Failed Meniscal Repairs After Anterior Cruciate Ligament Reconstruction Increases Risk of Revision Surgery

Søren Vindfeld,*† MD, Torbjørn Strand,† MD, Eirik Solheim,‡§ MD, PhD, and Eivind Inderhaug,†§ MD, MPH, PhD
Investigation performed at the Department of Orthopaedic Surgery, Haraldsplass Deaconess Hospital, Bergen, Norway

Background: Failed anterior cruciate ligament (ACL) reconstruction (ACLR) can lead to reduced quality of life because of recurrent episodes of instability, restrictions in level of activity, and development of osteoarthritis. A profound knowledge of the causes of a failed surgery can ultimately help improve graft survival rates.

Purpose: To investigate the patient-related risks of inferior outcomes leading to revision surgery after ACLR.

Study Design: Case-control study; Level of evidence, 3.

Methods: From a prospective cohort of primary ACLRs performed at a single center, patients who required later revision surgery were matched with a control group of uneventful primary ACLRs. Patient characteristics, data from the preoperative examinations, KT-1000 arthrometer laxity testing, Tegner activity scale, International Knee Documentation Committee subjective score, Knee injury and Osteoarthritis Outcome Score, and perioperative data from the initial surgery were included.

Results: A total of 100 revision cases and 100 matched controls, with a median follow-up time of 11 years, were included in the study. Those who had undergone revision surgery were younger at the time of reconstruction and had a shorter time from injury to surgery than their matched controls ($P = .006$). The control group—of uneventful ACLRs—had a higher incidence of meniscal repair at reconstruction ($P = .024$). Also, the revision group more frequently experienced later failure of the previous meniscal repair ($P = .004$). Surgeon experience was not found to affect the risk of revision ACL surgery. Those who had undergone ACL revision surgery had more frequently received a hamstring tendon graft size of <8 mm ($P = .018$) compared with the controls.

Conclusion: The current study demonstrated that failed meniscal repair and a hamstring tendon graft size of <8 mm were associated with primary ACLR failure. Also, younger age at the time of surgery and shorter time from injury to surgery were found to affect the risk of undergoing revision ACL surgery.

Keywords: revision surgery; anterior cruciate ligament; meniscal repair

Despite efforts to improve outcomes after anterior cruciate ligament (ACL) reconstruction (ACLR) for many decades, there is still a persistent and significant failure rate.[5] ACL registries commonly report an overall revision rate of 3%-10%,[1,5,20] but in subgroups of patients, up to 22%-30% experience failure.[6,38] Graft rerupture can have detrimental effects on quality of life because of recurrent episodes of instability, restrictions in the level of activity, and potential early development of osteoarthritis.[2,7] Also, results after revision surgery are commonly described as inferior to what is seen after the first reconstruction.[7]

Failure can in part be because of return to high-risk sports, as is commonly seen in the youngest group of patients.[37] The greatest risk is found in those returning to pivoting sports.[37] Also, the magnitude of injury at the initial ACL tear, defined as concomitant injures to other structures, can affect the outcome after surgery.[35] Further, predispositions such as female sex, a high posterior tibial slope, or a joint hyperlaxity add to patient-related risks.[13,18,19] Finally, factors related to surgery, such as choice of the graft, size of the graft, and choice of fixational devices, have also been found to be of importance.[18,26,30] Graft tunnel positioning, especially whether anatomic tunnel placement was achieved, is another topic that has been highlighted.[11,22]

As an increasing number of patients are being assessed for revision surgery,[5] there is a continuous need for knowledge on why the primary surgery fails. Such knowledge can help surgical decision-making at repeat surgery and lower the risk of overall failure. The current study, therefore, aimed to investigate the potential risks of failure after

ACLR in a retrospective case-control study that utilized prospectively collected data. A group of patients in need of revision surgery after their primary reconstruction were compared with a matched control group of patients with an uneventful postoperative course. The null hypothesis was that no difference would be found in pre- and peroperative potential risk factors for failure between the groups.

METHODS

Patient Selection

Patients who had undergone ACLR and had later undergone revision surgery from 1999 to 2015 at our clinic were eligible for the study and thus defined the sample size. Patients who had undergone concomitant ligament surgery such as medial collateral ligament, lateral collateral ligament, posterior cruciate ligament, or posterior cruciate ligament reconstruction were excluded. A matched control group of patients who had undergone ACLR without the need for revision immediately following in time to each of the cases that needed revision (and therefore made out the case group) was also included[7] (Figure 1). The ratio of case to control was set as 1:1. Such matching was performed to adjust for changing surgical techniques in the period of inclusion. A minimum of 2-year follow-up was required for patients to be included in the study. All participants included in the control group were contacted to ensure they had not undergone revision surgery at another clinic. If so (n = 1), they were excluded in favor of the next consecutive patient that had been reconstructed after the index case (later undergoing revision). The study was approved by a regional ethical review board.

Data Collection

All data were collected from a prospective institutional quality assessment database. The following preoperative data were extracted: age, side of injury, sex, height, weight, activity at injury, time of injury, time of surgery, and time of any revision surgery. Further, perioperative data such as graft type and size, the surgeon's level of experience (defined by the number of previous ACL surgeries performed: 0-25, under supervision; 26-100, moderate experience; and >100, experienced), and any concomitant lesion of meniscal or articular cartilage were included. Tegner activity score, International Knee Documentation Committee (IKDC) 2000 subjective score, and Knee injury and Osteoarthritis Outcome Score (KOOS) were extracted from
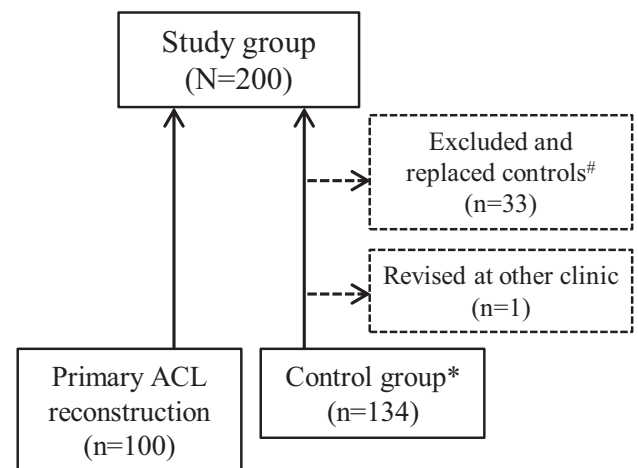
Figure 1. Patient selection for the revision and control groups. *Selected as the next consecutive primary anterior cruciate ligament (ACL) reconstruction leading to revision. #Excluded as controls owing to concomitant ligament surgery, loss to follow-up, or patient deceased.

preoperative assessment. Also, preoperative Lachman test, pivot-shift test,[23] and KT-1000 arthrometer (MEDmetric) measurements were included. For the latter, the maximum manual difference between injured and normal knee (side-to-side difference) was calculated and used for analyses.

Surgical Procedure

The primary reconstruction in both the revision group and the control group was performed from April 1990 to August 2014. Therefore, a certain variety in tunnel placement strategies (transtibial and anteromedial portal techniques), choice of graft source (hamstrings and patellar tendon autograft only), and graft fixation methods were seen. Surgical technique was, however, not individualized based on patient characteristics but rather a reflection of what was seen as the gold standard at all times throughout the period. Meniscal repair was done with one (or combinations) of the following techniques: inside-out, outside-in, or all-inside suture devices—depending on the type, size, and position of the tear. The rehabilitation protocol allowed partial weightbearing for 2-4 weeks and free range of motion. In cases of concomitant meniscal repair, patients were restricted to partial weightbearing for 6 weeks and range of motion from full extension to 90° of flexion. A standardized follow-up regimen included postoperative visits to

*Address correspondence to Søren Vindfeld, MD, Department of Orthopaedic Surgery, Haraldsplass Deaconess Hospital, Ulriksdal 8 C, PO 6165, 5892 Bergen, Norway (email: soren.vindfeld@gmail.com).
†Haraldsplass Deaconess Hospital, Bergen, Norway.
‡Aleris Hospital Nesttun, Nesttun, Norway.
§Department of Clinical Medicine, Faculty of Medicine, University of Bergen, Bergen, Norway.

TABLE 1
Characteristic Data in Revision and Control Groups[a]

	Revision (n = 100)	Control (n = 100)	P
Age at surgery, y	24.2	28.4	.006[b]
Female patients	56	44	ns[c]
Body mass index	24.4 ± 4.0	24.9 ± 4.3	ns[b]
Time from injury to surgery, mo, mean ± SD	11.9 ± 19.0	22.7 ± 43.4	.041[b]
Follow-up time, y, median (range)	11.0 (2.2-26.4)	10.9 (2.1-25.5)	ns[b]
Injured side (left)	46	46	ns[c]
Tegner preinjury, mean ± SD	7.58 ± 1.63	7.44 ± 1.60	ns[b]

[a]ns, not significant.
[b]Nonparametric Mann-Whitney U test.
[c]Chi-square test.

both physical therapist and surgeon at the clinic. All patients were offered functional testing at 9-12 months after surgery, including hop tests and isometric strength testing. Further rehabilitation and potential return to sports were advised according to the results of these tests.

Statistical Analysis

All statistical analyses were performed using the SPSS 23.0 software (IBM Corp). As measures of central location and spread of data, mean and standard deviation or median and range were calculated. Normality of continuous variables was investigated using QQ plots and Shapiro-Wilk test. If normality was found, independent-samples *t* tests were used; if not, the nonparametric Mann-Whitney *U* test was applied. Chi-square test was used for testing distributions of categorical variables such as sex and injured side. An a priori *P* value of .05 was used to denote statistical significance. A group size calculation was performed, aiming to detect a minimally clinical important difference for IKDC subjective score of 9 points.[24] With a statistical significance of .05, a β value of 0.1 (power of 0.9), and a standard deviation of IKDC of 15 (based on earlier data), a group size of 58 was found to be sufficient.

RESULTS

A total of 100 patients who had undergone revision surgery and 100 control patients were included in the study. There was no difference in median follow-up time (11 years) between the revision group and the control group. The median time from surgery to revision was 2.1 years (range, 14 days-21 years). One case was revised after 14 days because of an infection. Characteristic data for the 2 groups are presented in Table 1. The revision group was significantly younger at the time of surgery (*P* = .006) and had a significantly shorter time from injury to surgery (*P* = .041), as compared with the control group. Sex, injured side, body mass index (BMI), and preinjury Tegner score did not differ

TABLE 2
Findings From Preoperative Clinical Examinations and Patient-Reported Outcome Measures[a]

	Revision (n = 100)	Control (n = 100)	P
KT-1000 arthrometer side-to-side difference, mm	6.5 ± 3.0	6.8 ± 2.6	ns[b]
ALRI			ns[c]
0	2	0	
1	3	5	
2	59	61	
Classification not possible because of muscular guarding	14	16	
Lachman grade			ns[c]
0	0	0	
1	13	8	
2	71	75	
3	10	8	
IKDC	57 ± 15	55 ± 15	ns[b]
KOOS, Sports and Recreation	44 ± 27	44 ± 26	ns[b]
KOOS, Knee-Related Quality of Life	32 ± 18	31 ± 16	ns[b]

[a]IKDC, International Knee Documentation Committee; ALRI, anterolateral rotational instability; KOOS, Knee injury and Osteoarthritis Outcome Score; ns, not significant.
[b]Independent-samples *t* test.
[c]Chi-square.

between the groups. Further, type of activity at the time of injury was not significantly different between the 2 groups, with approximately 50% of injuries being related to soccer, 15% from team handball, and 15% from alpine skiing; and 20% of injuries were related to work, traffic accidents, or other activities.

The preoperative clinical examination displayed no differences in mean KT-1000 arthrometer side-to-side difference, distribution of pivot-shift, or Lachman grading. Also, KOOS and IKDC subjective score were not found to differ significantly between those who had undergone revision and controls (Table 2).

There was no significant difference between the groups in the distribution of meniscal injuries, articular cartilage injuries, treatment of cartilage injuries, or meniscal resections concomitant to the primary reconstruction. The control group patients were more frequently treated with meniscal repair compared with the revision group (*P* = .024) (Table 3). Of those who had undergone a meniscal repair, 6 of 8 in the revision group had a later meniscal resection, while only 6 of 21 in the control group had undergone later resection (*P* = .038).

The mean graft size was not found to differ between the 2 groups (8.5 mm in the revision group vs 8.7 mm in controls) (Table 4). A graft size of <8 mm was, however, more frequently used in the revision group than in the control group (*P* = .018). The distribution of graft type (hamstring or patellar tendon autografts) did not differ between groups. No allografts were used. When examining the effect of surgeon experience, no difference in risk of revision was seen

TABLE 3
Concomitant Meniscal and Cartilage Injuries
at Time of Surgery[a]

	Revision (n = 100)	Control (n = 100)	P
Meniscal tear	46	59	ns[b]
Meniscal resection	23	22	ns[b]
Meniscal repair	8	21	.024[b]
Cartilage injury	13	14	ns[b]
Later failed meniscal repair	6/8	6/21	.038[b]

[a]ns, not significant.
[b]Chi-square test.

TABLE 4
Perioperative Findings: Graft Size, Graft Type,
Length of Surgery, and Surgeon Experience[a]

	Revision (n = 100)	Control (n = 100)	P
Mean graft size, mm	8.5 ± 0.9	8.7 ± 0.8	ns[b]
Graft size <8 mm	9	1	.018[c]
Patellar/hamstring tendon autograft	18/82	21/79	ns[c]
Length of surgery, min	107 ± 35	107 ± 31	ns[b]
Surgeon experience			ns[c]
0-25	9	7	
25-100	24	26	
100+	67	67	

[a]ns, not statistically significant.
[b]Nonparametric Mann-Whitney U test.
[c]Chi-square test.

when comparing surgeons under supervision, surgeons with moderate experience, and experienced surgeons.

DISCUSSION

The most important finding in the current study is that patients in need of revision ACLR (because of a failed primary ACLR) had a lower survival rate of meniscal repairs when compared with a control group of patients who had not undergone revision surgery. Further, those who were in need of revision ACLR had more frequently received a hamstring tendon autograft of <8 mm diameter. The latter finding adds to the reports from other studies that smaller graft size is an independent risk for failure after ACLR. Differences were also seen between the revision group and the control group regarding time from injury to surgery and age at the time of surgery. Level of surgeon experience was, however, not found to affect the risk of needing later revision ACL surgery.

Proper repair of the meniscus is thought to restore its native function, which includes its role as a secondary stabilizer of the knee along with the reconstructed ACL.[16,17] This was evident in an experimental biomechanical study by Stephen et al,[33] who examined the effect of a posteromedial meniscocapsular lesion on tibiofemoral joint laxity in the ACL-deficient knee. They found normalization of sagittal and rotational stability of the knee only after the meniscal tear was repaired along with the ACLR. Clinical studies have also displayed the synergistic effect of meniscal repair and ACLR. A recent multivariate analysis of a cohort of US military personnel by Pullen et al[30] found concomitant meniscal repair to protect against later revision ACL surgery. Trojani et al[34] also noted the importance of meniscal repair. In their study, better functional results and better knee stability were seen after ACLR where repair rather than resection had been performed.

In a multivariate analysis investigating predictors for ACLR failure, Parkinson et al[27] found meniscal deficiency to be the single most important factor. The results from our study align with their finding, showing a protective effect of meniscal repair on graft survival. The choice to perform meniscal repair, whenever viable, seems to be paramount when performing ligament surgery. In accordance with the latter belief, a changing attitude toward meniscal surgery is shown in the data from the Norwegian ACL registry.[5] The number of ACLRs with concomitant meniscal repair procedures has risen from 7% to 40%, while resections have decreased from 73% to 48%, in the period from 2005 to 2016. In the current study, it is difficult to establish the causality between meniscal repair failure and increased risk of revision ACLR. On one side, one could argue that an injured meniscus can lead to additional strain on the ACL graft, but it might also be that residual laxity in and of itself increases the risk of a repeat meniscal tear. In addition to the favorable effect of meniscal repair on knee kinematics, one could speculate whether the resulting slower rehabilitation after a meniscal repair is also protective for risk of later revision surgery. This could, in particular, be the case for patients receiving hamstring tendon grafts, as they are believed to need a longer time for graft-to-bone healing.[12,25]

The relationship between graft diameter and patient outcomes has been the subject of investigation in several studies. Magnussen et al[18] reported that hamstring tendon autograft diameter of <8 mm was a predictor for early revision after surgery. Park et al[26] demonstrated how graft diameter was dependent on patient BMI, sex, and athletic level. Further, although there was no relation between smaller graft diameters and risk of revision ACL, patients with a graft size of <8 mm displayed inferior clinical outcomes.[26] In a study from the Swedish ACL registry, more than 2000 patients who underwent reconstruction with hamstring tendon autografts were analyzed.[32] The main finding was an increasing likelihood of undergoing revision surgery for each 0.5-mm decrease in graft diameter from 10 to 7 mm. In contrast to the studies mentioned above is a recent report from the Norwegian ACL registry investigating the effect of BMI and graft size on risk of undergoing revision.[10] When graft diameter was related to patient weight and height, no difference in the risk of revision surgery based on hamstring tendon autograft diameter was seen. In the present study, a smaller graft size of <8 mm was seen more frequently in the revision group compared with the control group. This adds to the notion that surgeons should aim to upsize the graft size whenever

encountering a small diameter during surgery. A careful consideration should, however, be made toward this upsizing, since data from a publication by Pennock et al[28] point toward higher graft failure rates when augmentation with allograft is used to achieve this.

The present study found patients who had undergone revision surgery to be younger at the time of surgery compared with the patients who had not undergone revision surgery.[19,29,36] In a prospective cohort by Kamien et al,[13] age below 25 years was found to be an independent risk factor for ACLR failure. Studies by Magnussen et al[18] and Shelbourne et al[31] have displayed the same findings. Further, reports[4,6,19] from the Swedish, Danish, and Kaiser Permanente registries also emphasize age as an independent risk factor for revision. With younger age comes a greater desire to return to high-risk activities that expose patients to repeat injury of their knee. As discussed by Marx et al,[21] participation in high-risk activity is likely the confounding factor making younger-aged patients more prone to undergo ACL revision surgery.

Several studies have reported on early versus delayed reconstruction after ACL rupture. The level of knee instability, concomitant injuries, and patient expectations are among the factors that influence timing of surgery.[9,14] As highlighted by Krutsch et al,[15] there might be a risk of secondary injuries related to delayed surgery. In their study, an increase in irreparable meniscal lesions was seen in those who underwent delayed surgery. A previous study[8] reported that patients returning to lower level sports can be managed well with proper nonoperative treatment and that "watchful waiting" can therefore be an option. Results from the current study indicated a shorter time from injury to surgery in patients who were in need for revision surgery, as compared with the control patients. While this finding could be interpreted as support for "watchful waiting," we believe that time from injury to surgery is also a derived factor, reflecting a population more eager to return to sports—exposing them to further risk of new injuries. It has to be acknowledged that this mean time from injury to surgery of 22.7 months could influence meniscus healing potential and thereby the results of the study.

There are several inherent limitations in the current study. First, defining failure only by the need for revision surgery will likely underestimate the number of failed ACLRs. Crawford et al[3] found that the overall rate of failure increased from 6% to 12% when patient-reported outcome measures and clinical evaluation of laxity were also accounted for. Not all patients who fail choose to undergo repeat surgery. Further, level of osteoarthritis and return to sports are unknown factors that could help define whether the primary surgery was successful or not. Strengths of the current study include the relatively large prospective cohort of ACLRs undergoing later revision surgery and a homogenous group of controls operated on by the same group of surgeons at a single center. Although data were collected through a long period of time, we believe that the design of the study, applying a matched control group, counterbalances the differences caused by the changing surgical techniques over the time span of the study. We acknowledge that the retrospective design is less robust toward confounding factors than if a prospective design had been applied. The study design supports the generalizability of the results, since in the included patients were an unselected group of patients who experienced failure after ACLR.

CONCLUSION

The current study, investigating the risks for failure after ACLR, demonstrated an association between failed meniscal surgery and the need for repeat ACL surgery. Second, the study found that hamstring tendon autografts of <8 mm diameter were more frequent in those who underwent revision ACLR. Finally, younger age at the time of surgery and shorter time from injury to surgery—both believed to reflect the risk of returning to high-risk activities—were also found to affect the risk of undergoing revision ACL surgery. With an increasing number of patients in need of repeat ACL surgery, knowledge of causes for failure is increasingly important. There is also a need for a better definition of what constitutes failure; thus, further studies should focus on this topic.

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