Research Article

Incidence of Posteromedial Meniscocapsular Separation and the Biomechanical Implications on the Anterior Cruciate Ligament

Cory Edgar, MD, PhD
Neil Kumar, MD, MBA
James K. Ware, MD
Connor Ziegler, MD
Dale N. Reed, MD
Jessica DiVenere, BS
Elifho Obopilwe, MS
Mark P. Cote, DPT
Robert A. Arciero, MD

Abstract

Purpose: To report the incidence of posterior medial meniscocapsular junction (PMCJ) separation in patients with anterior cruciate ligament (ACL) injury and to evaluate its biomechanical effect on the ACL.

Methods: Three hundred thirty-seven consecutive patients undergoing isolated primary ACL reconstruction were retrospectively analyzed for PMCJ lesion. Forty-four patients were identified with PMCJ lesion and studied. Eight cadaver knees underwent biomechanical testing to determine anterior tibial displacement and anteromedial bundle ACL strain in the intact, PMCJ lesion, and PMCJ repair states at 0°, 30°, 60°, and 90° of flexion. Mixed-effects linear regression with Bonferroni correction was used for statistical analysis.

Results: PMCJ tear incidence with ACL disruption was 13.1%. Specimen with PMCJ tears had statistically increased anterior tibial translation at 30° (1.2 mm; $P < 0.01$) and statistically increased ACL strain at 30° (24%; $P < 0.01$) and 90° (50%; $P < 0.01$). With PMCJ repair, translation reduced ($P > 0.05$) by 12%, 18%, and 10% at 0°, 30°, and 90° of flexion, respectively. PMCJ repair reduced ($P < 0.05$) ACL strain by 40%, 39%, 43%, and 31% at 0°, 30°, 60°, and 90° of flexion, respectively.

Conclusions: A PMCJ lesion was observed in 13% of ACL injuries. This injury contributes to increased ACL strain, and PMCJ repair markedly reduces ACL strain to preinjury levels.

Meniscal injuries in the setting of anterior cruciate ligament (ACL) disruption are a common occurrence.[1-3] In the acute setting, the incidence of concomitant meniscal tears after ACL injury is 41% to 82% and can approach 100% with chronic ACL insufficiency.[1-8] The supraphysiologic anterior tibial translation associated with ACL tear results in abutment of the medial femoral condyle on the posterior horn of the medial meniscus, placing this structure at particular risk of traumatic injury.[1,9] This mechanism may explain why the reported rate of peripheral posterior horn medial meniscal tears range from 20% to 40%.[1,2,9,10]

A unique variant of the peripheral posterior horn medial meniscus injury is the separation of the posterior meniscocapsular (PMCJ) junction. Such lesions have been defined as "ramp lesions"; however this terminology has

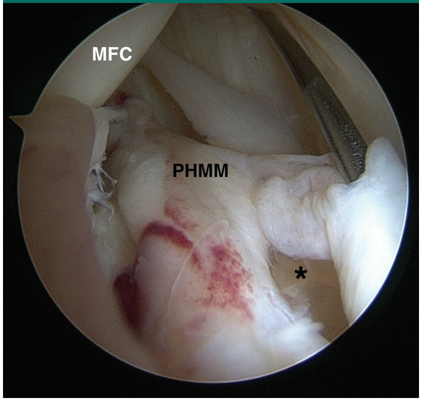
From the Department of Orthopaedic Surgery, University of Connecticut Health Center, Farmington, CT.

Correspondence to Dr. Kumar: neilskumar1@gmail.com

J Am Acad Orthop Surg 2018;00:1-9

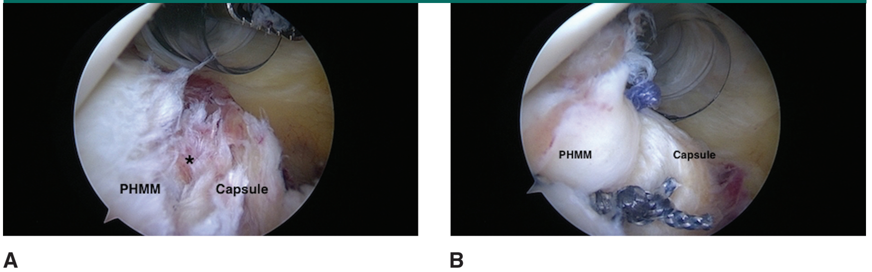
DOI: 10.5435/JAAOS-D-17-00327

Figure 1



An 18-gauge spinal needle is introduced into the posteromedial compartment of the left knee and used as a probe. Here, the posterior horn medial meniscus has a double-bucket tear, including a tear at the meniscocapsular junction (*). MFC = medial femoral condyle, PHMM = posterior horn medial meniscus

Figure 2



A, A lesion of the posterior medial meniscocapsular junction (*) is seen in a left knee. **B**, Two simple vertical sutures with #2 Orthocord (DePuy Synthes) are used to repair the lesion.

also been used to describe disruption of the meniscotibial ligament and tears in the red-red zone of the posterior horn.[11-14] Despite its recognition over 30 years ago,[15,16] PMCJ injury is currently under renewed investigation. Smith and Barrett[1] found PMCJ tears in 3.1% of patients with ACL deficiency, 73.3% of whom underwent reconstruction within 6 weeks of injury. However, other authors have found rates three to five times greater.[12,17]

Despite the recent increased recognition of PMCJ separation, much remains unknown regarding the incidence of these lesions. Furthermore, the implications of missed and repaired lesions on the ligamentous stability and chondral health of the knee are yet to be fully elucidated. The purpose of this study was to report the incidence of posteromedial meniscocapsular junction separation in a group of patients with ACL injury and to evaluate the biomechanical effect of missed and repaired lesions on the ACL. We suspected that >10% of our cohort had a PMCJ lesion identified arthroscopically. We further hypothesized that with biomechanical testing in a cadaver model, PMCJ lesions lead to increased anterior tibial translation and greater strain on the anteromedial bundle of the ACL, both of which can be reduced with PMCJ repair.

Methods

Incidence

To establish the incidence of PMCJ separation, 339 consecutive patients who underwent isolated primary ACL reconstruction by the senior author from October 2006 to March 2013 were analyzed retrospectively. Surgical reports and arthroscopic images were reviewed to identify all patients with a tear involving the meniscocapsular junction at the posterior horn of the medial meniscus.

In the practice of the senior surgeon, the posteromedial compartment is evaluated in all patients undergoing ACL reconstruction. With the knee at 90° flexion, a 70° arthroscope is placed into the posteromedial compartment via the Gillquist et al[18] maneuver to visualize the posterior meniscocapsular junction. An 18-gauge spinal needle (Figure 1), introduced into the posteromedial compartment of the knee, is used to probe the junction and identify the tear site.

All lesions, regardless of size or perceived instability, were repaired using an all-inside technique. A posteromedial portal ("Metcalf portal") is created, and an 8 × 25 mm cannula is placed.[19] Through the posteromedial portal, a Spectrum hook (ConMed) first pierces the capsular tissue and then pierces the posterior meniscus to create a vertical simple stitch. A zero PDS shuttle suture is deployed through the hook and retrieved from the posteromedial portal. A #2 Orthocord (DePuy Synthes) is shuttled through the capsular and meniscal tissue and tied arthroscopically (Figure 2).

For each patient with this injury, variables such as age, sex, side,

Dr. Edgar or an immediate family member is a member of a speakers' bureau or has made paid presentations on behalf of and serves as a paid consultant to DePuy Synthes Mitek. Dr. Arciero or an immediate family member has stock or stock options held in Biorez; has received research or institutional support from Arthrex; and serves as a board member, owner, officer, or committee member of the American Orthopaedic Society for Sports Medicine. None of the following authors nor any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Kumar, Dr. Ware, Dr. Ziegler, Dr. Reed, Ms. DiVenere, Mr. Obopilwe, and Mr. Cote.

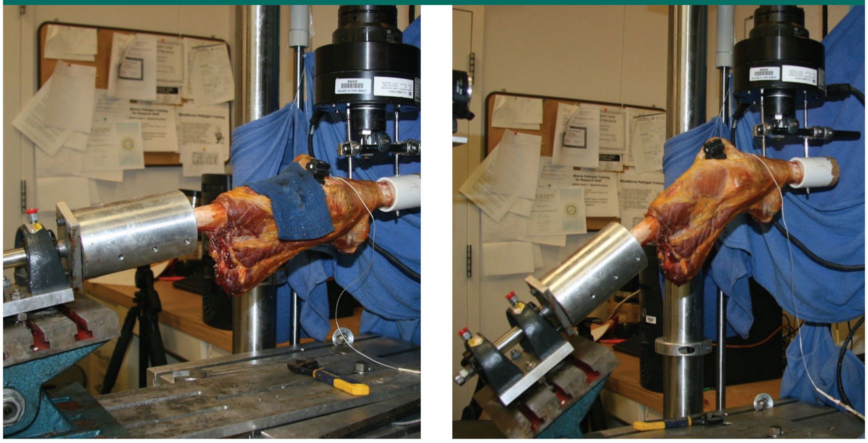
mechanism of injury, time from injury, time of MRI, and associated injuries identified at the time of surgery were recorded. All patients had obtained preoperative MRI. All patients who underwent isolated bundle ACL or patients without surgical records available for review were excluded.

Biomechanical Study

Specimen Preparation

To determine the biomechanical effects of PMCJ injury and repair, eight fresh-frozen human cadaver knees, two males and six females, were used. All specimens had no evidence of previous knee surgery, injury, or degenerative disease. Arthroscopic examination of the specimens verified the lack of intra-articular pathology. Specimens ranged from 36 to 49 years in age, with a mean age of <45 years. The knees were stored in a −20°C freezer and thawed overnight before testing. Adequate amounts of soft tissues were removed to allow for mounting and testing while preserving the soft tissue around the joint. The capsular and ligamentous structures in and around the knee joint, including the cruciate and collateral ligaments, the popliteus, and the oblique popliteal ligament, were carefully preserved. The femur and tibia were cut approximately 20 cm proximal and distal to the joint line, respectively. The femur and tibia were potted in a cylindrical polyvinylchloride mold using polymethyl methacrylate. Three 5-mm stainless steel self-drilling and self-tapping Schantz pins (Synthes) were inserted in an anterior-posterior direction along the midsagittal plane in both the femur and tibia approximately 5, 10, and 15 cm from the joint line. A lateral parapatellar arthrotomy was performed, taking care to preserve the anterior meniscal horns and intermeniscal ligament to prevent destabilization of the medial meniscus anterior horn.[20]

Figure 3



A **B**

The Materials Testing System is fixed to the tibia with three external fixation pins, and the tibia is translated anteriorly in relation to the femur within the cylinder. The testing system is shown with the knee in (**A**) 0° and (**B**) 30° flexion.

Testing System

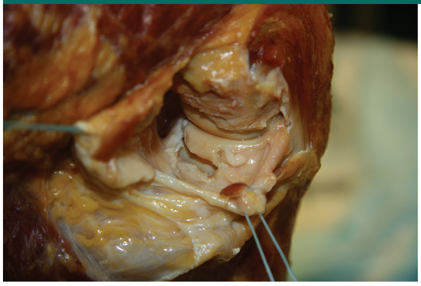
The testing fixture followed the primary principles of knee and cruciate ligament testing described by Beynnon and Amis.[21] Three large external fixator clamps (Synthes) were used to secure an 11-mm-diameter carbon fiber bar (Synthes) to the tibial Schantz pins. The tibia was then secured in neutral rotation directly to the actuator of the Materials Testing System (model 858; Materials Testing Systems) (Figure 3) using three more identical external fixator clamps such that it was perpendicular to the actuator's axis of movement. The actuator was centered inferior to the tibiofemoral joint line and central to the long axis of the tibia. The actuator was free to rotate during testing. Anterior-posterior loads were applied perpendicular to the tibia, whereas the combined fixtures allowed unconstrained superior-inferior and medial-lateral translation of the femur, internal-external rotation of the femur, and varus-valgus movement of the tibia. The femur was mounted in an aluminum cylinder and secured with six screws positioned equidistant around the cylinder, which allowed free rotation about the long axis of the femur.

Figure 4

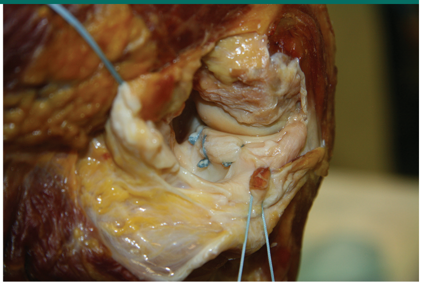
For strain testing, the differential variable reluctance transducer is placed within the midsubstance of the anterior cruciate ligament, and a limited notchplasty is performed to prevent transducer impingement.

A differential variable reluctance transducer (DVRT) (2.0 mm ultra-microminiature sensor; MicroStrain) was positioned collinear with the ACL anteromedial bundle and pressed into its midsubstance before securing the specimen to the actuator (Figure 4). To prevent impingement

Figure 5



A



B

A, Cadaver dissection of the posteromedial knee showing a meniscocapsular lesion. **B**, Meniscocapsular separation repaired anatomically with three sutures.

Table 1

Demographics and Associated Lesions in Patients With Posterior Meniscocapsular Lesion

Demographics		Associated Lesions	
Sex		Chondral lesions	14
Male	28 (64%)	MFC	8
Female	16	LFC	1
Age (yr)		Trochlea	2
Mean	23.0	Patella	3
Range	12-52	Lateral meniscus tear	9
Side			
Right	25 (57%)		
Left	19		

LFC = lateral femoral condyle, MFC = medial femoral condyle

against the sensor with knee extension, a limited notchplasty, as previously reported by Spang et al,[22] was performed. The knee was taken through a range of motion to ensure that DVRT output remained in the readable range. The DVRT was subsequently secured at its inferior aspect with a single stitch.

Testing Protocol

Preconditioning was performed with anterior-posterior directed loads of 100 N applied for 10 cycles at 0.25 Hz. Subsequently, anterior-posterior loads of 150 N were applied perpendicular to the tibia for 10 cycles, during which time DVRT output was recorded for anterior tibial displacement and anteromedial bundle ACL strain. The tibia was allowed to "relax" to a resting position at the desired flexion angle being tested between each cycle while no posterior loads were applied and was reconfigured as PMCJ state was altered. Data generated were based on a previously described standard curve, with strain calculated as a percent change in strain from a baseline resting position.[22]

Each knee was tested in the intact, PMCJ tear, and PMCJ repair states. First, anterior tibial translation and ACL strain were tested in the intact knee at 0°, 30°, 60°, and 90° of flexion. A posterior meniscocapsular defect was then generated in each specimen. Using dry arthroscopy, a posteromedial cannulated portal was created under direct visualization. This technique ensured adequate localization of the portal to form the capsular lesion. A No. 11 surgical scalpel was introduced intra-articularly through the cannula and used to separate the posterior horn of the medial meniscus from the posterior joint capsule for a length of approximately 1 cm. A probe verified separation of the meniscocapsular attachment. At this point, the specimens were tested for translation and ACL strain from 0° to 90° of flexion in the PMCJ tear state. The lesion was repaired arthroscopically using the previously created posteromedial cannulated portal. A curved suture passer was first passed through the capsule and then taken through the posterior horn of the medial meniscus. A #2 FiberWire (Arthrex) was passed through the capsule and meniscus using a zero PDS suture shuttle and tied using arthroscopic technique. Each cadaver knee was repaired using three vertical simple sutures placed approximately 3 mm apart (Figure 5). The PMCJ repair specimens were retested for translation and ACL strain from 0° to 90° of flexion.

Statistical Analysis

The study was reviewed and approved by the University of Connecticut Health Center's Human Subjects Protection Office Institutional Review Board. Statistical analysis used a mixed-effects linear regression with Bonferroni correction to determine changes in translation and strain with the progression of various PMCJ conditions. Statistical significance was determined at $P < 0.05$. Stata Statistical Software Release 14 (StataCorp) was used for evaluation.

Results

Incidence

A total of 337 patients ultimately met our inclusion criteria; 44 were

Table 2

Mechanism of Injury for Patients Sustaining Anterior Cruciate Ligament Disruption and Meniscocapsular Separation

Sports		Nonsports	
Soccer	11	Plant/twist	7
Basketball	6	Jump	2
Football	6	Trip	1
Lacrosse	3	Unspecified	2
Skiing	2	Contact	
Ultimate frisbee	2	Football	5
Field hockey	1	Basketball	1
Baseball	1		

found to have a posteromedial meniscocapsular separation, an incidence of 13.1%. Most patients were men (64%), with a mean age of 23 years (Table 1). The time of injury was not available in the clinical notes for 3 of the 44 patients. Of the remaining 41, the average time from injury to surgery was 7.6 months, with a range of 0.25 to 72 months. The median duration from injury to confirmation of the posteromedial meniscocapsular separation was 3 months. The PMCJ lesion was found arthroscopically within 6 months of injury in 76% of patients.

The most frequent cause of injury was sports participation (73%), with soccer accounting for a third of sports injuries (Table 2). Twenty-six (81%) of the 32 sports injuries were due to a noncontact mechanism, whereas six (19%) were contact injuries. Of the nonsports injuries, most were due to a planting or twisting mechanism. Eighteen patients (41%) were found to have additional intra-articular pathology at the time of surgery. Thirty-two percent of patients had concomitant chondral injury, and 21% had evidence of lateral meniscal tear.

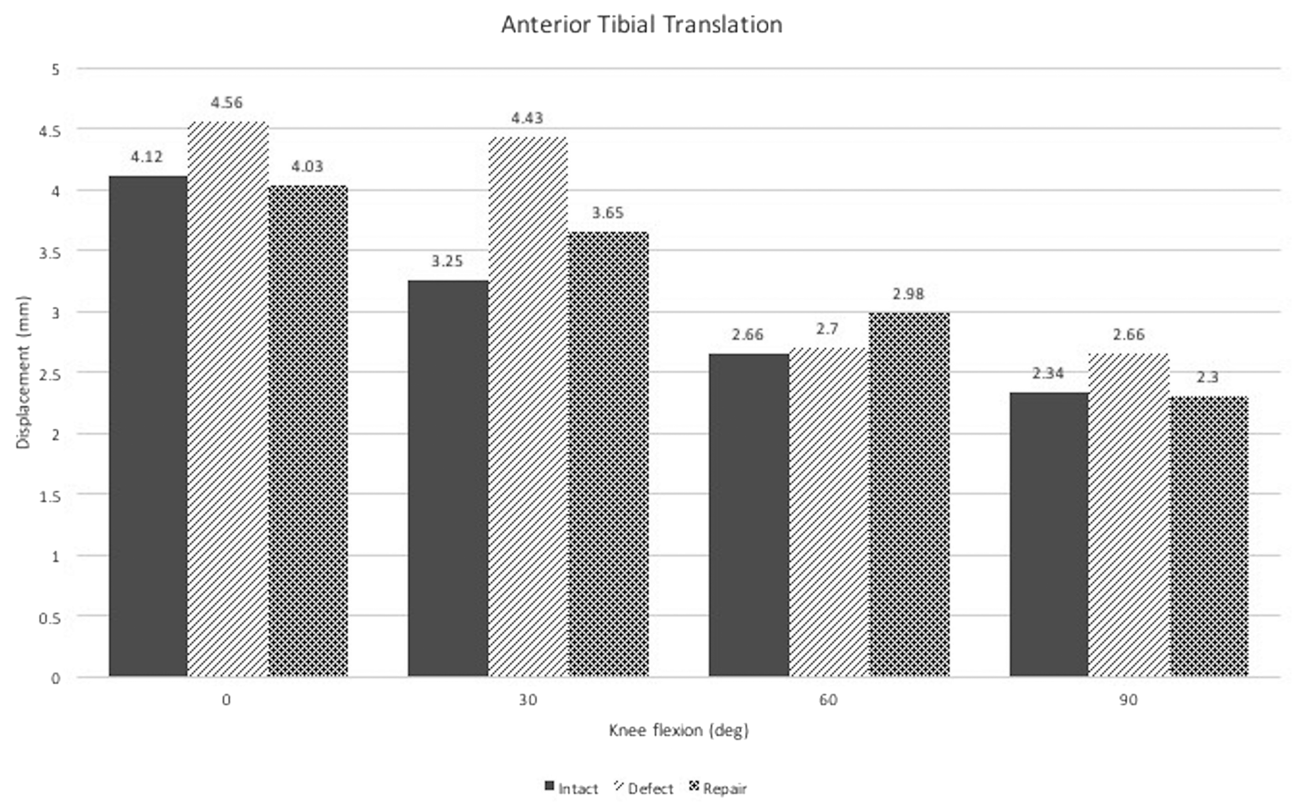
Anterior Tibial Translation

Anterior displacement of the tibia was greatest with the knee in full extension for the intact (4.12 ± 1.23 mm), PMCJ tear (4.56 ± 0.69 mm), and PMCJ repair (4.03 ± 1.25 mm) testing states (Figure 6). At 0° flexion, no statistically significant difference was found in tibial translation in knees with PMCJ lesion (P = 0.68) or PMCJ repair (P = 1.00) compared to intact knees. At 30° flexion, anterior translation measured 3.25 ± 0.67 mm in the intact knee, 4.43 ± 0.82 mm with PMCJ tear, and 3.65 ± 0.86 mm with repair. At 30° flexion, compared with intact specimen, anterior tibial translation was statistically different ($P < 0.01$) with PMCJ lesion, but not statistically different after PMCJ repair (P = 0.72). At 60° flexion, anterior tibial translation was 2.66 ± 0.70 mm in intact specimen, 2.70 ± 0.42 mm after PMCJ tear, and 2.98 ± 0.67 mm after repair. No statistically significant differences were found in translation after PMCJ tear (P = 1.00) or PMCJ repair (P = 0.47) compared with intact specimen at 60° flexion. At 90° flexion, anterior translation measured 2.34 ± 0.57 mm in the intact knee, 2.6 ± 0.44 mm with PMCJ tear, and 2.30 ± 60.59 mm with repair. No statistically significant differences were found in translation after PMCJ tear (P = 0.56) or PMCJ repair (P = 1.00) compared with intact knees at 90° flexion.

Anterior Cruciate Ligament Strain

With the resting position in full extension, strain on the anteromedial bundle of the ACL increased by 2.4% in intact knees, 3.5% with PMCJ tears, and 2.1% after PMCJ repair after an anterior tibial translational force. However, differences in ACL strain were not statistically significant after PMCJ tear (P = 0.11) or PMCJ repair (P = 1.00) compared with intact specimen (Figure 7). From the resting position at 30° flexion, ACL strain increased by 3.7% in intact knees, 4.6% with PMCJ tears, and 2.8% after PMCJ repair. Compared with the native knee, ACL strain in knees with PMCJ lesions were statistically different ($P < 0.01$), but similar after repair (P = 1.00) With the resting position at 60° flexion, ACL strain increased by 3.5% in intact knees, 5.1% with PMCJ tears, and 2.9% after PMCJ repair. ACL strain increased was not statistically different after PMCJ tear (P = 0.06) or PMCJ repair (P = 1.00) compared with intact specimen. From the resting position at 90° flexion, ACL strain increased by 3.2% in intact knees, 4.8% with PMCJ tears, and 3.3% after PMCJ repair. Compared with the native knee, ACL strain in knees with PMCJ lesions were statistically

Figure 6



Magnitude of anterior tibial translation at 0°, 30°, 60°, and 90° of flexion.

different (P = 0.01), but similar after repair (P = 1.00).

Summary

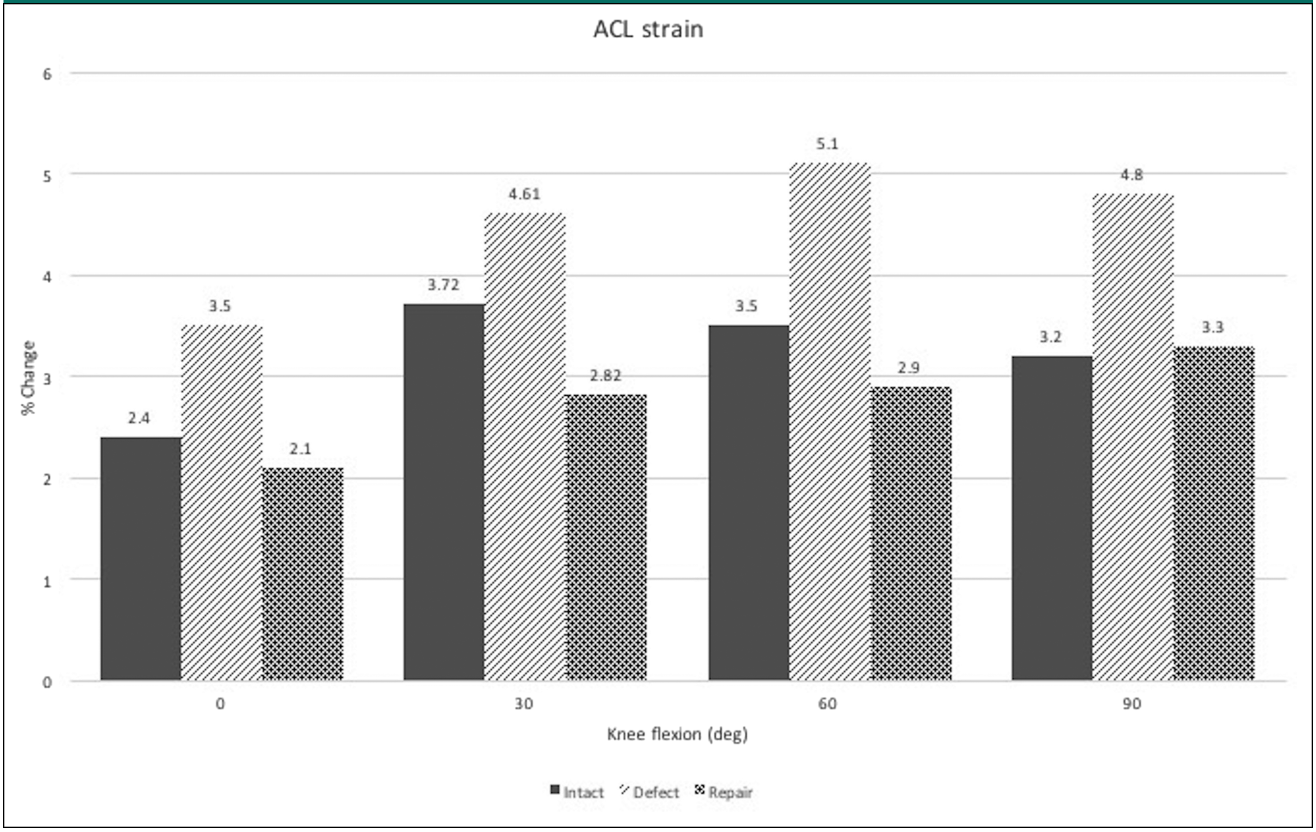
Compared with intact knees, specimen with PMCJ tears had statistically increased anterior tibial translation at 30° and statistically increased ACL strain at 30° and 90°. Compared with knees with PMCJ tears, PMCJ repair resulted in a statistically significant reduction of ACL strain at 0°, 30°, 60°, and 90° of flexion.

Discussion

The clinical arm of this study aimed at determining the incidence of posterior meniscocapsular separation after ACL disruption. Over a 7-year period, the incidence of PMCJ lesion was 13.1% in patients who underwent primary ACL reconstruction. One of the difficulties when determining the true incidence of PMCJ disruption is the variable definition of "ramp lesion."[11] Strobel[23] and Woods and Chapman[15] originally described ramp lesions specifically referring to injuries to the meniscocapsular junction of the posterior horn of the medial meniscus. In a prospective investigation, Bollen[17] reported a PMCJ incidence of 9.3% in 183 consecutive patients undergoing ACL reconstruction and zero in 700 patients without ACL deficiency who underwent knee arthroscopy. Smith and Barrett[1] investigated 575 patients with concomitant ACL and meniscal tears and found only 3.1% had meniscocapsular lesions. The authors did not note how many of these tears were medial lesions, but their reported incidence was much lower than the results of this study. This phenomenon could be due to injury chronicity, which may increase the risk of posterior horn medial meniscal and meniscotibial injury.[12,14] Most (76%) of our patients were diagnosed with PMCJ tear arthroscopically within 6 months of injury, whereas a similar percentage (73.3%) of their patients were identified within 6 weeks.

The detection of PMCJ injuries can be difficult to identify whether by MRI or arthroscopically. De Maeseneer and colleagues[24,25] correlated MRI of PMCJ tears in cadavers with radiologic findings in patients with a knee MRI and found perimeniscal fluid and an irregular meniscal outline to correlate best; however, the authors cautioned that even these

Figure 7

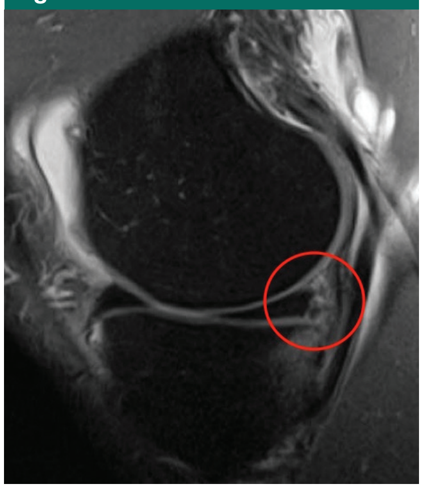


Percent change in anterior cruciate ligament strain at 0°, 30°, 60°, and 90° of flexion.

findings could be confused with normal anatomy. In 23 patients with known medial PMCJ separation, Rubin et al[26] examined preoperative MRI for various parameters indicating injury. Positive predictive values for meniscal displacement (8%), meniscocapsular signal change (10%), fluid deep to the MCL (6%), and fluid superficial to the MCL (11%) were quite poor. Because MRI is performed with the knee extended, the lesion may reduce, making detection more difficult.[17] In our study, the attending orthopaedic surgeon identified a continuous superior to inferior fluid outline through the peripheral posterior horn of the medial meniscus on T2-weighted sagittal magnetic resonance images, which specifically indicates PMCJ pathology[27] (Figure 8). In our cohort, this technique was 77% sensitive and 84% specific for arthroscopically identified PMCJ tears. Previous reports indicate that without viewing or probing the medial posterior meniscocapsular junction through a posteromedial portal, 15.4% to 16.8% of lesions may be missed.[13,28] In our opinion, utilization of the 18-gauge spinal needle technique to probe this area reduces the risk of missing such lesions.

A missed PMCJ lesion can alter the natural mechanics of the knee. Ahn et al[29] noted that peripheral longitudinal tears of the posterior horn of the medial meniscus immediately adjacent to the capsular attachment resulted in an increased anterior translation with ACL deficiency. Anterior tibial translation increased by 87% to 101% from 0° to 60° of knee flexion, with the lowest at 90°

Figure 8



A T2-weighted sagittal magnetic resonance image of the right knee showing fluid extending around the posterior border of the medial meniscus indicating meniscocapsular separation.

(48%). Our study found that anterior laxity increased by 1.5% to 36% from 0° to 90° flexion; however, we tested only with an anterior translation force, whereas Ahn et al[29] included an axial compressive force. Repair in both studies reduced anterior laxity by 10% to 18% at all flexion angles, except at 60°. Stephen et al[30] reported a 42% and 33% reduction in anterior tibial translation at 30° and 90° flexion, respectively, with PMCJ repair after ACL reconstruction. Similar to our study, PMCJ repair corrected a greater amount of laxity at 30° flexion; however, our investigation examined the knee with the native ACL rather than a reconstructed ligament.

We hypothesized that PMCJ tears would increase both anterior tibial translation and strain of the anteromedial bundle of the ACL. In the PMCJ tear state, ACL strain increased by 24% to 50% up to 90° flexion. These results were statistically significant at 30° and 90° and trending toward significance at 60°. PMCJ repair reduced ACL strain by 31% to 43%; all reductions in strain were statistically significant for every flexion angle. In fact, PMCJ repair reduced ACL strain by 12.5% to 24% compared with the intact knees up to 60° of flexion. At 90°, ACL strain after PMCJ repair state was 3% greater than the intact state. These results affirm the need for further research regarding the recognition and treatment of PMCJ disruption with ACL reconstruction. Protection of the ACL graft to maintain ligamentous stability may be critical for long-term graft survival. To the best of our knowledge, our study is the first to examine the potential negative effect of a missed PMCJ lesion on ACL strain. Increased ACL strain could lead to early graft failure and continued instability of the knee. In the laboratory setting, repair of this lesion can reduce strain on the ACL up to 43%, which may help with graft survival. Our study may indicate that repair of PMCJ lesions could confer a degree of biomechanical protection with regard to strain seen by the anteromedial bundle of the ACL. However, the clinical implications of these findings are yet unknown, and further investigation is warranted.

Limitations

Retrospective reviews involve several limitations. Patients with PMCJ lesions may have been missed during record review, and some records may not have included imaging of the meniscocapsular junction. Such errors would be greatly reduced with a prospective examination and may provide a truer indicated of lesion incidence. Patients who had missed PMCJ lesions would also not have been included; however, we suspect this group to be small because the senior author examines the meniscocapsular junction on all patients with ACL injuries.

Limitations also include those inherent with cadaver study. The testing protocol did not include multiplanar forces and flexion only to 90°, which may be different from knee mechanics seen clinically. Cadavers were approximately 20 years older than PMCJ tear patients seen clinically, and retesting of the same specimen in various situations may alter the mechanics of the specimen after each state. ACL strain was determined from the native ACL and not after ACL reconstruction. However, although this may be considered a limitation, we feel it represents the "perfect" ACL reconstruction. Evaluating the effects of PMCJ tears on ACL strain after reconstruction would introduce other variables that would be difficult to control in a laboratory environment. It is conceivable that the effect of a PMCJ lesion on an ACL graft could be greater. The study examined only a specific repair technique, and various PMCJ repair methods may affect knee mechanics differently. Finally, the clinical implications of the biomechanical findings were not investigated.

Conclusion

Posterior medial meniscocapsular separation is not an unusual concomitant injury with ACL disruption, with an incidence of 13.1% in our cohort. PMCJ tears can lead to increased strain on the native ACL. PMCJ repair can reduce ACL strain to magnitudes more reflective of the preinjury state.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 3 are level I studies. References 1 and 26 are level II studies. Reference 12 is a level III studies. References 2, 7, 13, 14, 15, 16, and 28 are level IV studies. Reference 4 is a level V report or expert opinion.

References printed in **bold type** are those published within the past 5 years.

1. Smith JP III, Barrett GR: Medial and lateral meniscal tear patterns in anterior cruciate ligament-deficient knees: A prospective analysis of 575 tears. *Am J Sports Med* 2001;29:415-419.
2. Tandogan RN, Taser O, Kayaalp A, et al: Analysis of meniscal and chondral lesions accompanying anterior cruciate ligament tears: Relationship with age, time from injury, and level of sport. *Knee Surg Sports Traumatol Arthrosc* 2004;12:262-270.
3. **Cox CL, Huston LJ, Dunn WR, et al: Are articular cartilage lesions and meniscus tears predictive of IKDC, KOOS, and Marx activity level outcomes after anterior cruciate ligament reconstruction? A 6-year multicenter cohort study. *Am J Sports Med* 2014;42:1058-1067.**
4. Bellabarba C, Bush-Joseph CA, Bach BR Jr: Patterns of meniscal injury in the anterior

cruciate-deficient knee: A review of the literature. *Am J Orthop (Belle Mead NJ)* 1997;26:18-23.

5. Warren RF, Levy IM: Meniscal lesions associated with anterior cruciate ligament injury. *Clin Orthop Relat Res* 1983;172:32-37.

6. Wickiewicz TL: Meniscal injuries in the cruciate-deficient knee. *Clin Sports Med* 1990;9:681-694.

7. Ahn JH, Lee YS, Yoo JC, Chang MJ, Koh KH, Kim MH: Clinical and second-look arthroscopic evaluation of repaired medial meniscus in anterior cruciate ligament-reconstructed knees. *Am J Sports Med* 2010;38:472-477.

8. Slauterbeck JR, Kousa P, Clifton BC, et al: Geographic mapping of meniscus and cartilage lesions associated with anterior cruciate ligament injuries. *J Bone Joint Surg Am* 2009;91:2094-2103.

9. Noyes FR, Chen RC, Barber-Westin SD, Potter HG: Greater than 10-year results of red-white longitudinal meniscal repairs in patients 20 years of age or younger. *Am J Sports Med* 2011;39:1008-1017.

10. Cannon WD Jr, Morgan CD: Meniscal repair: Arthroscopic repair techniques. *Instr Course Lect* 1994;43:77-96.

11. **Chahla J, Dean CS, Moatshe G, et al: Meniscal ramp lesions: Anatomy, incidence, diagnosis, and treatment. *Orthop J Sports Med* 2016;4:2325967116657815.**

12. Liu X, Feng H, Zhang H, Hong L, Wang XS, Zhang J: Arthroscopic prevalence of ramp lesion in 868 patients with anterior cruciate ligament injury. *Am J Sports Med* 2011;39:832-837.

13. **Sonnery-Cottet B, Conteduca J, Thaunat M, Gunepin FX, Seil R: Hidden lesions of the posterior horn of the medial meniscus: A systematic arthroscopic exploration of the concealed portion of the knee. *Am J Sports Med* 2014;42:921-926.**

14. Mariani PP: Posterior horn instability of the medial meniscus a sign of posterior meniscotibial ligament insufficiency. *Knee Surg Sports Traumatol Arthrosc* 2011;19:1148-1153.

15. Woods GW, Chapman DR: Repairable posterior menisco-capsular disruption in anterior cruciate ligament injuries. *Am J Sports Med* 1984;12:381-385.

16. Weiss CB, Lundberg M, Hamberg P, DeHaven KE, Gillquist J: Non-operative treatment of meniscal tears. *J Bone Joint Surg Am* 1989;71:811-822.

17. Bollen SR: Posteromedial meniscocapsular injury associated with rupture of the anterior cruciate ligament: A previously unrecognised association. *J Bone Joint Surg Br* 2010;92:222-223.

18. Gillquist J, Hagberg G, Oretorp N: Arthroscopic visualization of the posteromedial compartment of the knee joint. *Orthop Clin North Am* 1979;10:545-547.

19. Ogilvie-Harris DJ, Biggs DJ, Mackay M, Weisleder L: Posterior portals for arthroscopic surgery of the knee. *Arthroscopy* 1994;10:608-613.

20. Nelson EW, LaPrade RF: The anterior intermeniscal ligament of the knee. An anatomic study. *Am J Sports Med* 2000;28:74-76.

21. Beynnon BD, Amis AA: In vitro testing protocols for the cruciate ligaments and ligament reconstructions. *Knee Surg Sports Traumatol Arthrosc* 1998;6(suppl 1):S70-S76.

22. Spang JT, Dang AB, Mazzocca A, et al: The effect of medial meniscectomy and meniscal allograft transplantation on knee and anterior cruciate ligament biomechanics. *Arthroscopy* 2010;26:192-201.

23. Strobel M: *Manual of Arthroscopic Surgery*. Berlin; New York, Springer-Verlag, 2002.

24. De Maeseneer M, Lenchik L, Starok M, Pedowitz R, Trudell D, Resnick D: Normal and abnormal medial meniscocapsular structures: MR imaging and sonography in cadavers. *AJR Am J Roentgenol* 1998;171:969-976.

25. De Maeseneer M, Shahabpour M, Vanderdood K, Van Roy F, Osteaux M: Medial meniscocapsular separation: MR imaging criteria and diagnostic pitfalls. *Eur J Radiol* 2002;41:242-252.

26. Rubin DA, Britton CA, Towers JD, Harner CD. Are MR imaging signs of meniscocapsular separation valid? *Radiology* 1996;201:829-836.

27. Hash TW II: Magnetic resonance imaging of the knee. *Sports Health* 2013;5:78-107.

28. **Peltier A, Lording TD, Lustig S, Servien E, Maubisson L, Neyret P: Posteromedial meniscal tears may be missed during anterior cruciate ligament reconstruction. *Arthroscopy* 2015;31:691-698.**

29. Ahn JH, Bae TS, Kang KS, Kang SY, Lee SH: Longitudinal tear of the medial meniscus posterior horn in the anterior cruciate ligament-deficient knee significantly influences anterior stability. *Am J Sports Med* 2011;39:2187-2193.

30. **Stephen JM, Halewood C, Kittl C, Bollen SR, Williams A, Amis AA: Posteromedial meniscocapsular lesions increase tibiofemoral joint laxity with anterior cruciate ligament deficiency, and their repair reduces laxity. *Am J Sports Med* 2016;44:400-408.**