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Clinical and Radiographic Outcomes of Meniscus Surgery and Future Targets for Biologic Intervention: A review of data from the MOON Group

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Abstract

Meniscus injury and treatment occurred with the majority of anterior cruciate ligament reconstructions (ACLR) in the multicenter orthopaedic outcomes (MOON) cohort. We describe the patient reported outcomes, radiographic outcomes and predictors of pain from meniscus injuries and treatment in the setting of ACLR. Patient reported outcomes improve significantly following meniscus repair with ACLR, but differences exist based on the meniscus injury laterally (medial or lateral). Patients undergoing medial meniscus repair have worse patient-reported outcomes and more pain compared to those with uninjured menisci. However, lateral meniscal tears can be repaired with similar outcomes as uninjured menisci. Medial meniscal treatment (meniscectomy or repair) results in a significant loss of joint space at 2 years compared to uninjured menisci. Menisci treated with excision had a greater degree of joint space loss compared to those treated with repair. Clinically significant knee pain is more common following injuries to the medial meniscus and increased in patients who undergo early re-operation after initial ACLR. Future research efforts aimed at improving outcomes after combined ACLR and meniscus treatment should focus on optimizing biologic and mechanical environments that promote healing of medial meniscal tears sustained during ACL injury.

Keywords

Meniscus; patient reported outcome; ACL; repair; meniscectomy; joint space; pain

Introduction

Anterior cruciate ligament (ACL) and meniscal tears are common in young/active patient populations and may predispose some to osteoarthritis^{7, 21, 28, 33, 35, 36}. The meniscus is a secondary stabilizer of anterior-posterior knee translation and also plays a key role in transmitting load across the knee joint to prevent high contact stresses on articular cartilage.^{3, 4, 19} Injuries to the meniscus have proven challenging to treat; historically, they were treated with excision. Given its important structural properties, efforts have been made

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over the past two decades to preserve the meniscus when possible. Peripheral longitudinal tears, primarily in the vascular zone, have been treated with meniscal repair at increasing rates.^{1, 38}

The Multicenter Orthopaedic Outcomes Network (MOON) prospectively identified a cohort of patients who sustained an ACL injury and underwent subsequent ACL reconstruction. Validated patient reported outcomes including the Knee Injury and Osteoarthritis Outcome Score (KOOS), the International Knee Documentation Committee Subjective form (IKDC), and Marx activity scores were collected at the time of enrollment, 2 and 6-year follow-up. The general cohort has been studied with 6-year follow-up exceeding 85%. A nested cohort within the MOON cohort has evaluated radiographic outcomes between 2–3 years after surgery. The influence the meniscal injury and treatment has on patient-reported and radiographic outcomes in the MOON cohort have been published in the literature.^{9, 10, 17, 38}

The purpose of this review was to describe how outcomes of meniscus injury and treatment can inform basic and translational science to improve clinical care. We will evaluate how meniscus injury and treatment influences reoperation and patient reported outcomes, describe radiographic outcomes of meniscus surgery at the time of ACL reconstruction, and identify predictors of pain in patients undergoing meniscal treatment at the time of their ACL reconstruction. This review will identify targets of future biologic interventions that could make meaningful impacts on patient outcome.

Meniscus Reoperation

The MOON Group developed a large multi-center cohort of patients who underwent ACL reconstruction with a natural experiment of meniscus injuries with standardized meniscus treatment guidelines¹¹. Patients who had undergone meniscus surgery at the time of the ACL reconstruction have been evaluated by several metrics^{9, 10, 34, 38}.

Westermann et al³⁸ evaluated reoperation (i.e meniscal repair failure treated operatively) following meniscus repair in a cohort of 235 patients at a minimum of 6 years from surgery. The cohort consisted of 154 medial tears, 72 lateral tears, and 9 bilateral meniscal tears. The medial meniscal repair failure rate was 13.9% and failures occurred at a mean of 2.1 years from repair. The lateral meniscus repair failure rate was found to be 13.9 % at a mean of 3.7 years from repair. The isolated meniscus reoperation rate (i.e. failure rate, excluding cases of revision ACL reconstruction) was 8.3 % for lateral repairs and 10.4% for medial repairs.³⁸ Similarly, Toman et al³⁴ noted lower lateral repair reoperation at the 2-year report of meniscus repair in MOON patients. Certain tears to the meniscus can successfully be left alone without treatment during ACLR. In an analysis of 194 patients with 208 meniscus tears initially left alone without treatment 6 years from surgery, the decision to leave certain meniscal tears in situ was successful in avoiding an isolated meniscus reoperation in 96.6% of cases.¹⁰ Small medial tears required more subsequent reoperation than small lateral tears (< 10 mm). Reoperation was more frequent for medial meniscus tears treated with repair or left alone without treatment; these injuries and treatment have been found to predict patient reported outcomes.

Patient Reported Outcomes

Validated patient reported outcome instruments including KOOS³⁰, IKDC⁵ and Marx scores²² were used to assess the success of meniscus repairs performed concurrently with ACL reconstruction. All scores improved by both a statistically and clinically significant amount (>10 points for KOOS^{29, 39} subscales, and >11.5 points for IKDC¹⁶ scores) from baseline to 2-year follow-up. Good outcomes were well maintained from 2- to 6-year follow up; (Table 1) Median KOOS pain scores improved from 72.2 at baseline compared to 91.7 and 94.4 two and years after combined ACL reconstruction and meniscus repair. IKDC scores improved from a baseline of 47.1 to 85.1 and 87.4 two and 6 years following surgery. Marx activity scores decreased over time between 2 and 6-year follow-up³⁸.

While the meniscal repair cohort improved well as a whole after surgery, there were certain independent factors that were found to portend worse outcomes as assessed by multivariate analysis. Cox et al⁹ evaluated the outcomes of 1307 patients 6 years out from ACL reconstruction and associated procedures. Using a multivariate model, independent risk factors for lower KOOS or IKDC scores were found to be medial or lateral meniscus injuries and grade 3 or 4 chondral lesions. Upon further analysis, medial meniscal repair was an independent factor associated with worse outcomes compared to medial meniscectomy at 6 years. Stable lateral meniscus tears left alone were found to be associated with improved outcomes. While the presence of meniscus tear or treatment did not predict future activity, grade 4 medial femoral condyle articular defects were associated with decreased Marx scores at 6 years.

Patient outcomes differed when comparing medial and lateral sided meniscectomy at the time of ACLR. The impact of meniscectomy was analyzed in MOON data at 6-year follow-up.⁹ Small medial meniscectomies (when less than one-third of the meniscus was removed) fared worse when compared to larger meniscectomies by KOOS scoring⁹. Conversely, on the lateral side, both small excisions and large meniscus excisions performed favorably at 6-year follow-up.⁹ This time frame may be too early to detect the ramifications of meniscus excision on patient reported outcome and further follow-up is warranted. Overall, knees with ACL injury appear to be least tolerant of meniscectomies on the medial side; this structure should be considered a target to improve outcomes.

Patient Reported Outcomes Summary—In summary, medial and lateral menisci function and respond to treatment differently; medial meniscus injuries more frequently require reoperation, and treatments (including both repair and excision) are associated with worse patient reported outcomes. The MOON Group's findings on the problematic nature of medial meniscus injuries has been corroborated in the literature^{6, 32}. It appears there is little to no room for meaningful clinical improvement with regard to lateral meniscus injuries: lateral repairs appear to function as well as uninjured menisci. With meniscal injury, the structure should be recognized as a target for biologic augmentation in order to improve repair techniques.

Joint Space Changes after Meniscus Injury

A novel nested cohort was designed within MOON to assess the relationship between various patient factors, injury characteristics, surgical treatments, and radiographic signs of post-traumatic osteoarthritis (PTOA). Patients were included in the nested cohort if they were 35 or younger, were injured playing a sport, denied prior knee ligament injury or surgery on either knee, and did not report any knee ligament injury or surgery on either knee during the follow-up period. These inclusion criteria were selected to ensure that radiographic signs of PTOA were related to ACL injury and treatment rather than pre-existing conditions, and to allow the contralateral knee to serve as a control during radiographic assessments. Standardized radiographs were performed using the metatarsophalangeal joint (MTP) positioning technique²⁷, and medial compartment minimum joint space width (JSW) was measured using a semi-automated computerized measurement technique accurate to 0.3 mm.¹²

Radiographs were obtained in 262 subjects at 2 – 3 years after ACL reconstruction. There were 148 females and the median age was 17.5 years. Of these, 159 patients had normal menisci, 52 had meniscal repair, 23 had arthroscopic partial meniscectomy, and 28 had stable tears that were not treated. Multivariable models were constructed that adjusted for age, gender, BMI, graft choice, Marx activity level, and presence of high-grade articular cartilage lesion in the medial compartment.

Overall, the mean medial compartment minimum joint space width was wider in the ACL reconstructed knees than the contralateral normal knees by 0.35 mm. We theorize that this was possibly due to cartilage swelling, and may represent the earliest radiographic manifestation of PTOA. This finding is consistent with MRI evaluation after ACL reconstruction and with animal studies of PTOA^{2, 15, 20, 23–25}. A limitation of the study worth mentioning is differences in original and repaired menisci (0.35 mm and 0.31 mm) approaching the margin of accuracy of the measurement. Knees with meniscus repair had 0.31 mm narrower minimum joint space width compared to knees with normal menisci, and knees with partial meniscectomy had 0.64 mm narrower minimum joint space width compared to knees with normal menisci. Knees with untreated stable tears had no difference in medial compartment minimum joint space width compared to knees with normal menisci. Knees from older subjects had narrower medial compartment joint space width than knees from younger subjects after adjustment for patient and treatment-related factors.

The present study on joint space changes does have some limitations worth mentioning. First, the differences detected between groups, while statistically significant, do approach the standard error of measurement¹². Because of the variability in measurement (0.3mm), it is necessary to assemble a large cohort of patients and perform a multivariable analysis to adjust for potential confounding factors. Our multivariable regression model in 262 patients shows that even in the context of this variability in the measurement, there are highly significant differences in joint space width between the ACL reconstructed and contralateral knee based on age and meniscus treatment status two years after ACL reconstruction.

The study did not evaluate changes in the sagittal plane. Finally, given athletes do not have pre-injury plain films of a normal knee, we are unable to compare pre-injury studies to those

post-surgery. We do feel that contralateral uninjured knee films do provide an adequate reference.

Therefore, both meniscal repair and partial meniscectomy at the time of ACL reconstruction are associated with narrower medial compartment joint space width 2–3 years after surgery, and older subjects are at risk for more narrowing than younger subjects. Improved medial meniscal repair techniques that better restore the normal function of the medial meniscus are critical to prevent this early onset of PTOA in young, active individuals.

Predictors of Pain after ACL and Meniscus injury

The state and treatment of the meniscus at both the time of injury and following ACL surgery may significantly influence the likelihood of a patient reporting a painful knee. While it is generally accepted that meniscal repair is more successful in the setting of ACLR than when performed alone,³⁷ this does not guarantee pain-free status. Both the meniscal and articular cartilage status are likely related to the development of early post-traumatic arthritis²⁶ and subsequent pain, however, such a relationship is multifactorial and difficult to assign cause-effect.

Meniscal surgery concurrent with index ACLR—The contribution of meniscal status at the time of ACLR on reported pain in follow-up is to some degree inconsistent, and not fully understood. In the MOON cohort, meniscal surgery performed concurrently with ACLR significantly influenced patient-reported pain at both 2- and 6-years after surgery. Cox et al.⁸ reported the long-term outcomes on the 2002-4 MOON cohort (n=1512 patients). Like other PRO, meniscal injury on the lateral side appears to have less influence and in fact may even be associated with improved outcomes in follow-up. For example, the odds of reporting better KOOS_{pain} subscale scores was increased when a patient had an untreated lateral meniscal tear (OR 1.64) in comparison to those who had no tear at all. There are a number of potential explanations for this interaction, which is consistent across KOOS subscales, but we favor the concept that a partial tear in the posterior horn of the lateral meniscus represents the meniscus functioning in its purported role of protecting articular cartilage such as during the pivot-shift injury. On the medial side, a medial meniscal tear which was repaired increased the odds of reporting higher pain on KOOS_{pain} subscale compared to a meniscus with no tear. Conversely, no medial meniscal tear fared better than knees treated with meniscectomy and >50% meniscus excision. Other factors such as both coronal and sagittal plane alignment and how they moderate this relationship have not been explored.

In contrast, a lower level of evidence for registry data has failed to demonstrate a relationship between concurrent meniscal surgery with ACLR and greater patient-reported pain, although the follow-up times available in the present literature are limited to 2-years. In the Norwegian Knee Ligament Registry¹⁸ patient-reported pain 2-years after ACLR did not differ among those who underwent ACLR with or without meniscal surgery (repair or resection). Pre-operative pain scores, however, were more likely to be lower with concurrent meniscal pathology on both the medial or lateral sides. When Norwegian registry data was combined with the Swedish registry the same relationship held true³¹.

Meniscal surgery subsequent to the index ACLR—In contrast to concurrent meniscal surgery, surgery that occurs on the meniscus after the index ACLR is more consistently associated with reporting higher pain levels. A meta-analysis¹⁴ of HRQoL measures after ACLR in a group of level-I through level-IV studies identified meniscal injuries sustained after index ACLR as a significant predictor of reporting higher pain in 5- and 10-year follow-up. Indeed, we demonstrated in the MOON cohort that patients who underwent subsequent additional meniscal surgery (the majority of which were partial meniscectomy) after index ACLR reported significantly higher pain at both 2- and 6-years. This finding was consistent across pain definitions, including a >10 point drop (minimal clinically important difference) in KOOS_{pain}, >2 standard deviations of KOOS_{pain} score compared to population norms, or via the Englund criteria of a painful knee¹³.

Conclusions

Patient-reported outcome and radiographic data from the MOON cohort suggest there is significant room for improvement in the treatment of medial meniscus tears. Medial meniscectomy is associated with worse patient-reported outcomes, and the greatest degree of joint-space loss after surgery. In order make the most meaningful improvement on patient outcome, basic science and biologic research programs should focus on scaffold development to replace medial meniscus tears that are treated with excision. Current medial meniscus repair techniques are associated with more frequent reoperation, worse patient outcomes, loss of joint space, and pain. Research efforts should be directed at improving the mechanical and biologic healing environments for medial meniscus repairs at the time of ACL reconstruction.

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Take Home Point

Medial meniscus damage during ACL injury independently predicts poor outcomes after surgery. Future studies should aim at improving treatments for medial meniscus tears suffered at the time of ACL injury in order to make meaningful impacts on patient outcomes.

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Table 1 Median Scores at Baseline and 2- and 6- Year Follow-up³⁸

Median Scores at Baseline and 2- and 6- Year Follow-up ^a						
All Repairs (n = 235)	Successful Medial Repair (n = 133)	Failed Medial Repair (n = 21)	Successful Lateral Repair (n = 62)	Failed Lateral Repair (n = 10)	Successful Bilateral Repair (n = 7)	Failed Bilateral Repair (n = 2)
KOOS symptoms						
Baseline	67.9	67.9	67.9	75.0	67.9	55.4
2 years	85.7	87.5	85.7	82.1	96.4	82.1
6 years	85.7	82.1	88.4	83.9	85.7	89.3
KOOS pain						
Baseline	72.2	77.8	72.2	77.8	72.2	61.1
2 years	91.7	97.2	91.7	88.2	100.0	86.1
6 years	94.4	94.4	94.4	91.7	97.2	91.7
KOOS ADL						
Baseline	85.3	85.3	86.8	80.1	75.0	68.4
2 years	98.5	98.5	98.5	95.5	100.0	91.2
6 years	98.5	98.5	98.5	98.5	98.5	97.1
KOOS Sports/Rec						
Baseline	45.0	50.0	45.0	36.9	50.0	22.5
2 years	85.0	85.0	90.0	80.0	95.0	85.0
6 years	90.0	85.0	85.0	85.0	90.0	82.5
KOOS KRQOL						
Baseline	31.3	43.8	28.1	31.3	18.8	25.0
2 years	75.0	78.1	75.0	68.8	87.5	46.9
6 years	78.1	81.3	78.1	68.8	68.8	75.0
Marx activity rating						
Baseline	12.0	16.0	11.0	16.0	6.0	6.0
2 years	9.0	9.5	8.0	9.5	8.0	8.0
6 years	7.0	7.0	6.0	8.0	3.0	1.0
IKDC						
Baseline	47.1	51.7	44.9	48.3	48.3	38.8
2 years	85.1	83.9	82.2	84.5	85.1	76.4

Median Scores at Baseline and 2- and 6- Year Follow-up^a

	All Repairs (n = 235)	Successful Medial Repair (n = 133)	Failed Medial Repair (n = 21)	Successful Lateral Repair (n = 62)	Failed Lateral Repair (n = 10)	Successful Bilateral Repair (n = 7)	Failed Bilateral Repair (n = 2)
6 years	87.4	87.4	85.1	87.4	80.5	85.1	88.4

^a Groups were analyzed by all cases undergoing meniscal repair, successful medial repair at 6 years, failed medial repair at 6 years, successful lateral repair at 6 years, failed lateral repair at 6 years, successful bilateral repair at 6 years, and failed bilateral repair at 6 years. Significantly decreased Marx activity scores were noted in failed bilateral repairs at 6-year follow-up. ADL, activities of daily living; KOOS, Knee Injury and Osteoarthritis Outcome Score; KRQOL, knee-related quality of life; Sports/Rec, sports and recreation.