Primary Versus Revision Anterior Cruciate Ligament Reconstruction: Patient Demographics, Radiographic Findings, and Associated Lesions

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Purpose: The purpose of this study was to evaluate the differences in intra-articular pathology, demographic characteristics, and radiographic characteristics of the knee associated with primary anterior cruciate ligament reconstruction (ACLR) versus revision ACLR at the time of initial presentation with either a native anterior cruciate ligament tear or an anterior cruciate ligament graft tear. Secondarily, we aimed to investigate risk factors for concomitant medial and lateral meniscal tears and cartilage injuries at the time of ACLR. **Methods:** This was a retrospective review of patients who underwent primary or revision ACLR by a single surgeon. The exclusion criteria were as follows: skeletally immature patients; patients with an intra-articular fracture; patients with an ipsilateral knee infection; or patients who underwent an osteotomy, cartilage restoration procedure, or meniscal transplantation either previously or concomitantly with the ACLR. Detailed patient demographic data, radiographic long-standing alignment, tibial slope, and intraoperative findings including articular cartilage injury grade and meniscus integrity were documented at surgery. **Results:** There were 487 patients included in this study (363 with primary ACLR and 124 with revision ACLR). There were no significant differences in age ($P = .119$), sex ($P = .917$), body mass index ($P = .468$), allograft versus autograft reconstruction ($P = .916$), or prevalence of meniscal tears ($P = .142$) between the primary and revision groups. Patients who underwent revision ACLR had a significantly increased medial tibial slope ($P = .048$) and a higher prevalence of chondral defects on both the medial ($P < .001$) and lateral ($P = .003$) femoral condyles when compared with primary ACLR patients. Logistic regression showed that a decreased tibial slope was correlated with femoral medial-sided chondral injuries and that varus or valgus coronal-plane malalignment was correlated with lateral meniscal tears in both groups. **Conclusions:** The findings of this study show that patients undergoing a revision ACLR have significantly more chondral lesions, as well as higher-grade chondral lesions, at the time of presentation. Furthermore, coronal malalignment and a decreased tibial slope may contribute to injury patterns of the lateral meniscus and medial compartment cartilage, respectively. **Level of Evidence:** Level III, retrospective case-control study.

Patterns of articular and meniscal pathology associated with primary anterior cruciate ligament reconstruction (ACLR) have been previously reported.[1-9] Prior literature has shown that 30% to 60% of primary anterior cruciate ligament (ACL) tears are associated with meniscal or chondral injury and that lateral meniscal tears are more common than medial tears.[9-12] Further studies have shown male patients to be at an increased risk of injury to both the meniscal and cartilage structures, but neither age nor sports participation level has been correlated with specific injury patterns.[13,14] Despite these previous studies, there have been limited data presented in the recent literature comparing injury patterns seen at the time of tears to the native ACL versus those found in patients presenting with recurrent instability and ACL graft

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tears. Furthermore, there is a paucity of literature discussing certain patient or demographic characteristics as risk factors for injury in revision ACLR patients in comparison with primary ACLR patients.[1,13,15-17]

With approximately 200,000 ACL tears occurring in the United States annually,[15] injuries to the meniscal and chondral structures seen at the time of ACLR are common.[18-20] Studies have shown that intra-articular pathologies noted at the time of primary or revision ACLR have led to inferior patient-reported outcomes compared with patients with intact menisci and cartilage surfaces.[13,18,19,21-24] A recent study of 4,691 patients identified through the Norwegian Knee Ligament Registry showed lower postoperative patient-reported outcome scores in patients with ACLR and associated medial or lateral meniscal repairs when compared with those with a meniscectomy at a minimum 2-year follow-up, indicating that the results of meniscectomies are not apparent until midterm follow-up.[25] Wu et al.[26] reported on 63 patients at approximately 10 years after ACLR. Subjects who had undergone any degree of meniscal resection had more subjective complaints than those who had intact menisci at the conclusion of ACLR. Furthermore, other studies have shown that high-grade chondral lesions similarly lead to decreased patient-reported outcomes.[18] Understanding patient factors associated with these injury patterns can also assist surgeons in counseling patients on possible future expectations and improve intraoperative diligence in examining for certain patterns of injury.

Although these studies do provide adequate groundwork for further studies, their utility is limited because of evaluation using binary outcomes (tear vs no tear or cartilage lesion vs intact cartilage) rather than specific descriptions of severity, location, or treatment intervention.[27] Furthermore, these studies have not fully evaluated other potentially important patient factors such as demographic characteristics, coronal-plane alignment, sagittal-plane tibial slope, or concomitant ligamentous injury. These demographic and radiographic descriptors are of importance because prior studies have shown improved patient-reported outcomes in primary versus revision ACLR and such factors may play a role in these differences.[16,18,27] Understanding the effect of these patient factors is crucial for prognosis. Furthermore, addressing factors that increase the risk of failure at primary ACLR may potentially increase the survival of the reconstruction.

The purpose of this study was to evaluate the differences in intra-articular pathology, demographic characteristics, and radiographic characteristics of the knee associated with primary ACLR versus revision ACLR at the time of initial presentation with either a native ACL tear or an ACL graft tear. Secondarily, we aimed to investigate risk factors for concomitant medial and lateral meniscal tears and cartilage injuries at the time of ACLR. We hypothesized that there would be an increased prevalence and severity of concurrent meniscal and articular cartilage injuries with revision ACLR when compared with primary ACLR. Furthermore, we hypothesized that these injury patterns would be correlated with standing limb alignment, tibial slope, and other patient demographic characteristics such as age, sex, and body mass index (BMI).

Methods

Patient Selection

This study was approved by our institutional review board. Patients who underwent primary or revision ACLR by a single surgeon (R.F.L.) from May 2010 to January 2016 were eligible for inclusion. The exclusion criteria were skeletally immature patients or patients who underwent an alignment-correction procedure, cartilage repair or transplant procedure, or meniscal transplantation either previously or concomitantly with ACLR. Other exclusion factors included an intra-articular fracture or history of an ipsilateral knee infection. Patients were evaluated using prospectively collected data that were stored in an outcomes registry and retrospectively analyzed.

Patient Details

Demographic and patient characteristic data included age, sex, BMI, prior surgical procedures, treatment history, additional pathologies, adjuvant treatments, and operative complications. The number of previous ACLR surgical procedures, location of the ACL tear at the time of surgery, and graft choice for both primary and revision ACLR were also recorded. The type of injury sustained (high or low energy) was recorded in addition to the type of activity at the time of injury (sport or non-sport).

Evaluation of Concomitant Injuries

For each patient, detailed descriptions of operative data and intraoperative findings were documented at the time of surgery. Meniscus integrity was recorded, and if a tear was present, the specific zone[19] and morphologic characteristics were noted. Articular cartilage surface pathology was recorded in each patient. Each compartment of the knee (medial femoral condyle, lateral femoral condyle, medial tibial plateau, lateral tibial plateau, patella, and trochlea) was examined. If pathology was noted, the location, size, and Outerbridge grade[28] were documented.

Radiographic Measurements

Radiographic variables considered in this study were coronal-plane alignment on long-standing radiographs and sagittal tibial slope on lateral

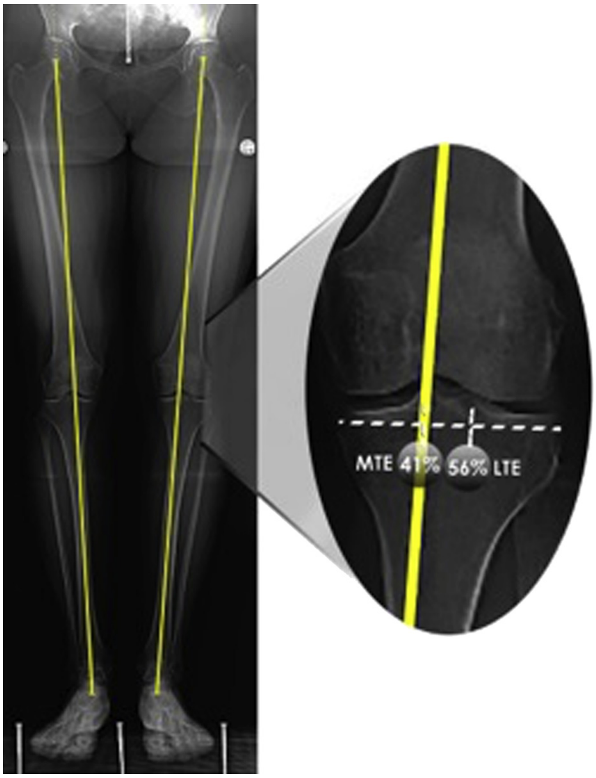

Fig 1. Anteroposterior standing radiograph of bilateral knees showing the technique for measurement of coronal-plane alignment. The medial tibial eminence (MTE) is located at 41% of the medial-to-lateral distance on the proximal tibia, whereas the lateral tibial eminence (LTE) is seen at an average of 56% of this distance. Measurements falling medial to these marks correspond to varus malalignment, and those falling lateral to these marks correspond to valgus malalignment.

radiographs. Radiographic long-standing alignment and coronal-plane alignment measurements were performed on all available radiographs based on previously described techniques[29-31] (Fig 1). Likewise, tibial slope was measured for all suitable radiographs based on previously described techniques[29,32,33] (Fig 2).

Statistical Analysis

Inter-rater and intrarater agreement was assessed for radiographic measurements by 3 raters (J.J.M., C.S.D., J.C.) by use of a 2-way random-effects model to calculate the intraclass correlation coefficient (ICC). The ICC values were interpreted as follows: less than 0.40, poor agreement; 0.4 to less than 0.75, fair to good agreement; and 0.75 or greater, excellent agreement.[34] All continuous demographic and radiographic variables were reasonably normally distributed. To compare primary versus revision cases, we used Welch independent *t* tests, Mann-Whitney *U* tests, Fisher exact tests, and χ^2 tests for continuous, ordinal, binary, and categorical covariates, respectively.

The prevalence of lateral and medial meniscal tears within the study groups enabled multiple logistic regression analysis to assess potential risk factors for meniscal tears; however, a similar analysis was not possible for cartilage lesions because of limited data points. To avoid model overfitting, we followed the rule of thumb that no more than 1 model parameter should be fit for every 15 cases (defects or tears). Independent variables were chosen a priori based on clinical rationale and included revision or primary reconstruction, sex, age, BMI, tibial slope, and coronal-plane alignment. The relations between the probability of a meniscal tear and each of the continuous predictors was not assumed to be linear. Thus, restricted cubic splines with 3 knots were used to model these independent relations flexibly. Statistical significance was determined using model likelihood ratio tests. Independent (adjusted) relations for each variable were presented as curves with 95% confidence regions that estimated the probability of medial and lateral meniscal tears assuming all other covariates were held constant. Overall predictive power for the models was assessed by reporting the area under the receiver operating characteristic curve (AUROC). All graphs and analyses were completed with the R statistical package (R Development Core Team, Vienna, Austria; with packages *rms* and *psy*).[35]

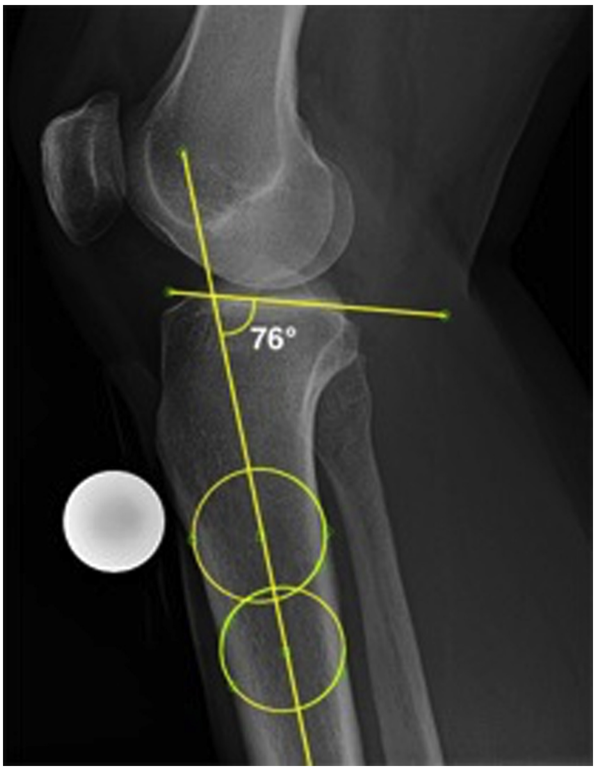

Fig 2. Lateral view of a left knee showing the technique for sagittal-plane tibial slope measurement. The angle measures 76°, constituting a posterior slope of 14°.

Results

Patient Demographic Characteristics

There were 487 total patients after application of our inclusion and exclusion criteria. Of the 487 patients, 363 (170 female and 193 male patients; mean age, 34.3 years [standard deviation, 13.9 years]) underwent primary ACLR and 124 (59 female and 65 male patients; mean age, 32.3 years [standard deviation, 12.1 years]) underwent revision ACLR. All bone-patellar tendon-bone reconstruction grafts were fixed with metal screws, and all hamstring reconstruction grafts were fixed with buttons on the femoral side and bioabsorbable screws on the tibial side. There was no overlap between the groups, and at the time of evaluation, patients in the primary group had not undergone failure or progression to revision ACLR. There were no significant differences in age ($P = .119$), sex ($P = .917$), BMI ($P = .468$), choice of allograft versus autograft reconstruction ($P = .916$), or ACL tear location ($P = .118$) between the primary and revision groups. A detailed description of patient demographic data and injury characteristics can be found in Table 1.

Table 1. Patient Demographic Characteristics and Surgical History Summarized for Primary and Revision Groups

	Primary (n = 363)	Revision (n = 124)	*P* Value (Test)
Patient demographic characteristics			
Sex			.917 (FET)
Male	193 (53)	65 (52)	
Female	170 (47)	59 (48)	
Age, yr	31 (23, 45)	30 (23, 41)	.119 (*t*)
BMI	23.7 (21.8, 26.6)	24.3 (22.2, 25.8)	.468 (*t*)
Knee			
Left	185 (51)	66 (53)	
Right	178 (49)	58 (47)	
Surgical history			
Previous surgery*			<.001† (FET)
No	334 (92)	91 (73)	
Yes	29 (8)	33 (27)	
Previous ACL reconstructions			NA
0	363 (100)	NA	
1	NA	82 (66)	
2	NA	37 (30)	
≥3	NA	5 (4)	
Injury characteristics			
Energy			.013† (FET)
Low	307 (85)	116 (94)	
High	56 (15)	8 (6)	
Activity			.002† (FET)
Sports related	211 (58)	52 (42)	
Non−sports related	152 (42)	72 (58)	
Current surgical information			
Graft type			.916 (FET)
Autograft	201 (55)	69 (56)	
Allograft	155 (43)	55 (44)	

NOTE. Data are presented as number (percent) or median (first quartile, third quartile).

ACL, anterior cruciate ligament; BMI, body mass index; FET, Fisher exact test; NA, not applicable; *t*, Welch independent *t* test.

*Previous surgery refers to prior non-ACL reconstruction on ipsilateral knee.

†Statistically significant.

Chondral Pathology

Most patients in both groups (66%) had either normal (grade 0) or nearly normal (grade 1) cartilage surfaces based on the Outerbridge classification.[28] Patients who underwent a revision ACLR had a significantly higher prevalence of chondral defects, as well as higher-grade chondral defects (grade 3 or 4), on the medial femoral condyle ($P < .001$) and lateral femoral condyle ($P = .003$) than those in the primary ACLR group. A detailed description and analysis of chondral defects by group and lesion location can be found in Table 2.

Concomitant Ligament Pathology

The overall prevalence of concomitant ligament pathology was 40%. In the primary ACLR group, 8% of patients had posterior cruciate ligament (PCL) tears, 24% had medial collateral ligament (MCL) tears, 23% had fibular collateral ligament (FCL) tears, and 2% had posterolateral corner (PLC) injuries. In the revision ACLR group, 4% had PCL tears, 8% had MCL tears, 17% had FCL tears, and 3% had PLC injuries. There were no significant differences in PCL ($P = .157$), FCL ($P = .165$), or PLC ($P = .747$) injuries between groups; however, there were significantly fewer MCL injuries seen in association with revision ACLR when compared with primary ACLR (odds ratio, 0.29; 95% confidence interval, 0.13-0.59; $P < .001$). Table 3 outlines the concomitant ligament pathology in both groups with statistical comparisons.

Radiographic Measurements

Coronal-plane alignment radiographs were available for 435 of the 487 patients examined (89%). Coronal alignment measurements had excellent inter-rater and intrarater measurement agreement (ICC of 0.99 for both). Appropriate lateral knee radiographs allowing for sagittal slope measurements were available for 462 of 487 patients (95%). Inter-rater agreement for sagittal tibial slope measurements was excellent (ICC, 0.979). Coronal-plane alignment in the primary ACLR group (44.1° ± 12.9°) was not significantly different from that in revision ACLR cases (43.7° ± 12.4°, $P = .740$). However, tibial slope among primary ACLR cases (10.3° ± 3.2°) was significantly decreased (less posterior slope) compared with that in revision ACLR cases (11.0° ± 3.4°, $P = .048$) (Table 4).

Meniscal Pathology

There were no significant differences in meniscal tear distribution between primary and revision ACLR. Patients with multiple previous ACLRs had fewer

Table 2. Chondral Lesions by Location and Outerbridge Grade for Primary and Revision Groups

Articular Cartilage Status	Primary (n = 363)	Revision (n = 124)	*P* Value (Test)
MFC			<.001* (MWU)
Normal or grade 1	320 (88)	93 (75)	
Grade 2	16 (4)	15 (12)	
Grade 3	20 (6)	10 (8)	
Grade 4	7 (2)	6 (5)	
LFC			.003* (MWU)
Normal or grade 1	339 (93)	105 (85)	
Grade 2	8 (2)	7 (6)	
Grade 3	12 (3)	7 (6)	
Grade 4	4 (1)	5 (4)	
MTP			.06 (MWU)
Normal or grade 1	355 (98)	117 (94)	
Grade 2	4 (1)	6 (5)	
Grade 3	1 (0)	1 (1)	
Grade 4	3 (1)	0 (0)	
LTP			.124 (MWU)
Normal or grade 1	351 (97)	116 (94)	
Grade 2	10 (3)	5 (4)	
Grade 3	1 (0)	3 (2)	
Grade 4	1 (0)	0 (0)	
TG			.08 (MWU)
Normal or grade 1	339 (93)	110 (89)	
Grade 2	8 (2)	3 (2)	
Grade 3	11 (3)	4 (3)	
Grade 4	5 (1)	7 (6)	
Patella			.855 (MWU)
Normal or grade 1	319 (88)	108 (87)	
Grade 2	28 (8)	12 (10)	
Grade 3	15 (4)	3 (2)	
Grade 4	1 (0)	1 (1)	

NOTE. Data are presented as number (percent).
LFC, lateral femoral condyle; LTP, lateral tibial plateau; MFC, medial femoral condyle; MTP, medial tibial plateau; MWU, Mann-Whitney *U* test; TG, trochlear groove.
*Statistically significant.

meniscal tears (odds ratio, 0.37; 95% confidence interval, 0.16-0.86; *P* = .016). Meniscal injury patterns are presented in Table 5.

Risk Factors for Medial and Lateral Meniscal Tears

The logistic regression model built to predict medial meniscal tears at the time of ACLR achieved an AUROC of 0.654. Age (*P* = .010), male sex (*P* < .001), and revision reconstruction (*P* = .022) were significant independent predictors of medial meniscal tears at the time of ACL surgery (Fig 3).

For the lateral meniscal tear logistic regression model, the nonlinear component of coronal-plane malalignment (*P* = .030) was the only significant independent predictor of lateral meniscal tears at the time of ACL surgery, with an increased risk in patients presenting with either varus or valgus malalignment. Patient sex was not a significant predictor of lateral meniscal tears (*P* = .063); however, as shown in Figure 4, a lower risk of lateral meniscal tears was observed for decreased tibial slope, medium age, and neutral coronal-plane alignment. The AUROC for lateral meniscal tear prediction was 0.622.

Table 3. Concomitant Ligament Pathology for Primary and Revision Groups

Concomitant Ligament Status	Primary (n = 363)	Revision (n = 124)	*P* Value (Test)
PCL			.157 (FET)
Intact	334 (92)	119 (96)	
Torn and reconstructed	27 (7)	5 (4)	
Torn and not reconstructed	2 (1)	0 (0)	
MCL			<.001* (FET)
Intact	279 (77)	114 (92)	
Torn and reconstructed	78 (22)	9 (7)	
Torn and not reconstructed	6 (2)	1 (1)	
FCL			.165 (FET)
Intact	279 (77)	103 (83)	
Torn and reconstructed	84 (23)	21 (17)	
Torn and not reconstructed	0 (0)	0 (0)	
PLC			.747 (FET)
Intact	354 (98)	120 (97)	
Torn and reconstructed	9 (2)	4 (3)	
Torn and not reconstructed	0 (0)	0 (0)	

NOTE. Data are presented as number (percent).
FCL, fibular collateral ligament; FET, Fisher exact test; MCL, medial collateral ligament; PCL, posterior cruciate ligament; PLC, posterolateral corner.
*Statistically significant.

Discussion

The most important finding of this study was that revision ACLR patients were at a significantly increased risk of a higher number and increased grade (grade 3 or 4) of chondral injuries in both the medial and lateral compartments and had an increased medial tibial slope compared with primary ACLR patients at the time of presentation for treatment. Furthermore, when we evaluated both groups for logistic regression, patients with increasing age, male sex, and revision ACLR were at an increased risk of medial meniscal tears, although multiply revised ACLRs were at a lower risk of subsequent meniscal injury. We found no significant difference between groups in patient demographic characteristics, pattern of meniscal injury, or coronal-plane alignment. However, patients presenting for primary ACLR had high-energy injury mechanisms significantly more frequently and were more

Table 4. Radiographic Measurements of Tibial Slope and Coronal Alignment for Primary and Revision Groups

Radiographic Measurements	Primary	Revision	*P* Value (Test)
Tibial slope	10.4 (8.2, 12.6)	11.1 (9.0, 13.4)	.048* (*t*)
Coronal-plane alignment	44.1 (35.4, 52.9)	43.7 (35.4, 50.4)	.740 (*t*)

NOTE. Data presented as median (first quartile, third quartile).
t, Welch independent *t* test.
*Statistically significant.

Table 5. Meniscal Lesions by Location for Primary and Revision Groups

Meniscal Status	Primary (n = 363)	Revision (n = 124)	*P* Value (Test)
Tear laterality			.142 (χ^2)
None	124 (34)	43 (35)	
Medial	80 (22)	36 (29)	
Lateral	85 (23)	18 (15)	
Medial and lateral	74 (20)	27 (22)	
Meniscectomy			.351 (χ^2)
Medial	24 (7)	12 (10)	
Lateral	51 (14)	23 (19)	
Medial and lateral	10 (3)	4 (3)	

NOTE. Data are presented as number (percent).

likely to be participating in sports at the time of the ACL tear when compared with lower-energy injury mechanisms for the revision ACL group.

Although it is difficult to evaluate risk factors for specific injury patterns in a diverse group of patients, identifying injury patterns in patients at the time of their initial presentation can help surgeons identify trends in patterns of injury that can assist in both treatment and preoperative counseling. Information on meniscal and cartilage status at surgery is important because the presence or absence of injuries to these structures has been correlated with subjective patient-reported outcomes after surgery. Defining specific injury patterns and patient demographic characteristics is potentially important for counseling patients about the long-term prognosis and function after ACLR. The MARS (Multicenter ACL Revision Study) group reported 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 damage having the worst outcome scores in patients who underwent revision ACLR.[16] In addition, Spindler et al.[36] reported on 448 ACLRs and noted that at 3 years of follow-up, patients who had undergone revision ACLR and had grade 2, 3, or 4 Outerbridge cartilage lesions had lower patient-reported outcome scores when compared with those with grade 0 or 1 lesions.

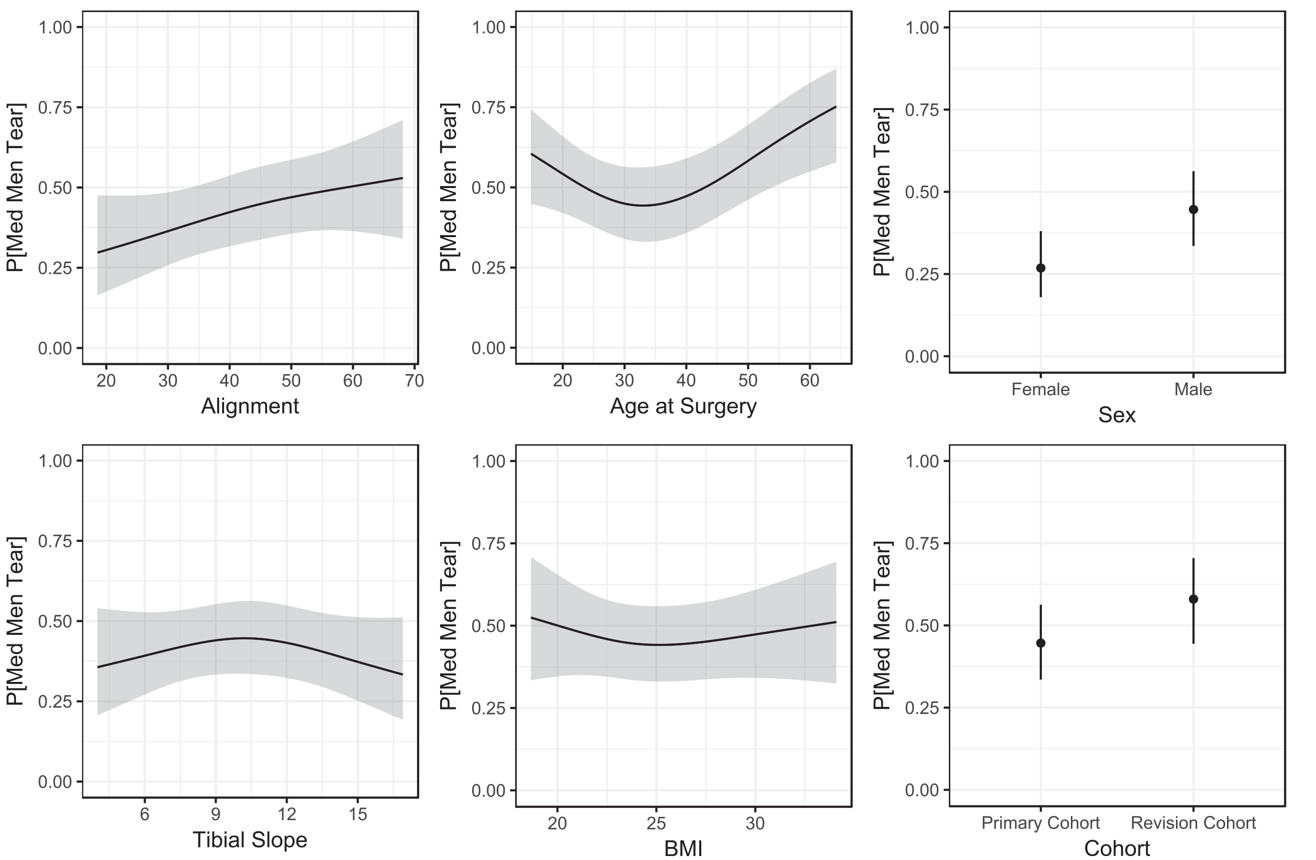

Fig 3. Modeled independent effects (adjusted for other covariates in the model) of 6 covariates on the probability of medial meniscal (Med Men) tears, assuming all other variables were held constant. Gray regions represent 95% confidence intervals for the curves and error bars represent 95% confidence intervals for group estimates. For each plot, continuous covariates not plotted were set at their median values: alignment, 45°; tibial slope, 11°; age, 31 years; body mass index (BMI), 24. Baseline sex was female and baseline group was primary reconstruction. Age ($P = .010$), male sex ($P < .001$), and revision reconstruction ($P = .022$) were significant independent predictors of medial meniscal tears at the time of anterior cruciate ligament surgery. A lower risk of medial meniscal tears was observed for medium age (approximately 25-45 years). The area under the receiver operating characteristic curve for medial meniscal tear prediction was 0.654.

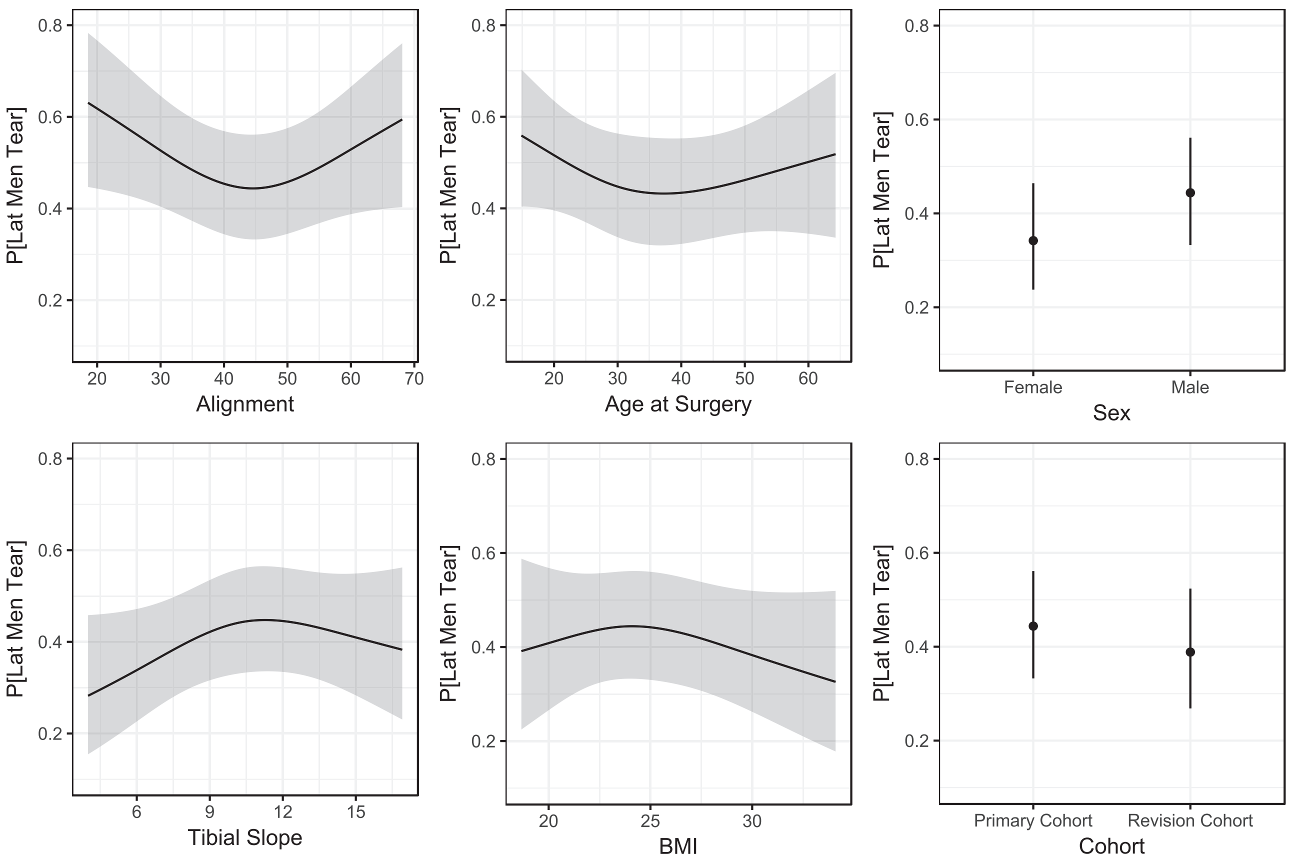

Fig 4. Modeled independent effects (adjusted for other covariates in the model) of 6 covariates on the probability of lateral meniscal (Lat Men) tears, assuming all other variables were held constant. Gray regions represent 95% confidence intervals for the curves and error bars represent 95% confidence intervals for group estimates. For each plot, covariates not plotted were set at their median values: alignment, 45°; tibial slope, 11°; age, 31 years; body mass index (BMI), 24. Baseline sex was female and baseline group was primary reconstruction. The nonlinear component of coronal-plane alignment ($P = .030$) was the only significant independent predictor of lateral meniscal tears at the time of anterior cruciate ligament surgery. A lower risk of lateral meniscal tears was observed for low tibial slope, medium age (approximately 30-50 years), and moderate alignment (40°-50°). The area under the receiver operating characteristic curve for lateral meniscal tear prediction was 0.622.

In our study there were no differences in the prevalence and laterality of meniscal tears between the primary ACLR and revision ACLR groups. Similar to previous studies, our study showed that revision ACLR patients had a higher prevalence and severity of chondral lesions; however, patients with multiple revision ACLRs had lower odds of having a meniscal tear. Wyatt et al.[13] recently reported that primary ACLR had an associated meniscal tear in 54.8% of cases whereas revision ACLR had a meniscal tear in 43.7% of cases. In our study, meniscal tears were found in approximately 65% of patients in either the primary or revision ACLR setting. Although these findings reasonably approximate those previously reported, it is possible that differences in patient populations and/or descriptions of tears, as well as over- or under-reporting of meniscal injuries, could play a role in differences in the percentages of meniscal injuries seen between studies.

Similar to previous studies, our study found that the prevalence of articular cartilage injuries was higher in revision cases than in primary cases (31.8% vs 14.9%).[13] The MOON (Multicenter Orthopaedic Outcomes Network) and MARS groups have evaluated intra-articular pathology differences between primary and revision ACLR and showed an increased odds ratio of having a medial meniscal tear and high-grade (grade 3 or 4) cartilage lesion in revision ACLR cases when compared with primary ACLR cases.[1,18]

Patients with an increased medial tibial slope were significantly associated with the revision ACLR group in our patient population. Recent literature has suggested that sagittal tibial slope may play a role in outcomes after ACLR.[37-42] Preliminary studies evaluating the effect of tibial slope on the ACL-deficient knee have suggested that alterations that lead to an increased posterior slope may place ACLR grafts and meniscal structures at increased risk of tear.[29,33,37-44] In our study, increasing tibial slope was correlated with revision ACLR status, and therefore, the radiographic findings presented in this article lend further credence to previously presented data. Although the difference in slope between the primary and revision groups was small (10.3° vs 11.0°) and may not be clinically relevant during patient care, the difference was statistically significant and may play a contributing role in associated injury patterns in the revision ACLR group. Dissimilar to this finding, an injury association was elucidated, given that a decreased tibial slope was correlated with high-grade cartilage lesions in the medial compartment. Although previous studies have shown that increased slope led to an increased risk of lateral-sided meniscal or chondral injuries,[45] it is unclear how decreasing slope specifically plays a role in the correlation with medial-sided injury at this time.

Cartilage status at the time of revision ACLR has previously been associated with coronal-plane alignment. In a study of 246 patients undergoing revision ACLR, Brophy et al.[1] identified that medial cartilaginous injuries were more frequently found in patients with varus malalignment. In this study, lateral meniscal tears were positively associated with both valgus and varus malalignment. This finding is difficult to explain; however, malalignment may play a role in knee stability during pivot-type or dynamic valgus-type ACL injury mechanisms and could lead to meniscal injury.

Limitations

Although this study does examine additional variables, it is not without limitations. The data were examined retrospectively, and as such, the inherent limitations of retrospective studies exist. However, all data were collected prospectively and stored in a registry database, which limits bias, to a certain extent. The nature of this study did limit the ability to perform a power analysis, and an a priori power analysis was performed because of the retrospective case-control study design. In addition, despite the relatively high numbers presented in this study, it is possible that the comparison was underpowered to detect some differences between groups.

Furthermore, the study evaluates patients at the time of their presentation and does not take into account the possibility of future injuries or pathology. This could mean that there are patients within the primary ACLR group who will later go on to have a graft tear and therefore could eventually switch groups. Statistically, this is very difficult to account for, and the time frame in which a patient could be considered to be no longer at risk of a graft tear is similarly challenging to delineate. As a result, conclusions from this study are limited by the unknown possibility of injury, and this could possibly represent a significant confounding variable.

Conclusions

The findings of this study show that patients undergoing a revision ACLR have significantly more chondral lesions, as well as higher-grade chondral lesions, at the time of presentation. Furthermore, coronal malalignment and a decreased tibial slope may contribute to injury patterns of the lateral meniscus and medial compartment cartilage, respectively.

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