 (of 49) patients, and the pivot-shift test showed normal laxity in 36 (of 49) patients. Mean side-to-side differences improved significantly from 10.8 mm to 3.3 mm ($p<0.01$). Second-look arthroscopic findings showed that all patients had a normal or a near normal anteromedial bundle. However, 8 patients (53.3%) were found to have partial or complete posterolateral bundle rupture.

Conclusion: Even though double-bundle ACL reconstruction was clinically effective means of restoring knee rotational and anteroposterior stabilities, there were some ruptured posterolateral bundles observed in cases under arthroscopy after double-bundle ACL reconstruction.

Key words: Double bundle, ACL reconstruction, Clinical outcome, second-look.

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