Meniscal and Articular Cartilage Predictors of Outcome After Revision ACL Reconstruction

A 6-Year Follow-up Cohort Study

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Investigation performed at Vanderbilt University, Nashville, Tennessee, USA

Background: Meniscal and chondral damage is common in the patient undergoing revision anterior cruciate ligament (ACL) reconstruction.

Purpose: To determine if meniscal and/or articular cartilage pathology at the time of revision ACL surgery significantly influences a patient's outcome at 6-year follow-up.

Study Design: Cohort study; Level of evidence, 3.

Methods: Patients undergoing revision ACL reconstruction were prospectively enrolled between 2006 and 2011. Data collection included baseline demographics, surgical technique, pathology, treatment, and scores from 4 validated patient-reported outcome instruments: International Knee Documentation Committee (IKDC), Knee injury and Osteoarthritis Outcome Score (KOOS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and Marx Activity Rating Scale. Patients were followed up at 6 years and asked to complete the identical set of outcome instruments. Regression analysis assessed the meniscal and articular cartilage pathology risk factors for clinical outcomes 6 years after revision ACL reconstruction.

Results: An overall 1234 patients were enrolled (716 males, 58%; median age, 26 years). Surgeons reported the pathology at the time of revision surgery in the medial meniscus (45%), lateral meniscus (36%), medial femoral condyle (43%), lateral femoral condyle (29%), medial tibial plateau (11%), lateral tibial plateau (17%), patella (30%), and trochlea (21%). Six-year follow-up was obtained on 79% of the sample (980/1234). Meniscal pathology and articular cartilage pathology (medial femoral condyle, lateral femoral condyle, lateral tibial plateau, trochlea, and patella) were significant drivers of poorer patient-reported outcomes at 6 years (IKDC, KOOS, WOMAC, and Marx). The most consistent factors driving outcomes were having a medial meniscal excision (either before or at the time of revision surgery) and patellofemoral articular cartilage pathology. Six-year Marx activity levels were negatively affected by having either a repair/excision of the medial meniscus (odds ratio range, 1.45-1.72; $P \leq .04$) or grade 3-4 patellar chondrosis (odds ratio, 1.72; $P = .04$). Meniscal pathology occurring before the index revision surgery negatively affected scores on all KOOS subscales except for sports/recreation ($P < .05$). Articular cartilage pathology significantly impaired all KOOS subscale scores ($P < .05$). Lower baseline outcome scores, higher body mass index, being a smoker, and incurring subsequent surgery all significantly increased the odds of reporting poorer clinical outcomes at 6 years.

Conclusion: Meniscal and chondral pathology at the time of revision ACL reconstruction has continued significant detrimental effects on patient-reported outcomes at 6 years after revision surgery.

Keywords: knee articular cartilage; anterior cruciate ligament (ACL); meniscus; outcomes; revision ACL reconstruction

Revision anterior cruciate ligament (ACL) reconstruction remains a difficult clinical problem. Orthopaedic surgeons continue to be challenged by not only the technical aspects of returning ligamentous stability to the knee but also the difficulty of optimizing clinical results to meet the expectations of the patients. Results of revision ACL reconstructions rarely match the clinical results of primary ACL reconstructions. Revision ACL cohorts commonly report outcomes inferior with regard to reoperations, graft failure, and patient-reported outcomes as compared with primary ACL reconstructions.[1,3,5,9,14,19,21]

The Multicenter ACL Revision Study (MARS) was developed to try to identify the modifiable and nonmodifiable factors that contribute to results after revision ACL reconstruction. A better understanding of this complex clinical issue would allow us to potentially change our technical approach and better counsel patients to appropriate expectations after these surgical procedures. This

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prospective multisurgeon and multicenter group has assembled a large cohort of patients that allows us to critically assess results and predictors. One area of significant concern among our group was the level of meniscal and chondral damage noted at the time of revision ACL reconstruction in these patients. Previous analysis of these patients at the time of enrollment and revision reconstruction revealed that ~90% had sustained either meniscal or chondral damage (modified Outerbridge grade $\geq$2).[10] Both meniscal and chondral damage was noted in 59% of these patients. Only 9% had neither meniscal nor chondral damage. These patients underwent previous analysis at 2-year follow-up, and findings demonstrated that the strongest predictors of outcome were the presence of trochlear groove chondral damage and a previous lateral meniscectomy.[10] The current study was undertaken to evaluate this same cohort of patients at minimum 6 years after revision ACL reconstruction to determine if later follow-up showed a broader, more significant effect on outcome as the articular cartilage potentially deteriorated further with time. We hypothesized that additional meniscal and chondral factors would affect the outcomes of these patients 6 years after their revision ACL reconstruction.

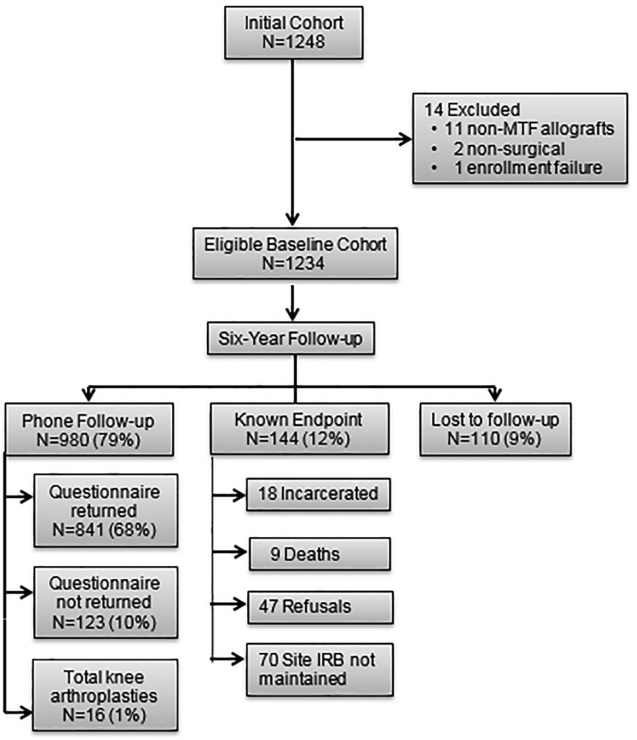

Figure 1. Patient enrollment flow diagram. IRB, institutional review board; MTF, Musculoskeletal Transplant Foundation.

METHODS

Study Design

The MARS Group was assembled in cooperation with the American Orthopaedic Society for Sports Medicine as a collection of 83 sports medicine fellowship–trained surgeons working at 52 sites. The surgeons are a mix of academic and private practitioners. Surgeon inclusion criteria included maintaining active institutional review board approval, completing a training session that integrated articular cartilage and meniscal agreement studies, reviewing the study design and patient inclusion criteria, and reviewing the surgeon questionnaire. Surgeons could perform ACL revision surgery according to their own practice preferences. If an allograft was chosen for reconstruction, the surgeon was required to utilize a Musculoskeletal Transplant Foundation graft to standardize and record allograft preparation methods.

The objective of this consortium has been to assess the short- and long-term outcomes after revision ACL reconstruction and to determine how the initial factors at the time of revision surgery may influence and predict disease progression. This study design involves a longitudinal prospective cohort for whom we currently have baseline and 2- and 6-year follow-up data.

Setting and Participants

After institutional review board approval from each institution, 1234 patients with documented ACL reconstruction failure who underwent revision ACL reconstruction surgery qualified for and provided consent to be in this study (Figure 1). This multicenter consortium began patient enrollment in 2006 and ended in 2011. Study inclusion criteria were revision ACL reconstruction performed by a MARS surgeon on patients with ACL deficiency whose previous ACL reconstruction had failed, as identified by magnetic resonance imaging, physical examination (positive pivot-shift and Lachman test results), KT-1000 arthrometer testing demonstrating >5-mm side-to-side difference, functional instability, or arthroscopic confirmation.

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Data Sources

After informed consent was obtained, each patient completed a self-reported questionnaire examining demographics, injury characteristics, sports participation history, and health status before revision ACL reconstruction surgery. Within this questionnaire, each participant completed a series of validated general and knee-specific outcome instruments: the Knee injury and Osteoarthritis Outcome Score (KOOS), the International Knee Documentation Committee (IKDC) subjective form, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and the Marx Activity Rating Scale. Surgeons completed a questionnaire that included physical examination findings, surgical technique utilized, and the intra-articular findings and surgical management of meniscal and chondral damage. Chondral damage was described using the modified Outerbridge system,[6] with worse grade defined in this study as grade $\geq$2. Meniscal injuries were classified by location (medial, lateral; anterior, posterior, anterior + posterior) and partial versus complete tears, and treatment was recorded as no treatment, repair, resection, or other (abrade and trephine, meniscal transplant, etc). For the purposes of this study, "previous" or "prior" refers to meniscal or articular cartilage injuries sustained and documented before the time of ACL revision surgery. This was determined either by previous operative reports or by noting surgical changes consistent with previous meniscal resection. "Current" refers to meniscal or articular cartilage damage noted for the first time at the time of ACL revision surgery.

Completed data forms were mailed from each participating site to our data coordinating center. Data from the patient and surgeon questionnaires were scanned with Teleform software (OpenText) utilizing optical character recognition, and the scanned data were verified and exported to a master database. A series of custom logical error and quality control checks were subsequently performed before data analyses.

Patient Follow-up

At 6 years, the same questionnaire was administered as at baseline and 2-year follow-up. Patients were also contacted by phone or email to determine if subsequent graft failure and/or any additional knee surgery had occurred.

Variables and Statistical Analysis

Descriptive statistics of each of the baseline patient and surgical characteristics were examined and reported. The effect of the independent variables (risk factors) was modeled with proportional odds logistic regression (outcome measures: IKDC, KOOS, WOMAC, Marx) and logistic multivariable regression (binary outcome: subsequent surgery, yes/no). Odds ratios (ORs) and 95% confidence intervals (95% CIs) were obtained by exponentiation of the parameter estimates. Patient and previous and current surgical-related covariates were included and controlled for in the models. Patient-related covariates were sex (male/female), age at the time of revision ACL reconstruction, body mass index, smoking status (nonsmoker, quit, current), education level (years), and baseline outcome measures (IKDC, KOOS, WOMAC, Marx). Covariates related to previous surgical information were as follows: time in years since patient's last ACL reconstruction, number of revisions, previous ACL reconstruction on the contralateral knee (yes/no), previous meniscal surgery (medial and lateral; yes/no), previous articular cartilage surgery (yes/no), prior graft type (autograft vs allograft), prior graft source (bone–patellar tendon–bone vs soft tissue), surgeon's opinion of failure (traumatic, technical, biological, other, combination), and surgeon's revision of one's own failed sugery (yes/no). Covariates related to current surgical information included the following: surgeon years of experience, mechanism of injury (nontraumatic, traumatic, contact, noncontact), surgical technique (1 incision transtibial, 1 incision anteromedial portal, 2 incision), graft type (bone–patellar tendon–bone autograft, soft tissue autograft, bone–patellar tendon–bone allograft, soft tissue allograft), meniscal pathology and treatment (medial, lateral; normal/no tear, no treatment for tear, repair, excision), articular cartilage pathology (normal/grade 1, grade 2, grade 3, grade 4 in each of the 6 compartments—medial femoral condyle [MFC], lateral femoral condyle [LFC], medial tibial plateau [MTP], lateral tibial plateau [LTP], patella, and trochlea), articular cartilage treatment (none, chondroplasty, other), and biological enhancement used (yes/no). Based on the low frequency counts of grade 4 chondral lesions in the MTP, LTP, patellar, and trochlear compartments, these grades were combined with their respective grade 3 compartment lesions to form a "grade 3 to 4" variable for each of the 4 compartments for analysis purposes. Three-knot restricted cubic splines were used for all continuous covariates to allow for nonlinear relationships with the outcomes.

The changes in outcome scores between baseline and 6 years were assessed through a comparison and medians and interquartile ranges at each time point and tested with Kruskal-Wallis tests. Additionally, minimal clinically important differences were examined between time points. The minimal clinically important difference was 11 points for the IKDC, 8 to 10 points for each of the 5 KOOS subscales, 8 to 10 points for the WOMAC, and 2 points for the Marx activity scale. Alpha was set at 0.05 for all statistical tests. Multiple imputation using predictive mean matching was used to address missing baseline data. Specifically, the "smoking status" and "time since the patient's last ACL reconstruction" variables were missing in 14 cases and were imputed. The 6-year data were not imputed. The *Hmisc* and *rms* packages of the open source R statistical software (https://www.r-project.org) were used for statistical analysis.

RESULTS

The study cohort included 1234 patients who met the inclusion criteria, with 716 (58%) males and a median cohort age of 26 years (see Appendix 1, available in the online version of this article). Surgeons noted previous

pathology (before the revision ACL reconstruction) in the medial meniscus (38%), lateral meniscus (21%), and articular surfaces (12%) at the time of revision surgery. Surgeons reported current pathology (defined as the time of the revision ACL reconstruction) in the medial meniscus (45%), lateral meniscus (36%), MFC (43%), LFC (29%), MTP (11%), LTP (17%), patella (30%), and trochlea (21%).

Six-year follow-up was obtained on 79% of the sample (980/1234) (Figure 1). Meniscal pathology—previous (before revision ACL reconstruction) and current (at the time of revision ACL reconstruction)—and current articular cartilage pathology (in the MFC, LFC, LTP, trochlea, and patella) were significant drivers of poorer outcomes at 6 years. The most consistent factors driving outcome in revision cases at 6 years were a previous or current excision of the medial meniscus and patellofemoral articular cartilage pathology.

Marx Activity Levels

Six-year Marx activity levels were negatively affected by having a repair or an excision of the medial meniscus (OR range, 1.45-1.72; 95% CI, 1.02-2.70; $P \leq .04$) (Table 1) or grade 3-4 patellar chondrosis at the time of the revision ACL reconstruction (OR, 1.72; 95% CI, 1.02-2.94; $P = .04$). In other words, the odds of going down 1 unit in the Marx score were 1.45 to 1.72 times higher for patients who underwent a repair or excision of the medial meniscus at the time of revision ACL surgery as compared with patients with no medial meniscal pathology. Similarly, the odds of going down 1 unit in the Marx score were 1.72 times higher for those patients with grade 3-4 patellar chondrosis than for patients with no patellar chondrosis. Conversely, 6-year activity levels were significantly higher if a patient had a lateral meniscal repair or excision at the time of revision ACL reconstruction (OR, 1.44-2.13; 95% CI, 1.02-3.88; $P \leq .04$). Put differently, the odds of a 1-unit increase in the Marx score were 1.44 times higher if the patient had a lateral meniscal meniscectomy and 2.13 times higher if they had a lateral meniscal repair versus no lateral meniscal pathology at the time of revision ACL surgery.

International Knee Documentation Committee

Six-year IKDC scores were negatively affected in patients who had previous medial meniscal surgery before the index revision ACL reconstruction, as well as patellar chondrosis documented at the time of the index revision ACL reconstruction (Table 1). Specifically, the odds of a 1-unit decrease in the IKDC score were 1.56 times higher in patients who underwent a repair (95% CI, 1.09-3.90; $P = .025$) of the medial meniscus before revision ACL reconstruction as compared with patients with no medial meniscal pathology. Similarly, the odds of a 1-unit decrease in the IKDC score were 1.52 times higher for those patients with grade 2 patellar chondrosis (95% CI, 1.05-2.22; $P = .026$) than for patients with no patellar chondrosis.

Knee injury and Osteoarthritis Outcome Score

Meniscal pathology negatively affected all KOOS subscales except for sports/recreation ($P < .05$) (Table 1). Specifically, having a medial meniscectomy (performed before the index revision ACL reconstruction or at the time of the revision ACL surgery) resulted in significantly lower KOOS scores at 6 years: symptoms (OR range, 1.45-1.59; 95% CI, 1.05-2.22; $P \leq .03$), pain (OR range, 1.63-1.67; 95% CI, 1.16-2.33; $P < .01$), activities of daily living (ADL) (OR, 1.41; 95% CI, 1.01-2.00; $P = .046$), and quality of life (QOL) (OR range, 1.41-1.62; 95% CI, 1.0-2.27; $P \leq .05$). Patients who had a previous lateral meniscal repair before the index revision ACL reconstruction had significantly lower KOOS scores at 6 years: symptoms (OR, 2.78; 95% CI, 1.12-6.67; $P = .027$), pain (OR, 2.70; 95% CI, 1.11-6.67; $P = .029$), and QOL (OR, 3.85; 95% CI, 1.52-9.09; $P = .004$).

Articular cartilage pathology significantly impaired all KOOS subscale scores ($P < .05$) (Table 1). The 6-year KOOS symptoms score was negatively affected by MFC (OR, 1.61; 95% CI, 1.12-2.27; $P = .009$) and trochlear (OR, 1.89; 95% CI, 1.18-3.03; $P = .009$) chondrosis. The KOOS pain score was negatively affected by LFC (OR, 1.56; 95% CI, 1.05-2.33; $P = .027$) and patellar (OR, 1.69; 95% CI, 1.02-2.86; $P = .042$) chondrosis. The KOOS ADL score was significantly affected by LFC chondrosis (OR, 1.92; 95% CI, 1.00-3.66; $P = .005$). The KOOS sports/recreation score was significantly affected by LFC (OR, 2.41; 95% CI, 1.27-4.57; $P = .007$), LTP (OR, 2.22; 95% CI, 1.12-4.55; $P = .022$), and trochlear (OR, 2.0; 95% CI, 1.25-3.23; $P = .004$) chondrosis. The 6-year KOOS QOL score was negatively affected by LFC (OR, 1.88; 95% CI, 1.05-3.39; $P = .035$) and patellar (OR, 1.54; 95% CI, 1.06-2.22; $P = .021$) chondrosis.

Western Ontario and McMaster Universities Osteoarthritis Index

Six-year WOMAC scores were negatively affected by having a previous medial meniscal excision (before the index revision ACL reconstruction) and MFC, LFC, patellar, and trochlear chondrosis documented at the time of the index revision ACL reconstruction (Table 1). Previous medial meniscectomies (OR, 1.41; 95% CI, 1.01-2.00; $P = .046$) and grade 4 LFC chondrosis (OR, 1.91; 95% CI, 1.00-3.66; $P = .05$) were predictive of significantly lower 6-year WOMAC ADL scores. Previous medial meniscectomies (OR, 1.59; 95% CI, 1.12-2.22; $P = .008$), previous lateral meniscal repairs (OR, 2.86; 95% CI, 1.12-7.14; $P = .028$), and grade 3-4 patellar chondrosis (OR, 2.17; 95% CI, 1.30-3.70; $P = .003$) were predictive of significantly lower 6-year WOMAC pain scores. Grade 4 MFC chondrosis (OR, 1.92; 95% CI, 1.06-3.45; $P = .032$) and grade 3-4

TABLE 1
Significant Odds Ratios (95% CI) for Individual Meniscal and Articular Cartilage Variables[a]

			KOOS						WOMAC		
Structure: Comparison	Worse Outcome	Marx	Symptoms	Pain	ADL	Sports/Rec	QOL	IKDC	Stiffness	Pain	ADL
			Meniscal status: previous pathology before enrollment								
Medial											
No tear vs excised	Excised		1.45 (1.05-2.04); .025	1.67 (1.19-2.33); .003	1.41 (1.01-2.00); .046		1.41 (1.00-1.96); .047	1.56 (1.12-2.17); .009		1.59 (1.12-2.22); .008	1.41 (1.01-2.00); .046
No tear vs unstable, not healed repair	No tear		2.07 (1.05-4.06); .035		2.04 (1.03-4.05); .042			2.07 (1.09-3.90); .025	2.06 (1.04-4.10); .039		2.04 (1.03-4.05); .042
Lateral											
No tear vs excised	Excised										
No tear vs stable/healed repair	Stable/healed repair		2.78 (1.12-6.67); .027	2.70 (1.11-6.67); .029			3.85 (1.52-9.09); .004			2.86 (1.12-7.14); .028	
			Meniscal status at time of revision ACLR								
Medial											
Normal vs repair	Repair	1.72 (1.12-2.70); .013									
Normal vs excision	Excision	1.45 (1.02-2.04); .038	1.59 (1.13-2.22); .007	1.63 (1.16-2.30); .005			1.62 (1.16-2.27); .005				
Lateral											
Normal vs repair	Normal	2.13 (1.17-3.88); .028									
Normal vs excision	Normal	1.44 (1.02-2.03); .039									
			Articular cartilage status: previous								
Yes vs no											
			Articular cartilage status: at time of revision ACLR								
MFC											
Normal/G1 vs G2	G2		1.61 (1.12-2.27); .009								
Normal/G1 vs G4	G4								1.92 (1.06-3.45); .032		
LFC											
Normal/G1 vs G2	G2			1.56 (1.05-2.33); .027							
Normal/G1 vs G4	G4				1.92 (1.00-3.66); .050	2.41 (1.27-4.57); .007	1.88 (1.05-3.39); .035				1.91 (1.00-3.66); .050
MTP											
Normal/G1 vs G3/4	G3/4										
LTP											
Normal/G1 vs G3/4	G3/4					2.22 (1.12-4.55); .022					
Patella											
Normal/G1 vs G2	G2						1.54 (1.06-2.22); .021	1.52 (1.05-2.22); .026			
Normal/G1 vs G3/4	G3/4	1.72 (1.02-2.94); .042		1.69 (1.02-2.86); .042						2.17 (1.30-3.70); .003	
Trochlea											
Normal/G1 vs G3/4	G3/4		1.89 (1.18-3.03); .009			2.00 (1.25-3.23); .004			2.22 (1.35-3.70); .002		

[a]Data are presented as odd ratio (9.% CI); *P* value (where significant). An empty cell indicates that the knee rating at the top of the column was not significantly affected by meniscal and articular surface conditions. Bold entries indicate that result was counterintuitive to the initial hypothesis. ACLR, anterior cruciate ligament reconstruction; ADL, activities of daily living; G1, grade 1; G2, grade 2; G3, grade 3; G4, grade 4; G3/4, grades 3-4; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; LFC, lateral femoral condyle; LTP, lateral tibial plateau; Marx, Marx Activity Rating Scale; MFC, medial femoral condyle; MTP, medial tibial plateau; QOL, quality of life; Sports/Rec, sports and recreation; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

TABLE 2
Significant Odds Ratios (95% CI) for Secondary Variables in Model[a]

				KOOS						WOMAC		
	Comparison	Worse Outcome	Marx	Symptoms	Pain	ADL	Sports/Rec	QOL	IKDC	Stiffness	Pain	ADL
Baseline patient-reported outcome score		Lower baseline score	2.54 (1.69-3.80); <.0001	2.98 (2.34-3.79); <.0001	3.17 (2.49-4.04); <.0001	5.09 (3.67-7.06); <.0001	2.43 (1.94-3.03); <.0001	2.23 (1.80-2.77); <.0001	2.62 (2.11-3.25); <.0001	2.53 (1.93-3.31); <.0001	3.27 (2.40-4.47); <.0001	5.09 (3.67-7.07); <.0001
Patient demographics												
Age, y		Older age	3.03 (1.89-5.00); <.0001									
Sex	Male vs female	Females	2.22 (1.64-2.94); <.0001	1.35 (1.01-1.79); .044								
Smoking status	Never vs current	Current smoker	2.08 (1.16-3.70); .013	3.13 (1.82-5.56); <.001	3.45 (2.00-5.88); <.001	3.85 (2.27-6.67); <.001	3.13 (1.79-5.26); <.001	3.85 (2.27-6.67); <.001	4.17 (2.44-7.14); <.001	3.33 (1.96-5.88); <.001	3.23 (1.89-5.56); <.001	3.85 (2.27-6.67); <.001
BMI		Higher BMI		1.04 (1.01-1.07); .014	1.04 (1.01-1.07); .008	1.06 (1.03-1.10); <.001	1.04 (1.01-1.07); .003	1.04 (1.01-1.07); .012	1.06 (1.03-1.09); <.001		1.05 (1.02-1.09); .001	1.06 (1.03-1.10); <.001
Baseline Marx activity level		Lower baseline Marx score	2.54 (1.69-3.80); <.0001						1.65 (1.09-2.50); .003			
Previous surgical information												
Time since last ACLR, y		Less time since last ACLR		1.87 (1.23-2.86); .037						1.60 (1.02-2.51); .021		
Previous ACLR on contralateral knee	No vs yes	Yes			1.61 (1.03-2.56); .035			1.67 (1.08-2.63); .023				

[a]Data are presented as odd ratio (9.% CI); *P* value (where significant). An empty cell indicates that the knee rating at the top of the column was not significantly affected by meniscal and articular surface conditions. ACLR, anterior cruciate ligament reconstruction; ADL, activities of daily living; BMI, body mass index; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; Marx, Marx Activity Rating Scale; QOL, quality of life; Sports/Rec, sports and recreation; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

trochlear chondrosis (OR, 2.22; 95% CI, 1.35-3.70; $P = .002$) were predictive of significantly lower WOMAC stiffness scores.

Subsequent Surgery

Predictors of patients having subsequent surgery by 6 years included medial meniscal repair done at the time of the index revision ACL reconstruction (OR, 2.2; 95% CI, 1.27-3.88; $P = .005$) as compared with no medial meniscal pathology at the time of the revision surgery. Similarly, patients who had grade 2 MFC chondrosis (OR, 1.7; 95% CI, 1.04-2.82; $P = .035$) or grade 3-4 MTP chondrosis (OR, 3.0; 95% CI, 1.07-8.54; $P = .037$) at the time of the index revision ACL reconstruction were 1.7 to 3 times more likely to have subsequent surgery by their 6-year follow-up.

Secondary Covariates

Lower baseline outcome scores, higher body mass index, and being a smoker at the time of the revision surgery significantly increased the odds of reporting consistently poorer clinical outcomes at 6 years (Table 2).

DISCUSSION

Meniscal and chondral damage, before and at the time of revision ACL surgery, has a significant detrimental effect on patient-reported outcomes 6 years later. Meniscal pathology—previous (before revision ACL reconstruction) and current (at the time of revision ACL reconstruction)—and current articular cartilage pathology (in the MFC, LFC, LTP, trochlea, and patella) were significant drivers of poorer patient-reported outcomes (Marx, IKDC, KOOS, and WOMAC) as well as surgery outcomes at 6-year follow-up. This was a broader but different pattern than that seen at 2-year follow-up in this cohort.[10]

This longitudinal cohort study design allows us to analyze how various baseline factors affect outcomes over time. There are few comparative data from the literature, as only 5 previous studies with 159 patients have a minimum 5-year follow-up to revision ACL reconstruction,[4,7,8,11,12] so the most relevant comparison is with our

previously published 2-year results.[10] Meniscal and/or chondral damage did not predict Marx activity level at 2-year follow-up. At 6 years, Marx activity levels were significantly lower in patients who underwent repair or excision of the medial meniscus and in patients with grade 3 or 4 patellar chondrosis. Conversely, 6-year activity levels were higher in patients who underwent a lateral meniscal repair or excision. The latter was counterintuitive, as lateral meniscal excision might be expected to promote articular cartilage deterioration and decreased activity after 6 years. We are uncertain why the intuitively expected deterioration of Marx activity levels with lateral meniscal excision did not occur by 6 years and in fact predicted higher activity levels. Less surprising is the fact that repair of a lateral meniscal tear had reasonable results at 6 years. Planned follow-up at 10 years will investigate this relationship further.

Lateral meniscal injury before the index revision ACL reconstruction, but not previous medial meniscal injury, had been shown to affect 2-year outcomes (IKDC and all KOOS and WOMAC subscales).[10] New meniscal pathology found at the time of revision reconstruction was not a significant risk factor for KOOS, IKDC, or WOMAC scores at 2 years. However, at 6-year follow-up, medial and lateral meniscal pathology before the index revision ACL reconstruction negatively affected all KOOS subscale scores in this cohort. These findings are consistent with previous literature reporting that meniscal pathology negatively affects outcome scores in the revision ACL reconstruction setting.[2,4,15,17,18] Anand et al[2] reported on 136 patients with a mean 5-year follow-up. Patients with an intact medial meniscus had significantly higher KOOS QOL scores at follow-up as compared with patients with medial meniscal pathology. Return to sports was not affected by meniscal status. Webster et al[17] collected IKDC, KOOS QOL, Marx, and Single Assessment Numeric Evaluation (SANE) scores in 180 patients who underwent revision ACL with a mean follow-up of 4.6 years (range, 2-8 years). They found that patients with medial meniscal pathology at the time of revision surgery had significantly lower functional and QOL scores than patients without pathology. No difference was found in any outcome score between patients with and without lateral meniscal pathology.

In a separate study, Webster et al[18] investigated the outcomes of re-revisions in 128 patients aged <25 years. In this study, the mean follow-up was 4.5 years (range, 2-9 years). Twenty-seven percent (35/128) of the patients had a third ACL injury by 2 years. Of the group who had graft reruptures, 70% had medial meniscal pathology (ie, tear or previous repair/resection). The authors found a significant association between having medial meniscal pathology and sustaining a graft rerupture ($P = .02$). There was no association with graft rerupture and lateral meniscal pathology or chondral pathology. They concluded that medial meniscal pathology and returning to high-risk sports are factors associated with re-revisions.

Our study found that meniscal pathology and chondral pathology documented at the time of revision surgery are risk factors for incurring subsequent surgery within 6 years. Specifically, patients who had a medial meniscal repair were >2 times more likely to have subsequent surgery when compared with patients who had no medial meniscal pathology at the time of revision surgery. Similarly, patients who had grade 2 chondrosis in the MFC or grade 3-4 chondrosis in the MTP at the time of revision surgery were 1.7 to 3 times more likely to incur subsequent surgery by their 6-year follow-up. These results are consistent with our work at 2-year follow-up[20] and are in concordance with published results from primary as well as revision ACL reconstruction cohorts.[13,16] Sullivan et al[13] reported on the predictors of subsequent surgery after primary ACL reconstruction. This cohort consisted of 3276 patients (56.3% male) with a median age of 23 years and a 6-year follow-up rate of 91.5%. They found that having a medial meniscal repair at the time of index primary ACL surgery was an independent significant risk factor for incurring subsequent meniscus-related surgery within 6 years. Similarly, Vindfeld et al[16] investigated patient-related risks of inferior outcomes leading to revision surgery after ACL reconstruction. The study included 100 revision cases and 100 matched controls, with a median follow-up of 11 years. The authors demonstrated that failed meniscal repair was among the significant factors associated with primary ACL reconstruction failure and affected the risk of undergoing revision ACL surgery.

Chondral pathology has been found to negatively affect patient outcomes in the midterm follow-up revision setting.[2,4,17] Anand et al[2] reported significantly lower 5-year Marx activity, KOOS QOL, and IKDC scores for patients with initial grade 3 or 4 chondral damage at the time of revision surgery as compared with those with grade 0, 1, or 2 changes. Similarly, Webster et al[17] noted significantly reduced functional scores (IKDC, KOOS QOL, Marx, and SANE) and lower rates of return to sports after 5 years in patients with revision ACL who had grade 3 or 4 chondral damage noted at the time of their revision surgery.

Boyle et al[4] followed 43 patients with revision ACL over a mean follow-up of 9 years (range, 5-15 years) and found a statistically significant correlation between increasing age and worse functional outcome scores (Lysholm) in those who had grade 3 or 4 chondral damage. Specifically, patients who had grade 3 or 4 chondral damage showed a reduction of about 25 points in the Lysholm score for every 10-year increase in age.

In our previous 2-year analysis, having grade 3 or 4 articular cartilage chondrosis of the trochlea at the time of revision ACL reconstruction consistently resulted in significantly poorer outcomes across all measures (IKDC and KOOS and WOMAC subscales), except for activity level (which was not affected).[10] In the current 6-year study, chondral pathology continued to negatively affect 6-year outcome measures, with the addition of activity level (Table 1). This negative effect spanned all articular cartilage regions, except for MTP. Because overall activity levels continue to trend downward for this cohort, patients may be decreasing their activities to control their pain levels.

There are strengths and limitations to this study. Patients were not brought back to each clinic to have a physician's assessment of the knee performed, nor were

follow-up radiographs or magnetic resonance images taken as part of the study protocol. As such, we cannot verify the integrity of the ACL in those who did not undergo subsequent magnetic resonance imaging, physician, or surgical verification. Similarly, we can report only on the meniscal and chondral findings at the time of the revision ACL reconstruction and not at the time of 6-year follow-up. It is likely that the meniscal and/or chondral pathology worsened over the course of follow-up in a subset of these patients, and this study could not determine this progression. This study had some counterintuitive results that will warrant further investigation and corroboration in the future. Strengths include the prospective enrollment and size of the cohort, which is the largest ever followed at 6 years after revision reconstruction. The retained follow-up at 6 years strengthens our conclusions. The multiple sites and surgeons make the findings generalizable to the sports medicine surgeon and the patient undergoing revision ACL.

CONCLUSION

Meniscal pathology and chondral pathology in the knee at the time of revision ACL reconstruction have significant detrimental effects on patient-reported outcomes 6 years after surgery. The effect is more wide-ranging at 6 years after revision ACL surgery when compared with 2-year follow-up. Medial meniscal repair/excision and patellofemoral chondrosis predict a lower activity level at 6 years, although lateral meniscal repair/excision predicts a higher activity level at 6 years. Independent predictors of lower IKDC, KOOS, and WOMAC scores at 6-year follow-up include chondrosis and a history of medial meniscal repair before the revision ACL reconstruction. Longer-term follow-up of this cohort will further characterize the role of meniscal and articular cartilage pathology in predicting outcomes of this procedure.

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