Meniscal and Articular Cartilage Predictors of Clinical Outcome After Revision Anterior Cruciate Ligament Reconstruction

MARS Group

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Meniscal and Articular Cartilage Predictors of Clinical Outcome After Revision Anterior Cruciate Ligament Reconstruction

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Investigation performed at Washington University, St Louis, Missouri, USA

Background: Revision anterior cruciate ligament (ACL) reconstruction has been documented to have worse outcomes compared with primary ACL reconstructions.

Purpose/Hypothesis: The purpose of this study was to determine if the prevalence, location, and/or degree of meniscal and chondral damage noted at the time of revision ACL reconstruction predicts activity level, sports function, and osteoarthritis symptoms at 2-year follow-up. The hypothesis was that meniscal loss and high-grade chondral damage noted at the time of revision ACL reconstruction will result in lower activity levels, decreased sports participation, more pain, more stiffness, and more functional limitation at 2 years after revision surgery.

Study Design: Cohort study; Level of evidence, 2.

Methods: Between 2006 and 2011, a total of 1205 patients who underwent revision ACL reconstruction by 83 surgeons at 52 hospitals were accumulated for study of the relationship of meniscal and articular cartilage damage to outcome. Baseline demographic and intraoperative data, including the International Knee Documentation Committee (IKDC) subjective knee evaluation, Knee injury and Osteoarthritis Outcome Score (KOOS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and Marx activity score, were collected initially and at 2-year follow-up to test the hypothesis. Regression analysis was used to control for age, sex, body mass index, smoking status, activity level, baseline outcome scores, revision number, time since last ACL reconstruction, incidence of having a previous ACL reconstruction on the contralateral knee, previous and current meniscal and articular cartilage injury, graft choice, and surgeon years of experience to assess the meniscal and articular cartilage risk factors for clinical outcomes 2 years after revision ACL reconstruction.

Results: At 2-year follow-up, 82% (989/1205) of the patients returned their questionnaires. It was found that previous meniscal injury and current articular cartilage damage were associated with the poorest outcomes, with prior lateral meniscectomy and current grade 3 to 4 trochlear articular cartilage changes having the worst outcome scores. Activity levels at 2 years were not affected by meniscal or articular cartilage pathologic changes.

Conclusion: Prior lateral meniscectomy and current grade 3 to 4 changes of the trochlea were associated with worse outcomes in terms of decreased sports participation, more pain, more stiffness, and more functional limitation at 2 years after revision surgery, but they had no effect on activity levels.

Registration: NCT00625885

Keywords: anterior cruciate ligament; revision ACL reconstruction; meniscus; articular cartilage; chondrosis; predictors; outcomes

The outcome of revision anterior cruciate ligament (ACL) reconstruction has been reported in the literature to be inferior to that of primary ACL reconstructions,[1,9,12,18,30,36,37] although the reasons behind this are varied. The recurrent injury and instability cause more trauma to the joint, but it is unknown if specific joint injuries are associated with poorer results. The presence and severity of meniscal and/or chondral damage have the potential to influence these outcomes. Previous literature has reported both an increased risk of subsequent posttraumatic osteoarthritis[2,5,16,20,21,28,38] as well as poorer outcomes with the presence of these concomitant injuries at the time

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of primary ACL reconstruction.[‡] However, the effect of meniscal and chondral damage on *revision* ACL reconstruction outcomes has not been previously definitively determined with high-level evidence.[15,33]

Numerous publications on revision ACL reconstruction have reported a high incidence of meniscal and chondral lesions at the time of revision surgery, with ranges reported between 36% and 75% for meniscal injury and 24% to 67% for chondral lesions.[14,15,19,25,27,33,35] These were more frequently identified than in the typical primary ACL reconstruction setting.[34,37]

The Multicenter ACL Revision Study (MARS) Group (Brophy et al[4]) investigated the association between previous meniscal surgery and the presence of chondral lesions at the time of revision ACL reconstruction.[4] The group found that the articular cartilage condition noted at the time of revision surgery related to previous meniscal surgery, independent of the effect of patient's age.[4] In addition, previous partial meniscectomy was associated with a higher incidence of articular cartilage lesions, whereas previous meniscal repair was not. However, the Brophy et al[4] MARS study only looked at pathologic abnormalities at the time of revision surgery and did not investigate if meniscal and chondral damage predicted patient outcomes after the revision.

The goal of the present study was to determine if specific meniscal and/or chondral damage noted at the time of revision ACL reconstruction can be predictive of patient-reported activity level, sports function, and osteoarthritic symptoms at 2-year follow-up. It was hypothesized that the incidence of meniscus injury and high-grade articular cartilage damage portends a worse outcome as measured by patient-reported outcomes using the Knee injury and Osteoarthritis Outcome Score (KOOS), International Knee Documentation Committee (IKDC) subjective knee evaluation, Marx activity score, and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) 2 years after revision ACL reconstruction. If so, strategies could be developed by surgeons to improve these outcomes by modifying the management of meniscal and chondral injuries in the future.

METHODS

Study Design

The MARS Group was assembled with the aim of determining what affects outcome in an ACL revision setting and to identify potentially modifiable factors that could improve these outcomes.[22,23] This collaboration consists of a group of 83 sports medicine fellowship-trained surgeons at 52 sites. Surgeons are a mix of academic (n = 23; 44%) and private practitioners (n = 29; 56%). Surgeon inclusion criteria included maintenance of an active institutional review board (IRB) approval, completion of a training session that integrated articular cartilage and meniscus agreement studies, review of the study design and patient inclusion criteria, and a review of the surgeon questionnaire. Surgeons performed the ACL revision surgery according to their own practice preferences.

Study Population

After IRB approval from each institution, 1205 patients with documented ACL reconstruction failure who underwent revision ACL reconstruction surgery qualified for and agreed to be included in this study. This multicenter consortium began patient enrollment in 2006 and ended in 2011. Study inclusion criteria were all ACL-deficient candidates presenting to the clinic between the ages of 12 and 65 years who were scheduled to have a revision ACL reconstruction by a participating (MARS Study) surgeon. All participants were required to have undergone a prior ACL reconstruction and had failure of their ACL reconstruction, as defined by the surgeon by magnetic resonance imaging (MRI), knee laxity (KT-1000 side-to-side difference of >5 mm), a positive pivot-shift or Lachman test, functional instability, and/or arthroscopic confirmation. Patients with ACL deficiency and concomitant injuries to the medial collateral ligament, lateral collateral ligament, posterior cruciate ligament, or posterolateral complex were included but subsequently excluded from the analysis for this study. Exclusion criteria were patients presenting to the clinic with prior infection, arthrofibrosis, or complex regional pain syndrome. Patients unwilling or unable to complete their repeat questionnaire 2 years after their initial visit were also excluded.

Data Sources and Measurement

After informed consent was obtained, the patient filled out a 13-page questionnaire that included questions regarding demographics, sports participation, injury mechanism, comorbidities, and knee injury history. Within this questionnaire, each participant also completed a series of validated general and knee-specific outcome instruments, including the KOOS, IKDC, and Marx activity rating scale. Contained within the KOOS was the WOMAC. Surgeons filled out a questionnaire that included the impression of the cause of the previous ACL reconstruction failure, physical examination findings, surgical technique used, and the intra-articular findings and surgical management of meniscal and chondral damage. Chondral damage was described using the modified Outerbridge system,[7] with *worse grade* defined in this study as being a grade 2 or higher. Meniscus injuries were classified by location and partial versus complete tears, while treatment was recorded as no treatment, repair, resection, or other (ie, abrade + trephine, meniscal transplant, etc). For the purposes of this study, *previous* or *prior* refers to meniscal or articular cartilage injuries documented before the time of the 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 ACL revision surgery.

[‡]References 5, 6, 13, 17, 24, 29, 31, 32, 38.

Patient Follow-up

Two-year patient follow-up was completed by mail with readministration of the same questionnaire as the one they completed at baseline. Patients were also contacted by phone to determine whether any subsequent surgery had occurred to either knee since their initial revision ACL reconstruction. If so, operative reports were obtained, whenever possible, to verify pathologic condition and treatment.

Statistical Analysis

To describe our patient sample, we summarized continuous variables as percentiles (ie, 25th, 50th, and 75th) and categorical variables with frequencies and percentages. Multivariable regression analyses were constructed to examine which baseline risk factors were independently associated with each outcome variable. The primary outcome variables of interest were the 2-year outcome scores of the KOOS, IKDC, WOMAC, and Marx activity level. These primary outcome variables were all treated as continuous. The covariates that we controlled for were age, sex, body mass index, smoking status, baseline activity level, baseline outcome scores, revision number, time since last ACL reconstruction, incidence of having a previous ACL reconstruction on the contralateral knee, previous and current meniscal and articular cartilage pathology, graft choice, and surgeon years of experience to assess the meniscal and articular cartilage risk factors for clinical outcomes 2 years after revision ACL reconstruction. Due to the low frequency counts of grade 4 articular cartilage lesions in the medial tibial plateau, lateral tibial plateau, patella, and trochlear compartments, these grades were combined with their respective grade 3 compartment lesion to form a combined "grade 3 to 4" variable for each of these 4 compartments for analysis purposes. Statistical analysis was performed using open-source R statistical software (version 3.0.3; www.r-project.org).

RESULTS

A total of 1205 patients met the inclusion criteria and were enrolled in the study. Table 1 summarizes the baseline characteristics of the cohort, which consisted of 697 (58%) males and a median cohort age of 26 years (range, 12-63 years). The median time since their last ACL reconstruction was 3.4 years. The surgeons noted previous injury and treatment of the medial meniscus (38%), lateral meniscus (20%), and articular surfaces (12%) at the time of revision surgery as ascertained by direct observation and history and operative notes. The surgeons also reported current injury in the medial meniscus (45%), lateral meniscus (37%), medial femoral condyle (43%), lateral femoral condyle (29%), medial tibial plateau (11%), lateral tibial plateau (17%), patella (30%), and trochlea (20%). Patients in the cohort were noted to have either current or previous meniscus injury and/or grade 2 or greater articular cartilage lesions 91% of the time (Table 2). It was found that 59% of patients had both meniscus and articular cartilage damage. Only 9% (114/1205) of the patients had neither meniscus nor articular cartilage damage at the time of revision ACL reconstruction.

At 2 years, follow-up was obtained on 82% (989/1205). Previous medial and lateral meniscal injury and treatment, as well as current articular cartilage damage (all surfaces except for the lateral femoral condyle), were significantly associated with poorer outcomes at 2 years after revision ACL reconstruction (Table 3). The most consistent cartilage-related factors driving outcome in revision patients were previous lateral meniscus injury and current trochlea articular cartilage damage. Having a previous partial meniscectomy of the lateral meniscus resulted in significantly poorer outcomes on the IKDC (odds ratio [OR], 1.69; 95% CI, 1.16-2.44; $P = .005$), all KOOS subscales (OR range, 1.52-2.08; 95% CI, 1.04-3.03; $P < .03$), and all WOMAC subscales (OR, 1.56; 95% CI, 1.06-2.27; $P < .03$). Having a current grade 3 to 4 articular cartilage chondrosis of the trochlea resulted in significantly poorer outcomes in the IKDC (OR, 1.89; 95% CI, 1.25-2.86; $P = .003$), 4 of 5 KOOS subscales (OR range, 1.64-2.70; 95% CI, 1.09-4.17; $P < .02$), and 2 of 3 WOMAC subscales (OR range, 1.61-2.70; 95% CI, 1.04-4.17; $P \leq .03$).

Lower baseline outcome scores, lower baseline activity level, and shorter time interval between the patient's last ACL reconstruction and the ACL revision surgery also significantly increased the odds of reporting poorer clinical outcomes at 2 years (Table 4).

Interestingly, the degree of previous and current meniscal and articular cartilage damage associated with ACL revision surgery and number of revisions did not predict Marx activity levels at 2 years (Table 3). However, a variety of other factors were found to significantly influence decreased 2-year activity level: lower baseline activity level, older age, female sex, being a current smoker at baseline, and having a previous ACL reconstruction on the contralateral knee (Table 4).

DISCUSSION

The current study supports our hypothesis that patient-reported outcomes at 2 years are affected by both articular cartilage and meniscus damage. The most significant effect on outcomes at 2 years was when there was a previous lateral meniscectomy or high-grade trochlear groove articular cartilage lesion. Both produced consistently worse outcomes for the IKDC, KOOS, and WOMAC subscales at 2-year follow-up, compared with patients without this pathologic condition. Subjects with previous partial lateral meniscectomies were 1.5 to 2.1 times more likely to have a significantly poorer clinical outcome at 2 years after their revision surgery compared with those without previous partial lateral meniscectomy, whereas patients who had high-grade trochlear groove articular cartilage damage were 1.6 to 2.7 times more likely to report significantly poorer 2-year outcomes.

Previous studies have found, similar to the current study, a significant amount of articular cartilage and/or meniscus damage at the time of revision ACL reconstruction.[8,11,33] Garafolo et al[11] noted 32% of patients had grade 2 or worse articular cartilage changes and 39% had

TABLE 1
Baseline Characteristics of Overall Cohort and the Patients Lost to Follow-up[a]

	Overall Cohort (N = 1205)	Lost to Follow-up at 2 y (n = 219)
Patient demographics		
Sex		
Male	697 (58)	152 (69)
Female	508 (42)	67 (31)
Age, y	26 (20, 34)	25 (20, 33)
Body mass index	25.1 (22.6, 28.5)	26.3 (23.1, 30.5)
Baseline activity level (range, 0-16)	11 (4, 16)	9 (3, 14)
Smoking status		
Never	923 (77)	156 (71)
Quit	154 (13)	32 (15)
Current	109 (9)	25 (11)
Previous surgical information		
Time since last ACL reconstruction, y	3.4 (1.4, 8.3)	2.9 (1.4, 6.3)
Revision number		
1	1055 (88)	184 (84)
2	125 (10)	29 (13)
≥3	25 (2)	6 (3)
Previous medial meniscus surgery		
No	743 (62)	125 (57)
Yes, repair healed/stable	31 (3)	5 (2)
Yes, repair not healed/unstable	68 (6)	19 (9)
Yes, excision	362 (30)	69 (32)
Previous lateral meniscus surgery		
No	958 (80)	156 (71)
Yes, repair healed/stable	28 (2)	7 (3)
Yes, repair not healed/unstable	23 (2)	6 (3)
Yes, excision	195 (16)	49 (22)
Previous articular cartilage surgeries		
No	1059 (88)	186 (85)
Yes	146 (12)	33 (15)
Previous ACL reconstruction on contralateral knee		
No	1083 (90)	203 (93)
Yes	122 (10)	16 (7)
Current surgical information		
Current graft type		
Autograft—BTB	336 (28)	67 (31)
Autograft—soft tissue	244 (20)	37 (17)
Allograft—BTB	286 (24)	49 (22)
Allograft—soft tissue	298 (25)	57 (26)
Other (ie, both autograft + allograft)	39 (3)	8 (4)
Surgeon experience, y	13 (8, 18)	13 (8, 17)
Current meniscal status		
Medial		
Normal	663 (55)	121 (55)
No treatment for tear	25 (2)	2 (1)
Repair	163 (14)	36 (16)
Excision	330 (27)	49 (22)
Other	24 (2)	10 (5)
Lateral		
Normal	765 (63)	134 (61)
No treatment for tear	57 (5)	9 (4)
Repair	62 (5)	13 (6)
Excision	313 (26)	58 (27)
Other	8 (1)	4 (2)
Current articular cartilage status		
Medial femoral condyle		
Normal/grade 1	682 (57)	118 (54)
Grade 2	288 (24)	56 (26)
Grade 3	164 (14)	34 (16)
Grade 4	71 (6)	10 (5)

(continued)

TABLE 1
(continued)

	Overall Cohort (N = 1205)	Lost to Follow-up at 2 y (n = 219)
Lateral femoral condyle		
Normal/grade 1	858 (71)	149 (68)
Grade 2	187 (16)	40 (18)
Grade 3	96 (8)	18 (8)
Grade 4	64 (5)	11 (5)
Medial tibial plateau		
Normal/grade 1	1075 (89)	188 (86)
Grade 2	93 (8)	24 (11)
Grade 3	21 (2)	4 (2)
Grade 4	16 (1)	2 (1)
Lateral tibial plateau		
Normal/grade 1	997 (83)	174 (80)
Grade 2	156 (13)	33 (15)
Grade 3	45 (4)	9 (4)
Grade 4	7 (<1)	2 (1)
Patella		
Normal/grade 1	843 (70)	150 (68)
Grade 2	234 (19)	45 (21)
Grade 3	119 (10)	21 (10)
Grade 4	9 (1)	2 (1)
Trochlea		
Normal/grade 1	959 (80)	180 (82)
Grade 2	101 (8)	11 (5)
Grade 3	90 (7)	12 (6)
Grade 4	55 (5)	15 (7)

[a]Data are reported as n (%) of nonmissing values or as median (lower quartile, upper quartile) for continuous variables. BTB, bone-tendon-bone.

TABLE 2
Overall Meniscal and Articular Cartilage (AC) Integrity[a]

	AC Status		
Meniscal Status	Normal	Abnormal	Total
Normal	114 (9)	146 (12)	260 (22)
Abnormal	229 (19)	716 (59)	945 (78)
Total	343 (28)	862 (72)	1205 (100)

[a]Data are reported as n (%). Chi-square statistic = 38.52; $P < .001$.

meniscus tears at the time of revision ACL reconstruction. Diamantopoulos et al,[8] in a study involving 107 revision patients, noted that 61.7% of patients had grade 2 or worse articular cartilage changes at the time of revision. In 2012, Wright et al[37] performed a mixed-effect model meta-analysis of the results of revision ACL reconstruction. It was noted that patients within studies where meniscus and articular cartilage damage was reported, 42% had undergone treatment of a meniscus tear at the time of their primary ACL reconstruction, and 38% underwent meniscus treatment at the time of revision ACL reconstruction.[37] Sixty-four percent of the time in patients undergoing revision ACL reconstruction, meniscal treatment involved the medial meniscus. Grade 1 articular cartilage lesions were noted in 34.1% of patients undergoing revision ACL reconstruction, grade 2 in 44.8%, grade 3 in 17.6%, and grade 4 in 3.4%. The anatomic location of the articular cartilage lesion included medial compartment (29.1%), lateral compartment (37.5%), and patellofemoral (33.3%). Fox et al,[10] in their series of patellar tendon allograft for revision ACL reconstructions, noted 70% of patients had articular cartilage damage in at least 1 of the 3 compartments. In the present study, which employed an equal number of autografts and allografts, 78% of patients exhibited abnormal meniscal findings at the time of revision, while 72% exhibited chondral damage in at least 1 of the 3 compartments. Remarkably, only 9% of the cohort had normal meniscal and chondral surfaces at the time of revision.

The early portion of the MARS cohort using similar prospective collection methods for primary and revision ACL reconstructions demonstrated that revision ACL reconstructions had a significantly higher incidence of articular cartilage damage compared with primary ACL reconstructions.[3] There was an increased risk of grade 3 and 4 articular cartilage changes in the lateral compartment (OR, 1.73) and trochlear groove–patellofemoral compartment (OR, 1.70) in the revision setting compared with primary ACL reconstructions.

Previous studies have suggested that meniscal and articular cartilage injuries may be proportional to the delay between ACL graft retear and revision ACL

TABLE 3
Significant Odds Ratios for Individual Meniscus and Articular Cartilage Variables

				KOOS						WOMAC		
Structure	Comparison	Worse Outcome	Marx	Symptoms	Pain	ADL	Sports/Rec	QoL	IKDC	Stiffness	Pain	ADL
Meniscus (previous injury)												
Medial	No tear vs excised	Excised		1.41 (1.05-1.89) P = .022	1.52 (1.12-2.04) P = .006					1.49 (1.10-2.04) P = .010		
	No tear vs unstable, not healed repair	***No tear***			1.94 (1.11-3.40) P = .021							
Lateral	No tear vs excised	Excised		1.79 (1.23-2.56) P = .002	1.54 (1.08-2.22) P = .019	1.56 (1.06-2.27) P = .024	1.52 (1.04-2.17) P = .029	2.08 (1.45-3.03) P < .001	1.69 (1.16-2.44) P = .005	1.56 (1.08-2.27) P = .021	1.56 (1.06-2.27) P = .022	1.56 (1.06-2.27) P = .024
	No tear vs unstable, not healed repair	Unstable, not healed repair								2.70 (1.08-6.67) P = .035	2.78 (1.08-7.14) P = .034	
Meniscus (current)												
Medial												
Lateral	No tear vs no Tx for tear	***No tear***				2.49 (1.31-4.74) P = .008					2.26 (1.17-4.38) P = .123, NS[b]	2.49 (1.31-4.74) P = .008
Articular cartilage (previous)	Yes vs no											
Articular cartilage (current)												
MFC	Normal/ G1 vs G4	G4						2.04 (1.18-3.45) P = .011				
	Normal/ G1 vs G3	***Normal/G1***			1.56 (1.03-2.36) P = .035							
LFC	Normal/ G1 vs G2	***Normal/G1***				1.63 (1.11-2.39) P = .013			1.52 (1.06-2.18) P = .023			1.63 (1.11-2.39) P = .013
MTP	Normal/ G1 vs G3/4	G3/4					3.23 (1.54-6.67) P = .002		2.22 (1.03-4.76) P = .042			
LTP	Normal/ G1 vs G2	G2					1.47 (1.01-2.17) P = .046					
Patella	Normal/ G1 vs G3/4	G3/4									1.75 (1.11-2.78) P = .017	
Trochlea	Normal/ G1 vs G3/4	G3/4		1.64 (1.09-2.50) P = .019	1.69 (1.11-2.56) P = .014	2.70 (1.75-4.17) P < .001	1.92 (1.25-2.94) P = .003		1.89 (1.25-2.86) P = .003	1.61 (1.04-2.50) P = .030		2.70 (1.75-4.17) P < .001

[a]Data in parentheses indicate 95% CI. An empty cell indicates that the particular knee rating at the top of the column was not significantly affected by meniscal and articular surface conditions. Bolded and italicized text indicates result was counterintuitive to initial hypothesis. ADL, activities of daily living; G, grade; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; LFC, lateral femoral condyle; LTP, lateral tibial plateau; MFC, medial femoral condyle; MTP, medial tibial plateau; NS, nonsignificant; QoL, quality of life, Sports/Rec, sports and recreation; Tx, treatment; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

[b]Nonsignificant P value, even though the odds ratio does not cross 1.00.

reconstruction.[4,27] Ohly et al[27] noted that in the early group who had revision ACL reconstruction within 6 months of graft failure, 76% had normal articular cartilage compared with 46.8% in the delayed revision ACL reconstruction group. In the current study, it is difficult to ascertain the time of failure. Many patients have an insidious failure of their graft and cannot identify the exact moment that ACL graft failure occurred. Thus, while it seems intuitive that instability episodes and prolonged delay before revision ACL reconstruction may increase the risk of meniscus and articular cartilage injury, this was unable to be accurately assessed in the present study.

Noyes and Barber-Westin,[26] in a series of revision ACL reconstructions performed with quadriceps tendon–patellar bone autograft, found that 93% had pathologic conditions in addition to the ACL graft rupture, including 56% that had articular cartilage lesions that resulted in decreased ability to return to sports activity. In addition, they concluded that the patients with varus malalignment should undergo high tibial osteotomy based on improved results in their cohort.

Articular cartilage damage has been previously noted in revision ACL reconstructions and has been presumed to be associated with worse patient-reported outcomes.[18] In results from the Swedish National Register, Kvist et al[18] noted that all KOOS subscales were lower in revision patients versus primary ACL reconstructions. The present study also found worse patient-reported outcomes in revision ACL reconstruction compared with results usually seen in primary ACL reconstruction patients.

TABLE 4
Significant Odds Ratios for Secondary Variables in Model

				KOOS						WOMAC		
	Comparison	Worse Outcome	Marx	Symptoms	Pain	ADL	Sports/Rec	QoL	IKDC	Stiffness	Pain	ADL
Baseline outcome score		Lower T_0 score	5.79 (4.01-8.35) $P < .0001$	3.86 (3.09-4.82) $P < .0001$	3.81 (3.05-4.76) $P < .0001$	5.09 (3.81-6.81) $P < .0001$	2.97 (2.42-3.63) $P < .0001$	2.15 (1.78-2.59) $P < .0001$	3.06 (2.50-3.74) $P < .0001$	4.34 (3.39-5.56) $P < .0001$	4.02 (3.03-5.34) $P < .0001$	5.09 (3.81-6.81) $P < .0001$
Patient demographics												
Age		Older age	2.17 (1.41-3.23) $P < .0001$									
Sex	Male vs female	Female	1.79 (1.39-2.33) $P < .0001$						1.64 (1.25-2.13) $P = .0002$			
Smoking status	Never vs current	Current smoker	1.72 (1.10-2.70) $P = .018$					1.75 (1.14-2.70) $P = .012$				
Baseline activity level		Lower Marx score	5.79 (4.01-8.35) $P < .0001$			1.63 (1.13-2.35) $P = .007$	1.81 (1.26-2.59) $P = .001$	2.00 (1.40-2.85) $P = .0001$	2.21 (1.55-3.15) $P < .0001$			1.63 (1.13-2.35) $P = .007$
Previous surgical information												
Revision number		More revisions						1.69 (1.09-2.63) $P = .019$				
Time since last ACLR, y		Less time since last ACLR		1.67 (1.14-2.45) $P = .0001$	1.93 (1.32-2.83) $P = .0001$	1.87 (1.25-2.78) $P < .0001$	2.03 (1.38-2.99) $P < .0001$	1.84 (1.25-2.72) $P = .0003$	1.92 (1.30-2.82) $P = .010$	1.77 (1.19-2.63) $P = .0003$	1.72 (1.14-2.58) $P = .001$	1.87 (1.25-2.78) $P < .0001$
Previous ACLR on contralateral knee	No vs yes	Yes	1.49 (1.01-2.22) $P = .047$					1.49 (1.02-2.17) $P = .037$				

Data in parentheses indicate 95% CI. An empty cell indicates that the particular 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; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; QoL, quality of life, Sports/Rec, sports and recreation; T_0, baseline time zero; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

In a previous study by the MARS Group,[4] an association was demonstrated between previous meniscectomy during prior ACL reconstruction and articular cartilage chondrosis at the time of revision ACL reconstruction. In that study, previous partial meniscectomy at the time of ACL reconstruction produced significantly more articular cartilage pathologic changes compared with when a normal meniscus was found or a meniscus repair was performed at the time of ACL reconstruction. The latter work demonstrates the importance of preserving meniscal tissue whenever possible and emphasizes the need for new and improved meniscus salvage techniques. We believe this is related to the observation in the current study that previous lateral meniscectomy is a stronger predictor for worse outcome than a meniscal tear treated at the time of revision ACL reconstruction. The patient has had a longer exposure to the deleterious effects of meniscus loss.

The reason for the large effect that trochlear groove chondrosis has on outcome compared with similar grades of chondrosis involving the tibial plateau or femoral condyle is uncertain. It may be that patellofemoral articular cartilage damage has a larger effect on activity performance than previous studies have been capable of demonstrating or measuring. The MARS Group will continue to monitor these findings in subsequent follow-up studies.

The use of validated patient outcomes in the current multicenter, large, carefully documented, prospective case study provides reliable information about what results can be expected from revision ACL reconstruction that was not previously available. These data have great value for the practicing orthopaedic surgeon, providing more accurate patient counseling with regard to their predicted outcome after revision ACL reconstruction.

Strengths of this study include the large cohort and the ability to do multivariable analysis given the number of patients with high follow-up at 2 years. The consistent use of validated patient-reported outcomes remains a strength of the cohort. In addition, the geographic variability along with the variability of academic and private practice surgeons makes the results generalizable. Weaknesses of the study include short 2-year follow-up and the lack of onsite follow-up and follow-up imaging.

CONCLUSION

Revision ACL reconstruction patients with prior partial lateral meniscectomy and revision ACL reconstruction patients with current grade 3 to 4 articular cartilage damage to the trochlear groove scored significantly lower at 2 years on the IKDC, KOOS, and WOMAC questionnaires than did revision ACL reconstruction patients with other injuries. The results of this study support the aggressive preservation of the lateral meniscus at the time of primary ACL reconstruction and the use of preventive and restorative techniques to preserve the integrity of the trochlear

articular cartilage at the time of ACL reconstruction and revision ACL reconstruction. Improved management of these findings both before and at the time of revision ACL reconstruction may be surgeon-modifiable factors that would improve patient outcomes.

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