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# Mid-Term Outcomes of Anterior Cruciate Ligament Reconstruction with Far Anteromedial Portal Technique

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**Purpose:** The purpose of this study was to evaluate the mid-term outcomes of anatomic anterior cruciate ligament (ACL) reconstruction using two anteromedial (AM) portals by comparing with short-term follow-up results.

**Materials and Methods:** Fifty patients who were treated by ACL reconstruction using a two AM portal technique were evaluated retrospectively. The follow-up period was at least 5 years. The mean follow-up period was 68.5±13.9 months. The mid-term clinical outcomes were compared with short-term (≥12 months) results. For the assessment of knee stability, anterior tibial translation was evaluated using the Lachman test and the KT-2000. Rotational stability was evaluated using pivot shift test. For clinical assessment, the Lysholm and International Knee Documentation Committee scores were used.

**Results:** The average anterior translation was 2.1±1.4 mm at the short-term follow-up and 2.8±1.8 mm at the mid-term follow-up. Stability and mid-term clinical outcomes were not significantly improved compared to the short-term follow-up results. At the mid-term follow-up, anteroposterior (AP) instability assessed by the KT-2000 was slightly increased, but still acceptable. On the other clinical physical evaluation, there was no statistically significant difference.

**Conclusions:** The short-term and mid-term outcomes of ACL reconstruction using the two AM portal technique were not significantly different except for AP stability although the value was less than 3 mm at both follow-ups. Therefore, this operative technique could be considered a satisfactory alternative for ACL reconstruction.

**Keywords:** **Knee, Anterior cruciate ligament, Reconstruction, Mid-term outcome**

## Introduction

The success rate of single-bundle anterior cruciate ligament (ACL) reconstruction, which is regard as a common orthopedic procedure, is 83% to 95%[1-3]. In particular, the conventional single-bundle ACL reconstruction using an 11- or 1-o'clock femoral tunnel has been considered effective in restoring anteroposterior stability except for rotational stability that is affected by the increased ACL ligament obliquity after the procedure. Conventional transtibial femoral tunnel drilling is not conducive to anatomic reconstruction because it is difficult to place a tunnel at the center of the ACL attachment on the femur when the starting point is dependent on the site of the tibial tunnel[4]. This could imply that the conventional single-bundle ACL reconstruction is deficient[5-7].

Recently, the obliquity of a reconstructed ACL has been reported as an important factor that affects rotational stability and long-term outcomes[8-10]. Accordingly, some authors introduced anatomical reconstruction techniques for overcoming shortcomings of the conventional non-anatomic reconstruction such as the ACL graft obliquity. They reported that an anteromedial (AM)

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drilling technique allowed for accurate tunnel positioning at the center of the femoral footprint in cadaveric studies and a more oblique femoral tunnel position[11,12]. The standard AM portal technique has some disadvantages such as poor visualization, short tunnel, and cortical bone destruction[13]. Therefore, Cohen and Fu[14] suggested a modified technique and we also performed single-bundle ACL reconstruction using 3 portals by adding a far AM portal to the frequently used two standard portals.

The short-term outcomes of ACL reconstruction performed using the 3-portal technique were compared with those using the conventional transtibial procedure in our previous study[15]. Our conclusion was that the two AM portal technique had the advantage of restoring rotational stability and graft obliquity (Table 1). A statistically significant intergroup difference was observed in the postoperative pivot shift test: the test was negative in 30 patients (90.9%) in the experimental group and in 26 patients (78.8%) in the control group (p=0.04)[15]. However, it was thought that a longer follow-up would be necessary because disadvantages such as the acute bending angle and short femoral tunnel could be impair the long-term outcome. Because the far AM portal technique has been recently developed, mid-term follow-up data and articles comparing short-term and mid-term outcomes are rare. The purpose of this study was to evaluate the mid-term (at least 5 years) outcomes of ACL reconstruction using the far AM portal by comparing with the short-term follow-up values. The hypothesis of this study was that there would be no significant difference between the short-term and mid-term outcomes and the short-term outcomes would be maintained until the mid-term follow-up.

## Materials and Methods

From September 2008 to April 2010, 97 patients were treated by an anatomical ACL reconstruction using the two AM portal technique. Among them, 50 patients available for ≥5 years of follow-up were included in this study and 31 patients were lost to follow-up. The mean follow-up period was 68.5±13.9 months (range, 60 to 84 months). The clinical outcomes of the mid-term follow-up were compared with the short-term (minimum 1-year follow-up) values in the same patients. There were 39 males and 11 females. Their mean age was 33.0±13.0 years (range, 19 to 70 years) at the time of surgery. The average body mass index of the patients was 24.7±2.8 kg/m$^2$ (range, 19.3 to 32.5 kg/m$^2$). Regarding the mechanism of injury, 35 patients were injured in sports activities including soccer (17 patients), basketball (9 patients), volleyball (3 patients), table tennis (3 patients), and skiing (3 patients). The remaining 15 patients were injured after slip down without sports activities. A combined injury was noted in the ACL-injured knee in 24 cases: lateral meniscus tear in 17 cases, medial meniscus tear in 4 cases, and combined lateral & medial meniscus tear in 5 cases. The Achilles tendon allograft was used in all patients (Table 2). The exclusion criteria were as follows: 1) an injury in the contralateral knee and 2) an injury to the posterior cruciate ligament or collateral ligament that could affect joint stability of the ACL-injured knee.

The standard AM portal was created adjacent to the patellar tendon. The far AM portal was established as distant as possible from the previous portal (–2 cm from the medial border of the patellar tendon), using a needle at a site that allows for the use of a reamer without damaging the medial femoral condyle.

Furthermore, we took care to locate the far AM portal proximal to the pes anserinus tendon and medial to the medial collateral ligament to set the length of the femoral tunnel to 30–44 mm. The mean length of the femoral tunnel created using this technique was 34.7 mm, and complications that could be caused by interference with a reamer or an arthroscope could be avoided (Fig. 1). The standard AM portal was used as the viewing portal and the far AM portal was used for femoral tunneling. This method allows for arthroscopic visualization of the medial wall of the lateral femoral condyle through the standard AM portal with the knee in hyperflexion; hence, the anatomical ACL insertion site on the femur and the posterior cortical bone could be observed with ease (Fig. 2). The femoral tunnel was located below the lateral intercondylar ridge and in the middle of the lateral bifurcate ridge which was located in the middle between the

**Table 1.** Previous Study Values

| Pivot shift test (grade) | Conventional transtibial ACL reconstruction | Two anteromedial portal technique |
|---|---|---|
| 0 | 26 (78.8) | 30 (90.9) |
| 1+ | 5 (12.3) | 2 (6.0) |
| 2+ | 2 (6.0) | 1 (3.0) |

Values are presented as number (%).
ACL: anterior cruciate ligament.

**Table 2.** Patient Demographics

| Parameter | Mean (range) |
|---|---|
| Age (yr) | 33±13 (18–55) |
| Sex (male/female) | 39/11 |
| Graft | Allo-Achilles tendon |
| Follow-up (mo) | 68.5±13.9 (60–84) |
| Range of motion (°) | 110.3±5.9 (104–120) |
| Time from injury to operation (wk) | 8.3 (7–12) |

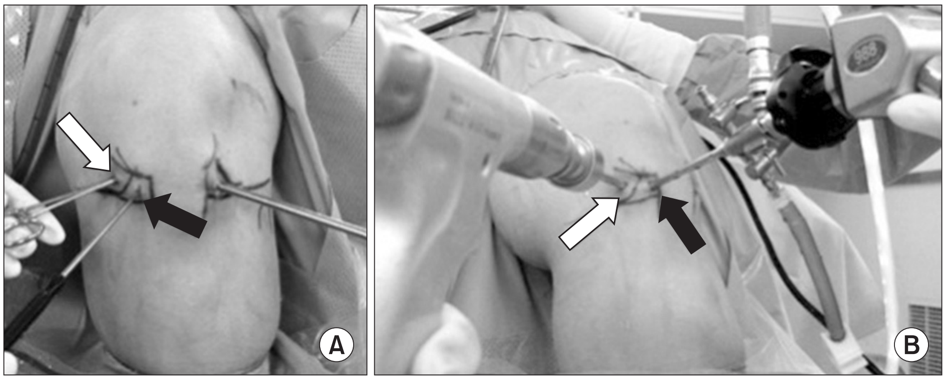


**Fig. 1.** (A) Standard anteromedial (AM) portal (black arrow) and far AM portal (white arrow) of the left knee. (B) The far AM portal (white arrow) is made slightly medial to the standard AM portal (black arrow).

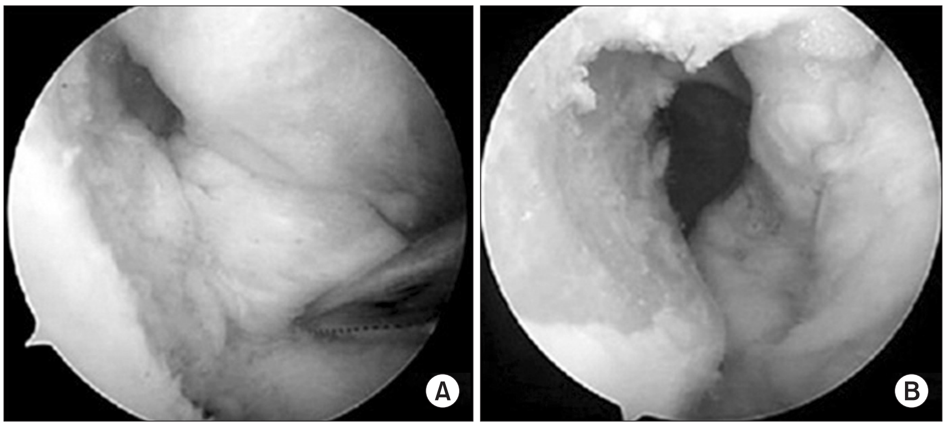


**Fig. 2.** (A) Arthroscopic view through the standard anterolateral portal. (B) Arthroscopic view through the anteromedial (AM) portal. The standard AM portal provides an excellent arthroscopic view of the medial wall of the lateral femoral condyle.

AM and posterolateral (PL) bundles. A guide pin was placed at the center of the ACL insertion site on the femur through the far AM portal, and a femoral tunnel was created using a 45-degree microfracture awl and a 10-mm reamer. We measured the intraoperative femoral tunnel length by a ruler (Zimmer, Warsaw, IN, USA). We set the tunnel to be 30–42 mm in length with an average length of 34.7 mm. A tibial tunnel was drilled with a guide pin placed at the center of the ACL insertion site on the tibia, taking care to preserve the remaining ACL tissue as much as possible. Then, a graft was passed through the femoral tunnel and a bio-absorbable interference screw (BioScrew poly L-lactic acid; Linvatec, Largo, FL, USA) that was inserted through the far AM portal was used for femoral fixation without additional screw and washer. A hybrid technique, using an interference screw and a suture anchor was used for the tibial fixation of the graft.

The same rehabilitation program was prescribed to all patients. On the first postoperative day, patients were allowed to perform quadriceps exercises without knee joint movement. On the 3rd postoperative day, 30° flexion was allowed in all patients. At 1 week after surgery, 45° flexion and walking with a crutch and brace were allowed. At 4 weeks after surgery, 90° flexion and walking with a crutch and brace were allowed. At 8 weeks after surgery, full range of motion, crutch walking, and stair climbing were allowed. At 12 weeks after surgery, simple exercises such as walking fast, cycling, and swimming were allowed. At 6 months after surgery, patients were allowed to do exercises as tolerated[15].

For the assessment of knee stability, anterior tibial translation was evaluated using the Lachman test and the KT-2000 arthrometer[15]. Rotational stability was evaluated using the pivot shift test. For clinical assessment, the Lysholm score and International Knee Documentation Committee (IKDC) knee score were used. The Lachman test and Pivot shift test were conducted by a senior orthopedic surgeon who had more than 20 years of experience in knee surgery. Statistical analysis was performed using IBM SPSS ver. 20.0 (IBM Co., Armonk, NY, USA). Paired *t*-test and Wilcoxon signed rank test were used for statistical analysis and a $p<0.05$ was considered statistically significant.

## Results

The average anterior translation assessed using the KT-2000 arthrometer was 2.1±1.4 mm at the short-term follow-up (12 months) and 2.8±1.8 mm at the mid-term follow-up (≥60 months), indicating statistically significant difference (p=0.010), but the values were less than 3 mm at both follow-ups. On the short-term follow-up Lachman test, there were 29 cases (58%) of grade 0+, 20 cases (40%) of grade 1+, 1 case (2%) of grade 2+, and no case of grade 3. On the mid-term follow-up test, there were 29 cases (58%) of grade 0+, 15 cases (30%) of grade 1+, 6 cases (12%) of grade 2+, and no case of grade 3 (Table 3). There was no statistically significant difference between the short-term follow-up and the mid-term follow-up Lachman test results (p=0.250). On the short-term follow-up pivot shift test, there were 36 cases (72%) of grade 0+, 10 cases (20%) of grade 1+, 4 cases (8%) of grade 2+, and no case of grade 3. On the mid-term follow up test, there were 38 cases (76%) of grade 0+, 9 cases (18%) of grade 1+, 3 cases (6%) of grade 2+, and no case of grade 3 (p=0.083).

**Table 3.** Comparison of Short-Term and Mid-Term Follow-up Knee Stability and Clinical Outcomes

| Parameter | ≥12 month F/U (N) | ≥60 month F/U (N) |
|---|---|---|
| KT-2000 (mm) | | |
| ≤3 | 39 | 33 |
| 3–5 | 9 | 10 |
| ≥5 | 2 | 7 |
| Mean | 2.1±1.4 | 2.8±1.8 |
| p-value | 0.010 | |
| Lachman test (grade) | | |
| 0 | 29 | 29 |
| 1+ | 20 | 15 |
| 2+ | 1 | 6 |
| 3+ | 0 | 0 |
| p-value | 0.250 | |
| Pivot shift test (grade) | | |
| 0 | 36 | 38 |
| 1+ | 10 | 9 |
| 2+ | 4 | 3 |
| 3+ | 0 | 0 |
| p-value | 0.083 | |
| IKDC grade | | |
| A | 25 | 19 |
| B | 20 | 25 |
| C | 5 | 6 |
| D | 0 | 0 |
| p-value | 0.627 | |
| Lysholm | | |
| Score | 87.0 | 86.9 |
| p-value | 0.880 | |

F/U: follow-up, IKDC: International Knee Documentation Committee.

We also assessed rotational instability in the intact AP stability group consisting of patients with AP translation below 3mm by the KT-2000 arthrometer. Thirty-nine cases were available for the short-term follow-up and 33 cases for the mid-term follow-up. On the short-term follow-up, there were 30 cases (77%) of grade 0+, 6 cases (15%) of grade 1+, and 3 cases (8%) of grade 2+. On the mid-term follow-up, there were 26 cases (79%) of grade 0+, 4 cases (12%) of grade 1+, and 3 cases (9%) of grade 2+ (Table 4). There was no statistically significant difference in rotational stability between the short-term follow-up and the mid-term follow-up (p=0.889).

The average Lysholm score was 87.0±10.1 (range, 70 to 100) at the short-term follow-up and 86.9±11.7 (range, 56 to 100) at the mid-term follow-up. There was no statistically significant difference between the short-term follow-up and the mid-term follow-up Lysholm scores (p=0.880). On the short-term follow-up IKDC score (symptoms, sports activities, and function checklist), there were 25 cases (50%) with grade A, 20 cases (40%) with grade B, 5 cases (10%) with grade C, and no case of grade D. On the mid-term follow-up IKDC score, there were 19 cases (38%) with grade A, 25 cases (50%) with grade B, 6 cases (12%) with grade C, and no case of grade D (Table 3). There was no statistically significant difference between the short-term follow-up and the mid-term follow-up scores (p=0.627).

Of the 50 patients involved in our study, no one had a postoperative complication such as posterior cortical breakage and abnormally short femoral tunnel; however, 1 patient had an articular damage to the medial femoral condyle during surgery.

## Discussion

The principal finding of this study was that the short-term and mid-term outcomes of ACL reconstruction were not statistically significantly different in terms of clinical results and knee stability. For ACL tears, single-bundle reconstruction has been suggested as the optimal treatment of choice with high success rates[5,16]. However, because of the lack of the PL bundle, several recent

**Table 4.** Pivot Shift Test in Knees with Intact Anteroposterior Stability

| Pivot shift test (grade) | ≥12 month F/U (N) | ≥60 month F/U (N) |
|---|---|---|
| 0 | 30 | 26 |
| 1+ | 6 | 4 |
| 2+ | 3 | 3 |

p=0.889 for differences between ≥12 months and ≥60 months.
F/U: follow-up.

studies have shown that the procedure is not sufficiently conducive to restoration of rotational stability of the intact knee joint[5]. Recent studies have focused on lowering the reconstructed ligament's obliquity because it has been reported that femoral tunnel obliquity is crucial for the recovery of rotational stability after the procedure[17,18]. In the study of Jepsen et al.[6], when the femoral tunnel position was moved from the 11-o'clock position to the 10-o'clock position, the subjective satisfaction of patients was significantly improved and accordingly greater clinical improvement could be expected. Scopp et al.[19] reported that the 10- or 2-o'clock position of the femoral tunnel in the coronal plane was associated with the recovery of rotational stability, while it had no effect on AP stability of the knee joint. Woo et al.[20] suggested that 10- or 2-o'clock position of the femoral tunnel or double-bundle reconstruction techniques will help to overcome the limitation of conventional single-bundle ACL reconstruction.

In an attempt to reduce the femoral tunnel obliquity using the transtibial technique, Rue et al.[21] moved the starting point of the tibial tunnel more proximally and medially than that in the conventional method and performed a 10- or 2-o'clock femoral tunnel placement. However, the limitations of their method included possible damage to the medial collateral ligament and pes anserinus, and difficulty to ensure firm fixation to the tibia due to the short tibial tunnel length. Harner and Poehling[13] reported that femoral tunnel placement using an AM portal, compared to that using a transtibial technique, had the advantage of locating the correct anatomical ACL attachment site on the femur and lowering femoral tunnel obliquity without notchplasty. In 2010, Alentorn-Geli et al.[22] compared the AM portal technique and the transtibial technique. They reported that the use of the AM portal elicited greater knee stability and range of motion and earlier return to running compared to the transtibial technique especially in the short-term follow-up. However, this technique carries potential risks of short femoral tunnel creation and damage to the medial femoral condyle's articular cartilage, the lateral femoral condyle's posterior wall, and PL structures such as the fibular nerve[1,23]. Additionally, the knee should be flexed ≥90° during tunnel drilling to prevent complications that may limit the field of view during surgery[24].

In our previous study[15] and this study, we conducted ACL reconstruction using two AM portals (a far AM portal and the conventional AM portal). The advantages of the proposed method are as follows: 1) close replication of the native femoral attachment of the ACL through visualization of the lateral femoral condyle's medial aspect with the knee in hyperflexion, 2) shortening of the operation time, and 3) reduction in posterior cortical bone loss.

In the conclusion of our previous study[15], we reported that ACL reconstruction using two AM portals would be an effective surgical technique that restores rotational stability with excellent clinical results. However, the two AM portal technique was a new technique, and thus the previous study had a limitation of short follow-up period (minimum 1 year).

In this study, we analyzed the clinical results at 1 year and 5 years after surgery in the patients who underwent ACL reconstruction using the two AM portal technique. The results demonstrated that AP instability assessed by the KT-2000 had slightly increased at the mid-term follow-up, but the results were still satisfactory. Considering that the data showed a tendency of increasing laxity over time, a long-term follow-up of AP instability is needed. On other clinical outcomes and physical examination findings, there was no statistically significant difference between the short-term follow-up and the mid-term follow-up. We can interpret the data as follows: excellent clinical results obtained by ACL reconstruction using the two AM portal technique were maintained from the short-term follow-up to the mid-term follow-up.

There are also some limitations of our study. First, this study was not a comparative study. Our previous study[15] was an age-matched controlled study comparing the AM portal technique to the transtibial technique. However, in the current study, we focused on the comparison of short-term and mid-term follow-up results of the two AM portal technique. Thus, further studies comparing long-term follow-up data of ACL reconstruction using the 2 AM technique and the conventional technique are needed. Second, the pivot shift test was conducted in a physical examination without the use of an accelerometer. This test was used for evaluating rotational stability. We thought that AP instability and collateral instability could affect the physical examination. Thus, we also performed the pivot shift test in the intact AP stability group and excluded the patients with an injury to the collateral ligament or iliotibial band for a more relevant physical examination. To ensure accuracy of the test, the pivot-shift test was done by a senior knee surgeon in hip abduction to release the iliotibial band. Because pivot shift test results are subject to interpretation of examiners, instruments such as accelerometers should be used to collect more accurate data on rotational instability in further studies.

## Conclusions

The short-term and mid-term follow-up results of ACL reconstruction using two AM portals were not significantly different except for AP stability that was <3 mm at both follow-ups. Therefore, the 3-portal technique could be considered a satisfactory alternative in ACL reconstruction.

## Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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