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on behalf of the MOON Consortium and the MARS Group

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# Intra-articular Findings in Primary and Revision Anterior Cruciate Ligament Reconstruction Surgery

## A Comparison of the MOON and MARS Study Groups

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*Investigation performed at Vanderbilt University, Nashville, Tennessee*

**Background:** At the time of anterior cruciate ligament (ACL) reconstruction, there are usually concurrent meniscal and articular cartilage injuries. It is unclear if there is a significant difference between intra-articular injuries at the time of a primary ACL reconstruction compared with revision ACL reconstruction.

**Purpose:** To compare the meniscal and articular cartilage injuries found at the time of primary and revision ACL reconstruction surgery and to determine associations between primary and revision surgery and specific intra-articular findings.

**Study Design:** Cohort study (prevalence); Level of evidence, 2.

**Methods:** Primary and revision ACL surgeries were identified from the Multicenter Orthopedic Outcomes Network (MOON) and Multicenter ACL Revision Study (MARS) study groups, respectively, from January 1, 2007 to November 1, 2008. Demographic data on individual patients were analyzed including age, body mass index (BMI), and gender. Intra-articular findings including the presence of medial or lateral meniscal tears and chondral damage to articular surfaces were analyzed for each patient. Comparisons of intra-articular findings at the time of surgery for the 2 groups were analyzed. Chondral damage in the medial and lateral compartments was analyzed considering previous meniscal tear as a possible confounder.

**Results:** There were 508 patients undergoing primary ACL reconstruction and 281 patients undergoing revision ACL reconstruction who were identified for inclusion. There were no differences in the mean age, BMI, and gender in the 2 study groups. There was a decreased odds ratio (OR) of new untreated lateral meniscal tears (OR, 0.54;  $P < .01$ ) but not of medial meniscal tears (OR, 0.86;  $P = .39$ ) in revision compared with primary ACL reconstruction. There was an increased OR of Outerbridge grade 3 and 4 articular cartilage injury in revision compared with primary ACL reconstruction in the lateral compartment (OR, 1.73;  $P = .04$ ) and in the patellar-trochlear compartment (OR, 1.70;  $P = .04$ ) but not in the medial compartment (OR, 1.33;  $P = .23$ ). There was an increased OR of Outerbridge grade 3 and 4 articular cartilage injury in patients from both groups having a prior medial meniscectomy on the medial femoral condyle (OR, 1.44;  $P < .01$ ) and on the medial tibial plateau (OR, 1.63;  $P < .01$ ). There was an increased OR of Outerbridge grade 3 and 4 articular cartilage injury in patients from both groups having a prior lateral meniscectomy on the lateral femoral condyle (OR, 1.65;  $P < .01$ ) and on the lateral tibial plateau (OR, 1.56;  $P < .01$ ).

**Conclusion:** Meniscal tears are a common finding in both primary and revision ACL reconstruction. These results show a decreased OR of new untreated lateral meniscal tears in revision compared with primary ACL reconstruction. A previous medial or lateral meniscectomy increases the OR of articular cartilage damage in the medial or lateral compartments, respectively. Even when controlling for meniscus status, there is an increased OR in revision compared with primary ACL reconstruction of significant lateral compartment and patellar-trochlear chondral damage but not medial compartment chondral damage.

**Keywords:** anterior cruciate ligament; chondral damage; meniscal tear; primary and revision surgery

Anterior cruciate ligament (ACL) injuries are among the most common knee ligament injuries diagnosed in an athletic population. An estimated 200 000 ACL injuries occur

in the United States each year.<sup>8</sup> In this population, ACL reconstruction is often performed to restore functional knee stability so that the patient can resume athletic activities and to prevent future meniscal tears.<sup>2,24</sup>

One of the most concerning problems after ACL injury is the development of osteoarthritis (OA) of the knee.<sup>7,13,22</sup> The development of OA after ACL reconstruction has been defined several ways, and the incidence has been

over a wide range. The risk factors are varied and not yet defined in a multicenter cohort.<sup>1,6,11,19</sup> A systematic review of risk of OA after both ACL tears and/or reconstruction found a meniscal tear to be a risk factor for radiographic OA.<sup>17</sup> For example, the risk of OA without meniscal tear was between 0% and 13%, but the risk increased to 21% to 48% with meniscal tear. Thus, meniscal injuries that accompany ACL tears are important in the long-term prognosis, especially for OA after ACL reconstruction.<sup>17,21</sup>

Primary ACL reconstruction is much more common than revision ACL reconstruction. It is estimated that between 2% and 6% of primary ACL reconstructions will fail and require revision surgery.<sup>23</sup> There are many suggested reasons for ACL graft failure after reconstruction. The ACL grafts may fail secondary to trauma, poor surgical technique, undiagnosed concurrent knee injuries, and failed biological incorporation of the graft.<sup>9</sup> No concurrent cohort studies have explored whether there are significant differences in the intra-articular findings at the time of revision ACL reconstruction compared with primary ACL reconstruction. Specifically, the incidence of meniscal injury and chondral damage has not been well established at the time of revision ACL reconstruction and has not been compared with the findings at the time of primary ACL reconstruction.

The purpose of this study was to examine the intra-articular findings of a large, multicenter cohort of primary and revision ACL reconstructions at the time of surgery. The primary hypothesis of this study was that there would be significant differences among the intra-articular findings (meniscal and articular cartilage injury) in these 2 cohorts with increased chondral damage in the revision reconstructions versus the primary reconstructions. A secondary purpose of this study was to analyze if prior meniscal injury and treatment (debridement or excision) were a significant factor in the presence of chondral damage in either primary or revision ACL reconstruction.

## MATERIALS AND METHODS

A retrospective cohort design was used to examine intra-articular findings during the same time period after either primary (Multicenter Orthopedic Outcomes Network [MOON]) or revision (Multicenter ACL Revision Study [MARS]) ACL reconstruction surgery from January 1, 2007 to November 1, 2008. Primary ACL reconstructions were identified during the study time period from MOON. MOON is a multicenter cohort that consists of participants from 7 centers enrolling patients who have undergone primary or revision ACL surgery. The MOON group began enrolling patients in 2002, but because only 10% of ACL reconstructions in the MOON database are revisions, independent risk factors for associated outcome measures after revision ACL reconstruction could not be determined.

MARS was created to help address this issue and represents a larger collaborative effort than MOON regarding evidence on revision ACL surgery. In July 2007, 43 surgeons with institutional review board approval began enrolling ACL revision patients in the MARS cohort. Revision ACL reconstructions were identified from the MARS cohort for this study. The enrollment criteria and times were identical for each data set (January 1, 2007 to November 1, 2008). MOON and MARS use identical intra-articular data-capturing forms based on interrater agreement studies for both meniscal and articular cartilage injury, with the details of reporting described in previous publications.<sup>5,16,26</sup>

An analysis of the data collected on participants of both cohorts at the time of ACL reconstruction was performed. The primary outcome measures were the presence of a medial meniscal tear, lateral meniscal tear, or grade 3 or 4 chondral lesion documented at the time of ACL reconstruction. The modified Outerbridge grade was used to describe the defect of the lateral tibial plateau, medial tibial plateau, lateral femoral condyle, medial femoral condyle, patella, and trochlea at the time of ACL surgery. Meniscal and cartilage lesions were evaluated and reported by the MOON/MARS surgeon at the time of ACL surgery. Previous surgical treatment for meniscal injuries, as determined by medical records and findings at arthroscopy, was also captured at the time of ACL reconstruction and was included in the analysis. According to the modified Outerbridge grading system, chondral surfaces were classified into 4 grades: 1 (softening and fibrillation), 2 (superficial changes), 3 (deep changes and no exposed bone), and 4 (exposed bone).<sup>3,18</sup> For the purpose of analysis, meniscal tears were considered as a binary variable (yes/no). Chondral lesions were also considered as a binary variable for analysis (<grade 3/ $\geq$ grade 3).

Demographic data were analyzed for each cohort including age, gender, and body mass index (BMI). Descriptive statistics were obtained for meniscal injuries and chondral damage for each participant in each cohort. Multivariable logistic regression was used to calculate odds ratios to evaluate the difference in meniscal tears or chondral damage at the time of surgery comparing primary versus revision ACL reconstruction. Chondral damage in the medial and lateral compartments was analyzed, considering previous meniscal tear as a possible confounder in both primary and revision ACL reconstructions. Data were analyzed using STATA 9.0 (StataCorp LP, College Station, Texas).

## RESULTS

A total of 789 patients (508 primary and 281 revision) were identified in the MOON/MARS databases and included in this analysis. There were no significant differences in demographics between the primary and revision groups (Table 1).

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TABLE 1  
Demographics: Revision Versus Primary Anterior Cruciate Ligament Reconstruction<sup>a</sup>

	Primary			Revision		
	Mean	SE	95% CI	Mean	SE	95% CI
Age, y	26.82	0.51	25.82-27.83	27.79	0.60	26.62-28.97
BMI	25.73	0.24	25.26-26.20	25.91	0.27	25.37-26.44
Sex, %	Male	Female		Male	Female	
	57	43		54	46	

<sup>a</sup>SE, standard error; CI, confidence interval; BMI, body mass index.

TABLE 2  
Prevalence (%) of Intra-articular Damage at the Time of Anterior Cruciate Ligament Reconstruction

Intra-articular Injury	Primary	Revision
New medial meniscal tear	40.35	40.21
New lateral meniscal tear	45.87	33.81
Lateral femoral condyle lesion <sup>a</sup>	4.72	11.03
Medial femoral condyle lesion <sup>a</sup>	10.43	21.71
Lateral tibial plateau lesion <sup>a</sup>	2.95	4.98
Medial tibial plateau lesion <sup>a</sup>	0.79	3.20
Patellar lesion <sup>a</sup>	6.50	12.46
Trochlear lesion <sup>a</sup>	2.76	11.03

<sup>a</sup>Chondral lesion: Outerbridge grades 3 or 4.

The percentage of meniscal tears or chondral damage at the time of primary or revision ACL reconstruction was analyzed (Table 2). Odds ratios were then calculated to compare the odds of meniscal tears or chondral damage for revision reconstructions versus primary reconstructions (Table 3).

There were differences noted in both meniscal tears and chondral damage when comparing revision reconstructions with primary reconstructions. With respect to meniscal tears, we are reporting new tears in the revision group and not an accumulated total. There was a decreased odds ratio (OR) of new lateral meniscal tears (OR, 0.54; 95% confidence interval [CI], 0.39-0.75;  $P < .01$ ) but not of medial meniscal tears (OR, 0.86; 95% CI, 0.62-1.21;  $P = .39$ ) in revision compared with primary ACL reconstruction regardless of any previous meniscal treatment. There was an increased OR of Outerbridge grade 3 and 4 chondral lesions in revision compared with primary ACL reconstruction in the lateral compartment (OR, 1.73; 95% CI, 1.02-2.93;  $P = .04$ ) and in the patellar-trochlear compartment (OR, 1.70; 95% CI, 1.01-2.84;  $P = .04$ ) but not in the medial compartment (OR, 1.33; 95% CI, 0.83-2.14;  $P = .23$ ) regardless of any previous meniscal treatment.

Both revision and primary reconstruction groups were analyzed for the effect of prior meniscectomy (excision only) on the presence of grade 3 or 4 chondral damage (Table 4). In both groups, patients who had a prior medial meniscectomy had an increased OR of Outerbridge grade 3 and 4 chondral lesions on the medial femoral condyle (OR, 1.44; 95% CI, 1.25-1.66;  $P < .01$ ) and on the medial tibial plateau (OR, 1.63; 95% CI, 1.18-2.27;  $P < .01$ ). Similarly, in both groups, patients who had a prior lateral partial meniscectomy had an increased OR of Outerbridge grade 3 and 4 chondral lesions on the lateral femoral condyle

TABLE 3  
Odds of Intra-articular Damage: Revision Versus Primary Anterior Cruciate Ligament Reconstruction

	Odds Ratio	$P$	95% Confidence Interval
Medial meniscal tear <sup>a</sup>	0.86	.39	0.62-1.21
Lateral meniscal tear <sup>b</sup>	0.54	<.01	0.39-0.75
Medial compartment <sup>a</sup>	1.33	.23	0.83-2.14
Lateral compartment <sup>b</sup>	1.73	.04	1.02-2.93
Patellar/trochlear compartment <sup>a,b</sup>	1.70	.04	1.01-2.84

<sup>a</sup>Controlling for previous medial meniscal treatment.

<sup>b</sup>Controlling for previous lateral meniscal treatment.

(OR, 1.65; 95% CI, 1.34-2.03;  $P < .01$ ) and on the lateral tibial plateau (OR, 1.56; 95% CI, 1.18-2.06;  $P < .01$ ).

## DISCUSSION

This study examines the differences in intra-articular injuries (ie, meniscal and articular cartilage) between revision ACL reconstructions and primary ACL reconstructions in 2 multicenter cohorts during the same time period. We are able to report on the intra-articular findings of both primary and revision ACL reconstructions in a relatively large participant sample and to compare the findings between these 2 groups using identical data-capture forms. These data may help clinicians estimate the risk of OA and outcome after ACL reconstruction.

Previous reports on intra-articular findings after ACL injury have been focused on either the chronic ACL-deficient knee or primarily findings at the time of primary reconstruction.<sup>10,20,21,25,27</sup> It has been more difficult to characterize these findings in revision ACL reconstructions secondary to the relatively uncommon occurrence compared with primary reconstructions. The large number of revision reconstructions in this study (MARS) allows for an improved characterization of intra-articular findings at revision ACL reconstruction and for comparison with similar findings for primary ACL reconstruction (MOON).

Our study was able to confirm the effect of previous meniscectomy in both revision and primary ACL reconstructions as a significant risk factor for chondral damage in the medial and lateral compartments. Kääh et al<sup>12</sup> have examined the effects of ACL transection and meniscectomy on articular cartilage in a rabbit model. The results of this study suggest that there is much greater damage to articular

TABLE 4  
Odds of Chondral Damage With Previous Meniscectomy  
Controlling for Primary or Revision Anterior Cruciate  
Ligament Reconstruction

	Odds Ratio	P	95% Confidence Interval
Lateral femoral condyle <sup>a</sup>	1.65	<.01	1.34-2.03
Lateral tibial plateau <sup>a</sup>	1.56	<.01	1.18-2.06
Medial femoral condyle <sup>b</sup>	1.44	<.01	1.25-1.66
Medial tibial plateau <sup>b</sup>	1.63	<.01	1.18-2.27

<sup>a</sup>Previous lateral meniscectomy.

<sup>b</sup>Previous medial meniscectomy.

cartilage after meniscectomy compared with isolated ACL transection. Meniscal injuries have been shown previously to increase the risk of OA after ACL reconstruction in many clinical studies.<sup>1,4,6,11,14,19,20,21</sup> A recent systematic review confirmed that meniscal tears are associated with radiographic OA.<sup>17</sup> Our results confirm that the risk of meniscal injury to the progression of chondral injury is significant in both primary and revision ACL reconstructions, and we hypothesize that meniscal injuries may be more important than the ACL injury as a risk factor for chondral damage and OA in both primary and revision ACL reconstruction.

Clinical outcome studies have suggested that chondral damage and meniscal injury at the time of primary ACL reconstruction are strong predictors for the progression of OA. Ichiba and Kishimoto<sup>10</sup> examined the effects of chondral damage and meniscal injury at the time of primary ACL reconstruction on the radiographic progression of OA in the affected knee. In participants with significant chondral damage, there was significant progression of OA compared with those without significant chondral damage. This result was similar for participants with meniscectomy at the time of reconstruction compared with those without meniscectomy. In our study, there was an increased OR of significant chondral damage in revision participants in the lateral and patellofemoral compartments compared with primary participants. This result suggests that there is likely progression of chondral damage after failed primary ACL reconstruction. While our current analysis cannot identify all risks after primary reconstruction for the progression of chondral damage, it suggests the need to closely examine the early time period after primary ACL reconstruction and the prevention of further chondral damage. This should be an emphasis of further study for the prevention of OA after primary or revision ACL reconstruction.

Our study is the first study to retrospectively evaluate the intra-articular findings from 2 prospective multicenter ACL databases designed to determine the risk factors for outcomes after both primary (MOON) and revision (MARS) ACL reconstructions. Given the relatively uncommon nature of ACL graft failure, significant results regarding the intra-articular findings after revision ACL reconstruction have largely been based on small case numbers and clinician experience. A recent 2-year follow-up from a population-based registry in Denmark reported on 442 ACL revision reconstructions.<sup>15</sup>

In this registry, 26% of revisions had identified and treated meniscal damage, and 31% had identified chondral damage. The prevalence of meniscal and chondral damage in revision ACL reconstructions in our study and in this recent study suggests that these are common findings and should be addressed with patients regarding progression of articular cartilage damage when ACL reconstruction fails.

Our study does have limitations. A binary finding of meniscal tear or no meniscal tear is potentially misleading, as small posterior horn lateral meniscal tears usually require little or no treatment, compared with large complex lateral meniscal tears that require repair or debridement.

In our analysis of the association of prior meniscectomy with the presence of chondral damage, the size of the meniscectomy was not included in the analysis. Similarly, we report grade (<grade 3/≥grade 3) but not size of chondral lesions. Also, in large multicenter cohorts such as the ones utilized in our study, there is the potential for missing data and misclassification of data to affect the results. Both of the cohorts examined for this study have standardized surgeon data collection vehicles, but there is still the possibility of missing and misclassification of data.

This study was intended as a first step in reporting and comparing intra-articular findings from revision and primary ACL reconstructions. There are potential confounders not examined in this study that may affect intra-articular findings such as participant age, activity level, and time from ACL injury to reconstruction. These factors have been studied previously but have not been compared in primary and revision ACL reconstructions.<sup>25,27</sup> It will be important to study these variables in the future. The exact timing of when meniscal and chondral injury occurred is also of value but beyond the scope of this study. The final limitation of this study is that although the sample sizes of the primary and revision groups are large, they are only a representation of the ACL reconstructions performed by fellowship-trained surgeons who are members of the American Orthopaedic Society for Sports Medicine (AOSSM), and generalizability to the rest of the United States or other countries has not been determined. These multicenter cohorts are the preferred study design to determine prognosis and evaluate intra-articular injuries along with other proposed risk factors for outcomes, especially OA.

## CONCLUSION

In conclusion, this study reports on the prevalence of intra-articular findings at the time of ACL revision reconstruction in a large cohort and compares those findings to a similar cohort of primary ACL reconstructions. Our findings suggest that the prevalence of new medial meniscal tears is similar between the 2 groups but that lateral meniscal tears are much more common in the primary ACL cohort. Prior partial meniscectomy is a risk for significant chondral damage in both cohorts. When controlling for meniscus status, there is an increased OR of chondral damage in the lateral and patellofemoral compartments in the revision cohort.

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