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# Risk factors for knee instability after anterior cruciate ligament reconstruction

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**Abstract**
*Purpose* The objective of this study was to estimate risk factors that influence postoperative instability after anterior cruciate ligament (ACL) reconstruction using multivariate logistic regression analysis.
*Methods* A total of 152 consecutive patients with symptomatic ACL insufficiency underwent arthroscopic ACL reconstruction between 2005 and 2011. Loss to follow-up and previous ligament reconstruction were exclusion criteria, resulting in 131 patients remaining for this retrospective study. The median follow-up was 55 months (range 25–100 months). Patients were sorted into two groups by anterior translation on stress radiograph and pivot shift test grade and were analysed for the statistical significance of various risk factors including age at surgery, gender, body mass index, preoperative instability, time from injury to surgery, single-bundle reconstruction with preserved abundant remnant versus double-bundle reconstruction with scanty remnant, and concomitant ligament, meniscus, and articular cartilage injury with use of multivariate logistic regression analysis.
*Results* Time from injury to surgery over 12 weeks was found to be a significant risk factor for postoperative instability [$p < 0.001$, adjusted odds ratio (OR) 6.22; 95 % confidence interval (CI) 2.14–18.06)]. Grade 2 injury of medial collateral ligament (MCL) was also a risk factor ($p = 0.02$, adjusted OR 13.60; 95 % CI 1.24–148.25). The other variables were not found to be a significant risk factor.
*Conclusions* Among the risk factor variables, concomitant grade 2 MCL injury and surgical delay of more than 12 weeks from injury were significant risk factors for postoperative knee instability after ACL reconstruction. The overall results suggest that surgery <12 weeks from injury and meticulous attention to concomitant MCL injury should be considered.
*Level of evidence* Retrospective case–control study, Level III.

**Keywords** Anterior cruciate ligament reconstruction · Postoperative instability · Risk factors · Multivariate logistic regression

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## Introduction

Anterior cruciate ligament (ACL) rupture is a common knee injury [13]. Many of these injuries require surgery and rehabilitation. The short-term goals of ACL reconstruction are to restore joint stability and eliminate symptoms. The long-term goals are to allow individuals to return to their prior level of activities and prevent future development of osteoarthritis [8, 17, 26]. Each of these goals may serve as outcome measures after ACL reconstruction [28, 38]. However, questions remain regarding which patient-related factors have the greatest impact on the postoperative prognosis of ACL reconstruction.

Critical analysis has shown that clinical outcomes are less than optimal. The persistence of postoperative instability may produce subsequent meniscal or chondral damage, leading to arthritic knee disease. A recent meta-analysis demonstrated that normal knee function is restored in only 37 % of patients undergoing ACL reconstruction [4]. Similarly, knee laxity is prevalent, with 31.8 % of patients exhibiting a positive Lachman test and 21.7 % of patients exhibiting a positive pivot shift [5]. Only 65–70 % individuals return to the preinjury level of sports activity after ACL reconstruction [4, 10]. Given that not all patients have an optimal outcome, it is important to identify prognostic factors that maximize a successful outcome.

Many comparative studies have been conducted about the postoperative results between the different pre-, intra- and postoperative factors including age, gender, operative technique [single bundle (SB) vs. double bundle (DB)], graft type, and coincident intraarticular pathology (meniscus, cartilage, and other ligament injuries). However, the postoperative result after ACL reconstruction may be influenced concomitantly by various factors; thus, there may be unexpected bias in comparative studies. A multivariate logistic regression model was applied to estimate the risk factors to influence postoperative results after controlling for confounders. Several studies have been conducted with a similar study design [21, 27], but they were multicentre studies, which may be another confounding factor. Our present study was a single-centre trial, and all reconstruction procedures and physical examination were performed by one surgeon. The purpose of this study was to identify the preoperative and intraoperative factors that predict postoperative knee instability as measured by stress radiographs for anterior translation and the pivot shift test after ACL reconstruction using multivariate logistic regression. It was hypothesized that one or more preoperative or intraoperative factors could reasonably predict knee instability outcome.

## Materials and methods

In total, 152 consecutive patients with symptomatic ACL insufficiency underwent arthroscopically assisted ACL reconstruction between 2005 and 2011. We only included patients with unilateral ACL insufficiency and more than a 2-year follow-up, retrospectively. Exclusion criteria were associated previous ligament reconstruction and loss to follow-up over 2 years. Among these 152 patients, 21 were excluded due to loss to follow-up over 2 years ($n = 15$) and previous ligament reconstruction ($n = 6$). Therefore, the 131 remaining patients (median age 39 years; range 20–53 years; 18 females and 113 males) composed the study group for this retrospective study. The median time from injury to surgery was 8 weeks (range 1–1080 weeks). Median follow-up was 55 months (range 25–100 months).

### Surgical technique

The selection criteria for SB and DB reconstruction were based on the amount of preserved ACL remnant tissue during operation. On the basis of the result from previous studies about remnant preservation during reconstruction [20, 32], SB reconstruction was done when the abundant remnant tissue of torn ACL could be spared, and DB reconstruction was done when there were scarce remnants of ACL.

### Single-bundle reconstruction

After routine diagnostic arthroscopy, meniscal repair or meniscectomy was performed when concomitant meniscal injuries were present. Quadruple-strand hamstring tendon autografts consisting of a doubled semitendinous and gracilis were used in all cases of single-bundle reconstruction. Using the anteromedial (AM) portal technique, the femoral tunnel was prepared at the ACL footprint centre. The femoral footprint was marked using a shaver, while viewing the target point with 70° arthroscope through the anterolateral (AL) viewing portal. The femoral tunnel was created by reaming along the inserted guide pin with the knee in more than 120° of flexion. The intraarticular point of the tibial guide was placed at the centre of the native tibial footprint of the ACL. During tibial and femoral tunnelling, ACL remnants were not removed at femoral or tibial extremities. The use of thermal device was restricted to avoid remnant tissue damage. After the tendon graft was passed through the tunnel, the hamstring tendon graft was fixed with an EndoButton (Smith and Nephew Endoscopy, Andover, MA) on the femoral side. The grafts were fixed on the tibia using a bioabsorbable interference screw, an additional cancellous screw, and a washer.

### Double-bundle reconstruction

Preoperative preparation and the concomitant meniscus operation were similar to SB reconstruction. Autologous hamstring tendons were used to make the anteromedial bundle (AMB) and the posterolateral bundle (PLB). Triple strands of semitendinous tendon were used for the AMB, and triple strands of the gracilis tendon were used for the PLB.

The femoral footprints of both the AM and PL bundles were observed and marked with a thermal device (Arthrocare Co., Sunnyvale, CA). If it was difficult to define the margin of the footprint, osseous landmarks at the femoral origin, such as the lateral intercondylar ridge and lateral bifurcate ridge, were used to decide the anatomical insertion sites of the two bundles [11]. For creation of the femoral tunnels, the 70° arthroscope was inserted through the AL viewing portal. The PL femoral tunnel was drilled first, using the AM portal. The AM femoral tunnel was also made at anatomical position. The tibial tunnels were then made with the knee flexed at 90°. The tip of the guide was centred at the previously marked anatomical insertion site of the PLB. The tunnel drilling was performed with the drill bit matched to the graft size. A similar procedure was repeated for creation of the AM tibial tunnel. After the tendon graft was passed through the tunnel, an EndoButton (Smith and Nephew Endoscopy) was used for femoral side fixation of AM and PL bundles. The grafts were fixed on the tibia using a bioabsorbable interference screw, an additional cancellous screw, and a washer.

### Assessment of postoperative results and risk factors

In all enrolled patients, the postoperative patency of the reconstructed ACL was estimated with follow-up magnetic resonance imaging (MRI) or second-look arthroscopy (follow-up MRI for 47 patients, second-look arthroscopy for 89 patients, and both follow-up MRI and second-look arthroscopy for five cases). Postoperative results were evaluated using radiologic instability and the pivot shift test at the last follow-up. Radiologic instability was evaluated by performing an instrumented laxity test using a Telos device (Telos stress device, Austin & Associates, Fallston, MD) at 30° of knee flexion and with a 30 lb anterior tibial load applied to the proximal tibia [2, 33]. The side to side difference (SSD) in anterior translation between the reconstructed knee and the normal contralateral knee was used to evaluate restoration of normal stability. Rotational instability was evaluated by pivot shift grade by one surgeon [7, 22].

Patients were sorted into two groups based on the knee instability results at the last follow-up: the SSD of anterior translation on the stress radiographs was ≤5 mm, and pivot shift test grade 0 or 1 (group 1), and the SSD on stress radiographs >5 mm, or pivot shift test grade 2 or more (group 2). The postoperative pivot shift test was performed by the same surgeon who did the operative procedure.

The variables of risk factors included the following: age at surgery (years), gender (male versus female), body mass index (BMI), preoperative radiologic instability (≤5 mm [referent group], >5, ≤10 mm, and >10 mm) preoperative pivot shift test (grades 0 [referent group], 1, 2, and 3), time from injury to surgery (≤12 weeks [referent group] vs. >12 weeks), method of reconstruction (SB reconstruction with preserved abundant remnant [referent group] vs. DB reconstruction with scanty remnant), concomitant medial collateral ligament (MCL) injury (none of injury [referent group], grades 1, 2, and 3), concomitant cartilage injury (outerbridge grades 1 [referent group], 2, 3, and 4), and concomitant meniscus injury (none [referent group], meniscal repair, partial meniscectomy, and subtotal meniscectomy).

In the measurement of the preoperative and postoperative rotational instability, pivot shift grade was repeatedly measured three times by one surgeon. The maximal grade among triple pivot shift tests was assessed as rotational instability. Intraobserver reliability in the measurement of the rotational instability was not assessed due to the lack of full data of repeated pivot shift tests.

In the measurement of the preoperative and postoperative radiologic instability, the SSD of anterior translation on the stress radiographs was performed by three orthopaedic surgeons who were blinded to the patient. The mean value of measured SSDs was assessed as radiologic instability. Interobserver reliability in the measurement of the radiologic instability was assessed with kappa value. The kappa value for interobserver variability was 0.86 and 0.92 for each preoperative and postoperative radiologic instability, respectively.

Institutional review board (IRB) approval was obtained (approval number: Dongguk University Ilsan Hospital IRB 2014-134).

### Statistical analysis

Binary logistic regression in SPSS version 19.0 (SPSS Inc., Chicago, IL) was used to analyse the influence of each risk factor on postoperative instability. A regression analysis was first run without adjustment (univariate logistic regression analysis) and then with adjustment for age at surgery, gender, BMI, preoperative instability, time from injury to surgery, reconstruction method, and concomitant injury of ligament, cartilage, and meniscus (multivariate logistic regression analysis). The results of regression analysis were presented as odds ratios (ORs) with accompanying 95 % confidence intervals (CIs). Results were considered to be statistically significant when the null value (1.00) was absent from the CI or $p$ values <0.05. Using G-Power 3.1 calculation software, the post hoc analysis for the multivariate logistic regression was performed to achieve statistical power of this study [9]. The computed power was achieved with a sample size of 131, each OR and an $R$-squared of 0.16 attributed to 11 independent variables using the $Z$ test with a significance level of 0.05.

## Results

The demographic and clinical characteristics of each group are shown in Table 1.

Among the risk factor variables, concomitant grade 2 MCL injury and delayed reconstruction over 12 weeks from injury were significant risk factors for postoperative knee instability after ACL reconstruction.

Early reconstruction (within 12 weeks from injury) was performed in 70 of 94 patients (74.4 %) in group 1, and 18 of 37 patients (48.6 %) in group 2. Time from injury to surgery over 12 weeks was a significant risk factor to predict postoperative instability after ACL reconstruction ($p = 0.04$ in univariate analysis [UA] and $p < 0.001$ in multivariate analysis [MA]). The OR of time from injury to

**Table 1** Patient demographics

| | Group 1 ($n = 94$) | Group 2 ($n = 37$) |
|---|---|---|
| Age (year); median (range) | 39 (20–53) | 41 (22–51) |
| Sex male/female | 81 (86.2 %)/13 (13.8 %) | 32 (86.5 %)/5 (13.5 %) |
| BMI (kg/m$^2$); median (range) | 25.5 (20.1–35.0) | 25.4 (20.5–37.0) |
| Preoperative stress X-ray (mm); median (range) | 7.8 (0.0–18.3) | 7.8 (0.1–25.5) |
| Preoperative pivot shift test (Gr.0/Gr.1/Gr.2/Gr.3) | 14 (14.9 %)/52 (55.3 %)/ 20 (21.3 %)/8 (8.5 %) | 4 (10.8 %)/18 (48.6 %)/10 (27.0 %)/ 5 (13.5 %) |
| TFI (week); median (range) (<12 weeks/excess 12 weeks) | 6 (1–1080) 70 (74.4 %)/24 (25.6 %) | 11 (1–1040) 18 (48.6 %)/19 (51.4 %) |
| Method of reconstruction (SB/DB) | 21 (22.3 %)/73 (77.7 %) | 12 (32.4 %)/25 (67.6 %) |
| No. of concomitant ligament injury (MCL) none/ligament injury (MCL) | 91 (96.8 %)/3 (3.2 %) | 29 (78.4 %)/8 (21.6 %) |
| No. of concomitant cartilage injury (Gr.1/Gr.2/Gr.3/Gr.4) | 26 (27.7 %)/58 (61.7 %)/ 7 (7.4 %)/3 (3.2 %) | 13 (35.1 %)/17 (46.0 %)/ 4 (10.8 %)/3 (8.1 %) |
| No. of concomitant meniscus injury | | |
| Medial meniscus (none/repair/partial meniscectomy/ subtotal meniscectomy) | 34 (36.2 %)/49 (52.1 %)/ 7 (7.4 %)/4 (4.3 %) | 13 (35.1 %)/19 (51.4 %)/ 1 (2.7 %)/4 (10.8 %) |
| Lateral meniscus (none/repair/partial meniscectomy/ subtotal meniscectomy) | 49 (52.1 %)/28 (29.8 %)/ 15 (16.0 %)/2 (2.1 %) | 21 (56.8 %)/12 (32.4 %)/ 3 (8.1 %)/1 (2.7 %) |

*BMI* body mass index, *MCL* medial collateral ligament, *TFI* time from injury to surgery

surgery over 12 weeks was 2.22 (95 % CI 1.01–4.89), and the adjusted OR was 6.22 (95 % CI 2.14–18.06).

For concomitant MCL injury, patients with concomitant grade 2 MCL injury had significantly worse outcome in postoperative instability than patients without such damage ($p = 0.03$ in UA and $p = 0.02$ in MA). The OR was 12.55 (95 % CI 1.34–116.84), and the adjusted OR was 13.60 (95 % CI 1.24–148.25).

Age at surgery, gender, BMI, preoperative radiologic instability, preoperative pivot shift test, method of reconstruction (SB reconstruction with the abundant remnant tissue or DB reconstruction with scanty remnant), concomitant cartilage injury, and concomitant meniscus injury were not found to be significant risk factors for postoperative knee instability (n.s.).

The ORs and adjusted ORs with 95 % CI for each risk factor variable are shown in Table 2.

Post hoc tests suggested that the power of our tests ranged from 0.49 to 0.96 with 131 participants, an $R$-squared of 0.16 and a significance level of 0.05. Although the power for concomitant MCL injury and time from injury to surgery analysis was 0.96 and 0.83 with high OR, the power for sex analysis was low (power = 0.49).

## Discussion

The most important finding of the present study was that increased knee instability which was measured by stress radiograph and pivot shift test [2, 22, 23] was strongly associated with surgical delay from injury and concomitant grade 2 MCL injury. Thus, for our primary hypothesis, it was supported that one or more preoperative and intraoperative risk factors would be associated with postoperative knee instability.

Associations between many of these risk factors and the postoperative results after ACL reconstruction have been reported. Bernstein [3] in a study of early versus delayed reconstruction found that early surgery for ACL tears may be the more effective overall approach. A study by Karlsson et al. [18] revealed that competitive athletes who underwent reconstruction at a subacute stage (<12 weeks from injury) after an ACL injury had a higher activity level and meniscal injuries were significantly more frequent if reconstruction was delayed. Similar to our findings, delayed reconstruction was associated with poor postoperative results in other previous studies. Contrary to our results, several studies revealed the disadvantage of early reconstruction [15, 31, 36, 37] or no difference between early and delayed reconstructions [6, 14, 16, 24, 30, 39]. In our study of 88 cases that had reconstruction <12 weeks postinjury, 12 cases had early reconstruction <2 weeks postinjury due to a meniscal bucket-handle tear, with a satisfying range of knee motion postoperatively. The presence of MCL injury was significantly related to postoperative instability. The most popular option for a combined ACL and MCL injury is ACL reconstruction with nonoperative MCL management [35]. In our study, we applied this treatment option to most cases of combined MCL injuries with <grade 2 valgus instability. Of all 11 MCL injuries, open MCL and posteromedial

**Table 2** Risk factors for postoperative instability in patients who underwent anterior cruciate ligament reconstruction

| | OR (95 % CI) | Adjusted OR (95 % CI) |
|---|---|---|
| Sex | 0.97 (0.32–2.95) | 2.78 (0.61–12.60) |
| Age | 0.99 (0.96–1.03) | 0.81 (0.31–2.15) |
| BMI | 1.03 (0.92–1.15) | 0.98 (0.51–1.90) |
| Preop stress X-ray | | |
| ≤5 mm | 1 | 1 |
| >5 mm, ≤10 mm | 1.46 (0.51–4.15) | 1.36 (0.32–5.63) |
| >10 mm | 1.83 (0.57–5.83) | 1.43 (0.30–6.66) |
| Pivot shift | | |
| Grade 0 | 1 | 1 |
| Grade 1 | 1.21 (0.35–4.16) | 1.02 (0.18–5.73) |
| Grade 2 | 1.75 (0.45–6.72) | 1.43 (0.25–8.23) |
| Grade 3 | 2.18 (0.45–10.57) | 1.99 (0.23–17.05) |
| TFI | | |
| ≤12 weeks | 1 | 1 |
| >12 weeks | 2.22 (1.01–4.89) | 6.22 (2.14–18.06) |
| Method of reconstruction | | |
| SB | 1 | 1 |
| DB | 0.59 (0.25–1.39) | 0.54 (0.16–1.77) |
| Concomitant MCL injury | | |
| None | 1 | 1 |
| Grade 1 | 9.41 (0.94–94.03) | 9.48 (0.83–108.16) |
| Grade 2 | 12.55 (1.34–116.84) | 13.60 (1.24–148.25) |
| Grade 3 | 3.13 (0.19–51.76) | 0.15 (0.01–2.10) |
| Osteochondral lesion | | |
| Grade 1 | 1 | 1 |
| Grade 2 | 0.58 (0.24–1.38) | 0.63 (0.18–2.12) |
| Grade 3 | 1.14 (0.28–4.62) | 0.80 (0.08–7.93) |
| Grade 4 | 2.00 (0.35–11.31) | 2.89 (0.23–36.18) |
| Concomitant MM injury | | |
| None | 1 | 1 |
| Meniscus repair | 1.01 (0.44–2.32) | 0.74 (0.22–2.52) |
| Partial meniscectomy | 0.37 (0.04–3.34) | 0.25 (0.01–3.47) |
| Subtotal meniscectomy | 2.61 (0.56–12.03) | 2.95 (0.38–22.89) |
| Concomitant LM injury | | |
| None | 1 | 1 |
| Meniscus repair | 0.58 (0.24–1.38) | 1.44 (0.47–4.38) |
| Partial meniscectomy | 1.14 (0.28–4.62) | 0.40 (0.05–2.90) |
| Subtotal meniscectomy | 2.00 (0.35–11.31) | 1.15 (0.04–30.86) |

*BMI* body mass index, *TFI* time from injury to surgery, *MM* medial meniscus, *LM* lateral meniscus

repair were performed for each one of the two cases in both groups with more than grade 3 laxity. In previous studies about combined ACL and MCL injuries, the majority opinion [30, 34] was that there was no significant effect of concomitant MCL injury on the postoperative result. However, in a cadaveric study, Mazzocca et al. [29] reported that ACL strain increases substantially only after MCL injury and that the ACL can be compromised in isolated MCL injuries. Despite surgical treatment of MCL laxity based on grade of instability, the residual laxity may have negatively influenced ACL stability in both treated and untreated cases.

Several studies have explored the association between postoperative results and predictors such as gender, concomitant meniscal injuries, and cartilage injuries [19, 25, 41]. Kartuset et al. [19] reported that patients who underwent meniscal surgery during ACL reconstruction had a worse clinical result. Laxdal et al. [25] suggested that concomitant joint damage including meniscus and cartilage injuries was one of the major risk factors for inferior outcome estimated by the IKDC system. We found no significant influence of concomitant meniscal surgery or cartilage injury on the objective postoperative knee instability. Other studies have found the significant relation between concomitant meniscus or cartilage injuries and functional scoring system such as Lysholm scores and the IKDC system, while our examination of objective postoperative stability did not show an association with meniscus and cartilage injuries. Andernord et al. [1] reported that soccer players and adolescents had an increased risk of revision surgery after ACL reconstruction in prospective cohort study with a large number of patients.

The patients enrolled in our present study were sorted into two groups by only an objective assessment of ligament stability, excluding subjective functional scores. Previous studies [22, 23] revealed no significant relationship between any subjective variables of symptoms and function, and objective knee laxity such as Lachman and pivot shift examinations. The objective parameters for grouping in our study may be a possible explanation for the different result in the correlation with concomitant meniscal surgery and cartilage injuries from other previous studies [19, 25, 41]. Several unique strengths were identified in our study. First, the results were analysed with multivariate logistic regression analysis, which was used to estimate the association between the postoperative knee instability after ACL reconstruction and numerous independent risk factors. In previous studies performed with a similar statistical method, the surgical technique difference about SB versus DB reconstruction was rarely included as risk factor variable, whereas we analysed the reconstruction technique variables, even though there was difference in the preserved remnant amount between both SB and DB techniques. The second strength was that our study was a single-centre hospital-based study and all surgeries were performed by the same surgeon. Most previous studies were designed with multicentre trial for a large volume of ACL injuries, and ACL reconstructions were performed by the various surgeons. Thus, their results could vary based on difference in surgical skills and divergent rehabilitation protocols of each institute.

Several limitations should be considered in our present study. First, retrospective data collection and analysis were required, which could have allowed for patient selection bias and also the opportunity for confounding. Although we adjusted for potential confounders, there may have been additional confounders such as the tibial slope [12] that we did not control. Second, we focused on the objective aspects of the postoperative results such as stress radiographs and pivot shift examinations but excluded patient-derived subjective assessments. The reason why the subjective functional scores were ruled out was to avoid the influence of patient general health-related factors on the postoperative results; however, this may have been a weak point, as we did not consider patient satisfaction after ACL reconstruction. The subjectivity in pivot shift testing may be another weak point, although pivot shift test was performed by the same surgeon. Third, there were only 11 MCL injuries, even though the difference was significant. This small number of patients with concomitant MCL injury may limit the strength of our present study. Fourth, the two surgical techniques of SB and DB reconstructions in our present study were not equal to those in most previous studies about SB versus DB reconstruction. There was an obvious difference in the preserved remnant amount between SB reconstruction with preserved abundant remnant and DB with scanty remnant. It should not be concluded that there was no difference as risk factor between SB and DB reconstructions with the same condition of remnant tissue. The tunnel malposition may be a potential risk factor for postoperative knee instability after ACL reconstruction. Nonanatomical ACL tunnel placement is the most common technical error, leading to recurrent instability and a failed ACL reconstruction [40]. But, the placement of tibial and femoral tunnels was ruled out in our study, because the postoperative three-dimensional computed tomography was not done in all the patients. The study's small sample size ($n = 131$) resulted in limited statistical power for several parameters such as sex and may have contributed to limiting the significance of the result.

## Conclusions

Among the risk factor variables, concomitant grade 2 MCL injury and surgical delay of more than 12 weeks from injury were significant risk factors for postoperative knee instability after ACL reconstruction. The overall results suggest that the surgery <12 weeks from injury and meticulous attention to concomitant MCL injury should be considered.

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