Review Article

Meniscal and Chondral Pathology Associated With Anterior Cruciate Ligament Injuries

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Abstract

Anterior cruciate ligament (ACL) ruptures are commonly associated with meniscal and articular cartilage injuries, and the presence of these defects influences both short- and long-term outcomes. Multiple variables are predictive of this pathology including time from injury, age, and sex. Revision ACL reconstructions demonstrate higher rates of chondral injury than primary reconstructions. Menisci are important secondary stabilizers of the knee in the setting of ACL deficiency, and specific tear types are more consistently associated with ACL injury. Successful outcomes with multiple treatment options for meniscal tears in conjunction with ACL reconstruction have been reported. Maintaining meniscal integrity may be protective of both joint surfaces and graft stability in the long term; however, clear treatment recommendations for tear subtypes remain ill defined. High-grade chondral defects have the most consistent and potentially largest negative effect on long-term patient-reported outcomes; however, optimal treatment is also controversial with successful results demonstrated with several modalities including benign neglect.

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Approximately 50% of primary anterior cruciate ligament (ACL) ruptures and over 90% of failed reconstructions will have coexisting cartilage and/or meniscal pathology.[1-4] Multiple factors contribute to joint surface injury in association with ACL tears, and the appropriate management of these concomitant lesions is an area of ongoing study. Recent literature has provided insight into the biomechanical interaction between the ACL and meniscal structures, garnering an improved understanding of injury patterns associated with ACL tears. Many studies have demonstrated a notable clinical association between chondral and meniscal pathology; however, optimal treatment of specific lesions remains an area of controversy.

Epidemiology

The incidence of associated cartilage and meniscal pathology with ACL tears varies widely in the literature. Recent studies suggest that between one and two thirds of patients will present with an associated meniscal tear in conjunction with a primary ACL rupture[1,3,5,6] and that approximately one fourth of patients will have combined medial and lateral tears.[5] The rates of chondral injuries with ACL ruptures are inconsistently reported because of variability in grading and chronicity. Variation in defect classification also exists with the Outerbridge and International Cartilage Restoration Society scales most commonly used. Regardless of the system used, virtually all studies

Table 1

Variables Associated With Chondral and Meniscal Pathology in Primary Anterior Cruciate Ligament Tears

Factor	Level of Evidence	Patients	Time From Injury	Increasing Age	Male Sex
Granan et al[3]	2	3,475	CD	CD	MT
	—	—	MT	—	—
Slauterbeck et al[5]	2	1,104	MMT: >3 mo	MMT, CD (MFC)	MMT, LMT, CD
	—	—	MMT/LMT/CD: >12 mo	—	—
Chhadia et al[9]	3	1,252	MMT, CD: >12 mo	CD	LMT, CD
Røtterud et al[10,a]	2	15,783	CD: >12 mo	CD	CD
Kluczynski et al[1,b]	3	541	MMT	CD	LMT, MMT

BMI = body mass index, CD = chondral defect, LMT = lateral meniscal tear, MFC = medial femoral condyle, MT = meniscal tear side unspecified, MMT = medial meniscal tear
[a] Grade 3, 4 CD; no MT reported.
[b] Linear association with an increasing number of instability episodes up to 5.

distinguish between "low-grade" (softening/fibrillations/slight fissuring) versus "high-grade" (deep fissuring/exposed subchondral bone) lesions, which correlates with grades 0 to 2 and 3 to 4 on either scale, respectively.[2,3,6-8] A systematic review of ACL reconstructions performed within 3 months of injury reported rates of chondral injury ranging from 16% to 46%.[7] However, high-grade defects were the lowest in frequency (16%), and other studies have reported rates of high-grade lesions to be as low as 7% to 9% irrespective of chronicity.[2,8]

Time from Injury

Several large level II and III observational studies have reported on the timing of ACL reconstruction and the observed incidence of associated pathology[1,3,5,9,10] (Table 1). Consistent findings include higher rates of both meniscal and chondral pathology with increasing time from initial injury to surgical reconstruction and have led some authors to conclude that early ligamentous stabilization may prevent secondary damage to the joint.[3,11] A large level II prospective cohort found that surgical delay increased rates of meniscal tears and chondral lesions by 1% per month and that the presence of a meniscal tear doubled the likelihood of an associated articular cartilage defect.[3] Additional studies have reported that medial meniscal tears are most prone to secondary injury with increasing time from surgery.[1,2,9,12] A delay as little as 6 to 12 weeks from point of injury has been shown to markedly increase the rate of medial meniscal tears (8% to 19%), whereas delays of greater than 1-year result in increased number, size, and grade of chondral defects.[1,5] Previous reports have cited higher rates of lateral meniscal tears in acute injuries, but with advancing chronicity, medial meniscal tear rates increase while lateral meniscal tears remain relatively constant.[1,12] Of note, the authors' definition of "chronicity" was based on the occurrence of secondary episodes of instability and not specific time intervals. Recent literature has also supported this observation with the increasing number of patient-reported instability episodes having the highest association with the risk of secondary medial meniscal tears but no association with lateral meniscal tears.[1]

Patient Specific Variables

Patient demographics also influence the type and degree of associated pathology with ACL injuries. Such variables include age and sex (Table 1) as well as body mass index and sport participation. Several studies have reported on increasing age as a risk factor for medial meniscal tears and chondral defects; however, authors have also observed the positive association between age and surgical delay, which likely contributes to this finding.[5,9] However, in studies that specifically evaluate grades of chondral defects, older patients, on average, have higher-grade lesions than younger patients.[3,5,10] Males consistently demonstrate higher rates of meniscal tears than females.[1,3,5,9,10] Although less frequently reported, obesity has been associated with higher rates of chondral defects (odds ratio [OR], 2.63; CI, 1.10 to 6.28).[1] Sport participation is less clear with some reports finding no increased risk for chondral or meniscal pathology.[1] However, using soccer as a referent as the most common sport associated with ACL tears, a large multinational cohort observed basketball to have significantly higher rates of lateral meniscal tears (OR, 1.28; CI, 1.06 to 154), chondral defects (OR, 1.23; CI, 1.01 to 1.51), and combined meniscal/chondral lesions (OR, 1.38; CI, 1.11 to 1.72)[13] and men's team handball to have an increased risk for lateral meniscal tears (OR, 1.27;

Table 2

Patient-reported Outcomes Based on Combined Chondral/Meniscal Pathology/Treatment

Factor	Level of Evidence	Patients (Mean Age and Follow-up) (yr)	Lateral Meniscal Tear	Medial Meniscal Tear	Chondral Defects (Grade 3, 4)
Shelbourne et al[11]	3	928 (23, 8.6)	Worse outcomes: partial lateral meniscectomy: (IKDC)	Worse outcomes: partial medial meniscectomy: (IKDC)	Worse outcomes: all locations: (IKDC)
Røtterud et al[2]	2	8,476[2,30]	No statistically significant findings	No statistically significant findings	Worse outcomes: all sizes, location unspecified (KOOS-all subscales)
Cox et al[6,a]	1	1,307[6,23]	Improved outcomes: nontreatment: (IKDC, KOOS-all subscales) & >50% lateral meniscectomy: (IKDC, KOOS-symptoms/activity)	Improved outcomes: >50% medial meniscectomy: (KOOS-pain)	Worse outcomes: MFC, LFC, MTP: (IKDC), MFC, LFC, MTP, LTP, trochlea: (KOOS-multiple subscales) & MFC (Grade 4 only): (Marx-K)
	—	—	—	Worse outcomes: <33% medial meniscectomy: (IKDC); medial meniscal repair: (IKDC, KOOS)	—
Dunn et al[38,a]	1	1,411[6,23]	Improved outcomes: nontreatment & >50% lateral meniscectomy (SF-36)	No statistically significant findings	Worse outcomes: LTP (SF-36)
MARS group[4,b]	2	989[2,26]	Worse outcomes: previous partial lateral meniscectomy (IKDC, KOOS/WOMAC-all subscales)	Worse outcomes: previous partial medial meniscectomy (KOOS-symptoms, pain, WOMAC-stiffness)	Worse outcomes: trochlea (IKDC, KOOS/WOMAC-6/8 subscales), all other locations-various subscales

IKDC = International Knee Documentation Committee, KOOS = Knee injury and Osteoarthritis Outcome Score, LFC = lateral femoral condyle, LTP = lateral tibial plateau, MFC = medial femoral condyle, MTP = medial tibial plateau, SF-36 = short-form 36, PCS = physical component summary
[a] Separate reports on the same patient population.
[b] Revision data.

CI, 1.10 to 1.48) and high-grade chondral defects (OR, 2.36; CI, 1.33 to 4.19).[10,13]

Failed Reconstructions

Recurrent knee instability secondary to a failed ACL reconstruction often results in progression of secondary injury patterns with rates exceeding those of primary reconstruction. The incidence of meniscal tears is as high as 75% and chondral injuries 67%, with over 90% of patients presenting with either lesion type.[4,14] In a level II study comparing 508 primary with 281 revision ACL reconstructions, the revision cases had a significantly higher incidence of high-grade defects involving the lateral femoral condyle (OR, 1.73; CI, 1.02 to 2.93; $P = 0.04$) and patellofemoral compartment (OR, 1.70; CI, 1.01 to 2.84; $P = 0.04$) irrespective of meniscal status. However, rates of lateral meniscal tears were lower in the revision group (OR, 0.54; CI, 0.39 to 0.75; $P < 0.01$), whereas medial meniscal tear rates were similar.[15] Additionally, high-grade chondral defects were associated with previous partial meniscectomies of the corresponding compartment regardless of primary or revision status. Similarly, a level II cohort evaluating 725 revision ACL reconstructions found that a previous meniscectomy was associated with a grade 2 or higher defect in any compartment including patellofemoral ($P < 0.0001$).[14] Furthermore, after adjusting for age, partial meniscectomies resulted in higher rates of chondral injury compared with normal menisci ($P < 0.0001$) or previous meniscal repairs in either compartment (P = 0.003) although lateral meniscal repairs were more protective of their respective articular surfaces than medial meniscal repairs (P = 0.03). In a large level II study comparing 989 patients undergoing revision reconstruction with their respective primary reconstruction findings, rates of medial meniscal tears increased slightly, 38% to 45%, and lateral meniscal tears increased 20% to 37%. A complete analysis of chondral lesions was limited by the lack of primary data; however, at the time of revision, 43% of patients had at least grade 2 changes of the medial femoral condyle, 29% lateral femoral condyle, 30% patellar, and 20% trochlear.[4] These studies suggest that although the overall rates of chondral injury are higher in revision cases, intact or preserved menisci at the time of primary reconstruction may decrease the incidence of associated chondral lesions observed in failed reconstructions. Additionally, patellofemoral chondrosis is markedly more likely to develop in patients undergoing revision than in primary cases.

Meniscal Tears

Biomechanics

Interest in the mechanism of injury with ACL tears and the associated stress imparted to supporting structures has led to several cadaver studies evaluating the role of the menisci in knee stability. The effect of total meniscectomies in the setting of ACL deficiency was assessed with simulated pivot shift and Lachman maneuvers.[16] A total medial meniscectomy resulted in markedly increased anterior tibial translation with Lachman maneuvers (11.4 ± 5.2 versus 5.9 ± 3.1 mm; $P < 0.001$) compared with an ACL tear alone, but no notable difference with pivot shift. Conversely, a total lateral meniscectomy resulted in significantly higher tibial translation with pivot shift (19.0 ± 4.6 versus 13.9 ± 4.3 mm; $P < 0.05$) and not Lachman maneuvers. Although total meniscectomies are relatively uncommon, the study demonstrates the roles of the medial and lateral menisci in anterior and rotatory stability, respectively.

Additional laboratory investigations have evaluated specific tear types with similar findings. The effects of peripheral longitudinal posterior horn medial meniscal tears (mean 28 mm length tear) in the setting of ACL deficiency were evaluated.[17] Findings included significant increases in anterior translation with simulated Lachman maneuvers at flexion angles up to 60° ($P < 0.05$) but no differences with pivot shift. Furthermore, the peripheral tear resulted in the same degree of instability as a total medial meniscectomy. After meniscal repair, however, stability was restored to the isolated ACL-deficient state. A similar cadaver study evaluated the effect of a posteromedial meniscocapsular defect with ACL insufficiency.[18] Maximal anterior translation (mean, 14 mm; $P < 0.001$) occurred with simulated Lachman maneuvers at 30° flexion in knees with a posteromedial meniscocapsular lesion. Repair (arthroscopic, all-inside) of the meniscocapsular defect restored translation to that of the isolated ACL-deficient state (mean, 10.1 mm; P = 001). After patellar tendon ligament reconstruction, stability was further improved to 4.1 mm but was then destabilized to 7.1 mm with resectioning of the meniscocapsular repair (P = 0.01). These studies suggest that the peripheral, posteromedial meniscal complex contributes markedly to the anteroposterior stability of the knee in the ACL-deficient state.

The effect on stability of posterolateral root avulsions with ACL tears has also been studied. A cadaver investigation evaluated simulated pivot shift and anterior tibial translational forces at varying degrees of knee flexion before and after arthroscopically creating a posterolateral root tear (including disruption of meniscofemoral ligaments). Progressive increases in tibial translation with pivot shift was noted from ACL intact (2.62 ± 0.53 mm), to ACL resection (6.01 ± 0.51 mm; P = 0.0005), and to ACL resection/root tear (8.13 ± 0.75 mm; $P < 0.0001$). However, the root tear did not change stability with simulated Lachman maneuvers.[19] In a similar study, isolated root tears with and without meniscofemoral attachment resections were assessed in cadaver knees with simulated pivot shift, internal rotation stress, and anterior drawer all at varying degrees of knee flexion. The authors found a statistically significant 1-mm ($P < 0.05$) increase in anterior tibial translation during pivot-shift testing at 20° and 30° with combined ACL/lateral meniscal root tears compared with isolated ACL deficiency. Conversely, the authors found a statistically significant 1.1-mm ($P < 0.05$) increase in anterior translation with anterior drawer at 30° and 60° between these groups. Furthermore, the lateral meniscal root insertion seemed to protect against excess internal rotation at higher degrees of knee flexion regardless of ACL status. The authors concluded that injury to the posterolateral root insertion may result in higher-grade pivot-shift findings clinically and meniscofemoral ligament status further contributes to rotational stability.[20]

Tear Subtypes

Specific tear patterns are often observed in conjunction with ACL ruptures. Variables include the location and orientation of tears, as well as injury to capsular and root attachments. In terms of location, 95% and 77% of medial and lateral menisci, respectively, involve the posterior horn.[1] More specifically, the peripheral and central zones of the posterior horns are the most common locations of tears, independent of age or injury chronicity.[5] However, these zone-specific data fail to report on root and capsular attachments, specifically. In terms of orientation, posterior vertical, longitudinal tears are commonly reported acutely, with degenerative and horizontal patterns becoming more prevalent in chronic cases.[21-24] Unstable bucket-handle morphology is also commonly recognized. In review of over 2,000 ACL reconstructions, the rates of medial and lateral bucket-handle tears were 7% and 23%, respectively.[22,23]

A more recently investigated tear pattern is the aforementioned posteromedial meniscocapsular defect, or "ramp" lesion[25] (Figure 1). The pathoanatomy is not entirely clear and possibly includes disruption of meniscotibial ligament attachments.[26] Authors have observed that this is an underappreciated lesion with MRI sensitivity in detecting ramp lesions ranging widely, 0% to 77%.[25] Two separate studies have reported an incidence of approximately 17% for ramp lesions in association with ACL tears.[26,27] In a consecutive series of 302 patients, investigators found an overall 41% rate of medial meniscal disruptions, of which 40% of these were ramp lesions (50/302; 16.6%). Of these capsular defects, 23% were diagnosed viewing through the intercondylar notch, and an additional 17% required utilization of a posteromedial portal—7% overall rate of "hidden" lesions.[26] Although the overall incidence of medial meniscal tears increases with chronicity, the rates of ramp lesions with surgical delay are less clear with some authors suggesting no increased incidence beyond 6 weeks from the time of injury,[26] whereas other reports observe increasing prevalence up to 24 months after injury.[27] Furthermore, young males seem to sustain the highest rates of ramp tears.[27]

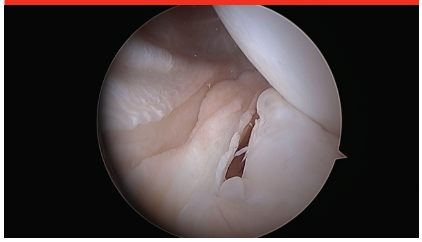
As mentioned previously, there is also increasing interest in the contributions of the posterolateral meniscal root attachments in the ACL-deficient knee. Association of this injury in conjunction with ACL tears is approximately 8% to 14%.[20] Conversely, posteromedial meniscal root avulsions are uncommonly observed with isolated ACL injury, although they have increased association with multiligament injuries, particularly those involving complete medial collateral ligament ruptures.[28]

Treatment

The diversity of meniscal tear patterns encountered in the ACL-deficient knee adds complexity to the treatment decision-making process, and questions still exist regarding the optimal strategies for maximizing outcomes. Treatment options for meniscal tears encountered during ACL reconstruction include débridement, abrasion/trephination, repair, and benign neglect. Acceptable outcomes have been reported with each of these options; however, high-level comparative studies are lacking. In revision cases with substantial meniscal deficiency, allograft transplantation may be considered to improve both stability and chondral protection, but further discussion is beyond the scope of this review.

Several authors have suggested that stable tear patterns are effectively treated with minimal or no intervention.[21,24,29,30] Although the exact definition of a "stable" meniscal tear is somewhat ambiguous, common descriptors often include: nondegenerative, nondisplaceable, incomplete, peripheral, longitudinal, and/or length less than 10 to 15 mm.[21,24,29,30] A recent level IV systematic review evaluated the results of benign neglect of stable meniscal tears during ACL reconstruction. Of 646 tears left in situ, the overall rate of revision surgery was 5.4%. However, medial meniscal tears had higher rates of revision surgery (9.5%) compared with lateral (3%).[24] A level III review with 6-year follow-up of 208 meniscal tears left in situ with ACL reconstruction found that 97.8% and 94.4% of lateral and medial tears required no further intervention, respectively. Risk factors for failure included younger patient age (18.6 versus 25.1; $P = 0.26$) and tear length >10 mm (11.5% versus 3.2%; $P = 0.35$).[30] All failures laterally were greater than 10 mm in length; however, 1/3 of medial failures were <10 mm. A level III case control study assessed patients undergoing trephination of a stable, peripheral medial meniscal tear during ACL reconstruction.[21] At mean 5-year follow-up, no differences were observed in subjective patient outcomes or radiographic grading compared with nontear controls. However, the tear cohort had a significantly higher rate of revision surgery (16.3% versus 5.8%; $P < 0.0001$). A level II prospective randomized study compared trephination/abrasion versus repair of stable (11 to 14 mm) posteromedial meniscocapsular lesions in 73 patients. At minimum 2-year follow-up, no differences were found in patient-reported outcomes, objective stability, or healing rates on follow-up MRI (92% completely healed).[29] Long-term clinical outcomes of unstable ramp lesions left in situ are lacking; however, aforementioned

Figure 1



Seventy degrees arthroscopic view through the intercondylar notch of a posteromedial meniscocapsular separation or "ramp" lesion.

biomechanical data suggest a potential detrimental effect on long-term stability.

Approximately 20% to 30% of ACL reconstructions include an associated meniscal repair.[31] Despite this, no prospective randomized studies have compared treatments/techniques involving unstable meniscal tear patterns with ACL reconstruction. In a level IV meta-analysis including 21 studies and 1,126 patients, failure rates of all-inside meniscal repairs were significantly higher than inside-out (16% versus 10%; $P = 0.016$) despite shorter mean follow-up times (58 versus 76 months).[31] Implant-related complications were also significantly higher with all-inside devices. The authors proposed that the inside-out technique be the current benchmark with ACL reconstruction but acknowledged the need for long-term randomized studies with modern implants. A large level II cohort of 4,691 patients with 2-year follow-up found that only medial meniscal repairs had significantly worse Knee injury and Osteoarthritis Outcome Score (KOOS) subscales compared with isolated ACL reconstructions (Symptoms: $\beta = -2.5$; CI, -4.6 to -0.5; $P = 0.023$, Quality of Life: $\beta = -3.8$; CI, -6.8 to -1; $P = 0.009$). However, all other treatments had no effect, including any lateral meniscal intervention.[32] The authors hypothesized that the respective negative and positive effects of partial meniscectomies and repairs may not be evident with relatively short follow-up. In terms of large, unstable tear patterns, a comparison of inside-out repair versus débridement of bucket-handle tears in patients without chondral damage has been evaluated with nonrandomized level III evidence. Lateral tears were repaired more frequently (74% versus 36%) because of higher rates of degenerative findings medially. In both groups, subjective outcomes (International Knee Documentation Committee [IKDC]) were similar at 7 and 9-year follow-up, respectively. Pain scores were slightly worse with partial lateral meniscectomies compared with repairs ($P = 0.0478$). Of all treatments, the worst overall outcomes were in patients with degenerative medial tears that were repaired ($P = 0.02$). However, the overall clinical success rates for repair of nondegenerative tears exceeded 97% in both compartments.[22,23]

Treatment of posterolateral root avulsions in conjunction with ACL reconstructions remains unclear. Some investigators have recommended repair based on the known biomechanical effect of these injuries in relation to knee stability;[19,20,28] however, clinical data supporting this are limited. Although high-powered studies are lacking, a single level III investigation evaluating 33 patients at a mean follow-up of 10.6 years demonstrated no significant difference in IKDC scores compared with a matched control group (84.6 ± 14 versus 90.5 ± 13; $P = 0.09$). However, the avulsion cohort had increased lateral compartment joint space narrowing radiographically (1.0 ± 1.6 versus 0 ± 1.1 mm; $P < 0.006$).[33] Markedly unstable root tears may be repaired with transosseous sutures (Figure 2).

High-level clinical evidence on the effect of meniscal integrity on postoperative stability is also lacking. One level III review of 482 patients at mean 7.6 years postoperatively found significantly higher KT-1000 side-to-side differences in patients with any medial meniscal resection compared with intact medial menisci (2.6 ± 1.7 versus 2.0 ± 1.5 mm; $P = 0.0065$), but no differences in graft failures were reported.[11] In a recent level III study with median follow-up 26 months, 118 patients were evaluated after anatomic single bundle hamstring tendon autograft ACL reconstruction. The investigators found that medial and lateral meniscal deficiency were the highest risk factors for graft failure (medial: hazard ratio, 15.1; CI, 4.7 to 48.5; $P < 0.001$, lateral: hazard ratio, 9.9, CI, 3 to 33; $P < 0.001$).[34]

Chondral Defects

Natural History

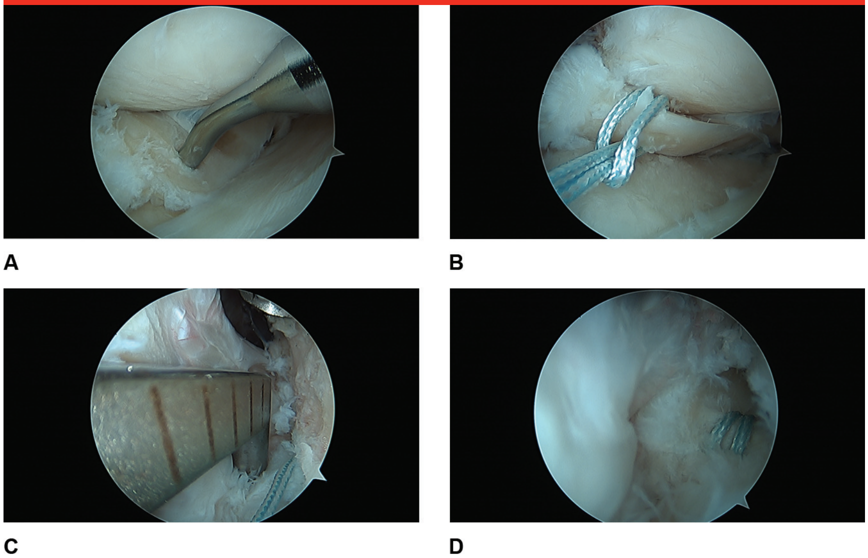
Articular cartilage injury associated with ACL reconstruction possibly has the greatest single effect on long-term subjective outcomes.[11] However, compared with meniscal pathology, the volume of literature focused on treatment of chondral defects in conjunction with ACL reconstruction is significantly inferior. The medial femoral condyle is the most common location reported overall; however, lateral femoral condyle defects are also reported in both acute and chronic cases[5-7] (Figure 3). In a large, level-III review of 2,770 patients, 4.5% were found to have an isolated high-grade chondral defect (treated with benign neglect, mean size 1.7 cm^2) in the absence of meniscal pathology. Compared with a cohort without meniscal or chondral pathology, at mean follow-up 8.7 years, IKDC scores were statistically lower but differences were likely not clinically significant (medial: 1.2; $P = 0.0451$, lateral: 3.1; $P = 0.0047$).[35] A similar study also compared untreated high-grade defects (mean size 2.1 cm^2) at 10- and 15-year follow-up with a matched control group. Findings included no subjective difference at 10 years and statistically, but again, not likely clinically significant, lower total IKDC scores at 15 years (79.6 versus 83.7; $P = 0.031$).[8]

Bone contusion patterns have long been recognized in association with ACL injury with questionable long-term effect on articular cartilage. The most common location for this finding is the lateral tibial plateau followed by the lateral femoral condyle.[36] A recent review found no correlation between severity or volume of bony contusions with clinical outcomes after ACL reconstruction. However, 21% of lateral contusions were associated with a "clinically significant" chondral defect (defined as Outerbridge ≥2) and resulted in markedly worse outcomes at all measured time points (Figure 4). Notably, patients with these defects were on average older (33.9 versus 26.4 years) and heavier (body mass index, 27.8 versus 24.3) than isolated contusion patients.[36]

Repair Techniques

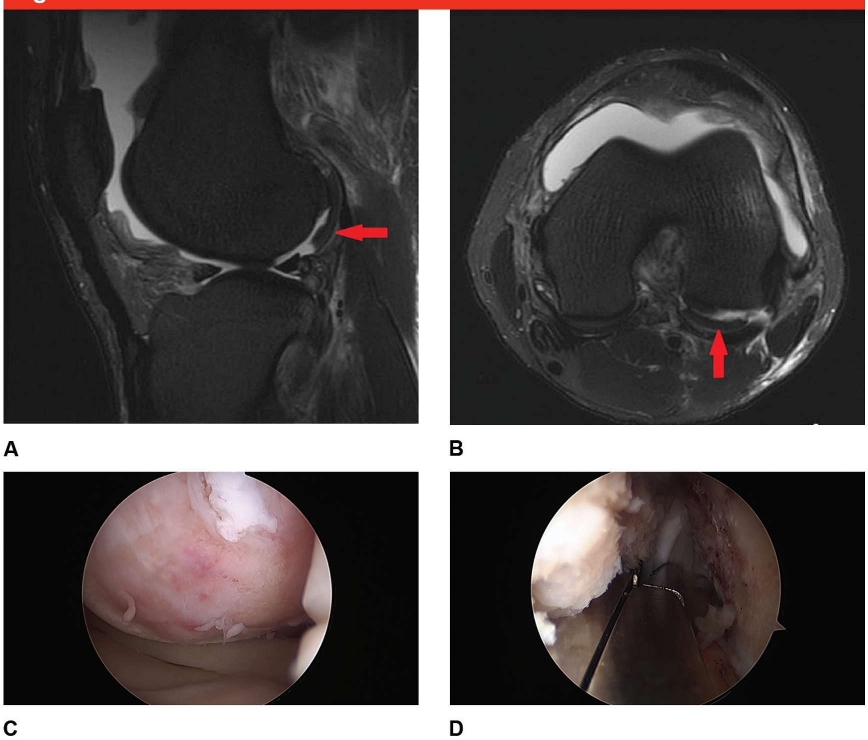
High-level studies evaluating ACL reconstruction with concurrent cartilage repair are lacking. Techniques described include chondroplasty, microfracture, autologous chondrocyte implantation, and osteochondral autograft/allograft transplantation. Reviews consistently report successful outcomes; however, most of these studies are level IV case series.[7] In a level II, nonrandomized comparison of microfracture, débridement, or benign neglect of full-thickness cartilage defects in 357 patients (mean age, 36) at the time of ACL reconstruction, the authors noted at 2-year follow-up that KOOS subscales of Sports/Recreation and Quality of Life were significantly lower with microfracture ($\beta = -8.6$; 95% CI, -16.4 to -0.7, and $\beta = -7.2$; 95% CI, -13.6 to -0.8) regardless of age, defect size, or associated meniscal pathology. No notable difference between débridement and benign neglect was found.[37] A prospective, randomized level II (nonblinded) study comparing osteochondral autograft transplantation, microfracture, and débridement of high-grade defects (mean, 2.6 cm^2) in conjunction with ACL reconstruction found at mean 36-month follow-up superior results with osteochondral autograft transplantation compared with microfracture

Figure 2



Unstable lateral meniscal root tear, displaced into joint space (**A**). Root secured with racking stitch (**B**). Drill guide used to create a docking tunnel for repair (**C**). Final repair with sutures secured through the tibia (**D**).

Figure 3



Massive lateral femoral condyle chondral defect associated with an acute anterior cruciate ligament tear with a fragment displaced into posterior joint space (**A** and **B**). Arthroscopic view of large full-thickness chondral loss (**C**). Retrieval of loose body through intercondylar notch (**D**).

Figure 4

Sixteen-year-old man with a typical lateral bony contusion pattern associated with pivot-shift mechanism in anterior cruciate ligament injury. Of note, an associated subchondral impaction injury is noted posterior to the sulcus terminalis.

(P = 0.024) or débridement (P = 0.018).[39] No difference between microfracture and débridement was noted, although all modalities were inferior to a control group with intact articular cartilage.

Clinical Implications

Several studies have attempted to qualify patient outcomes after ACL reconstruction based on multiple patient and pathologic variables, including the presence of meniscal and chondral lesions (Table 3). Scandinavian population-based studies provide the greatest patient numbers; however, they have relatively poor follow-up and provide limited details of treatment. One such study with 54% follow-up reported 2-year outcomes based on meniscal and chondral pathology. Only the presence of high-grade chondral defects was associated with worse KOOS outcomes at 2 years, although a subanalysis based on meniscal tear treatment was not performed.[2] Two level I prospective investigations, both reporting on data from the same pool of patients with 6-year follow-up, found, compared with uninjured menisci, worse patient-reported outcomes with medial meniscal repairs and improved outcomes with nontreatment of lateral meniscal tears.[6,38] Additionally, repair or resecting more than 50% of the lateral meniscus resulted in improved quality of life and activity scores, whereas resecting more than 50% of the medial meniscus improved pain scores.[6] Currently, an explanation for the observation of improved outcomes in both nontreatment of lateral meniscal tears or large resections of either meniscus is lacking. In the same studies, the presence of chondral defects negatively affected outcomes but varied based on the defect location. A level-III review with longer mean follow-up of 8.6 years found that both meniscal resections and chondral defects were associated with worse subjective outcomes.[11] Data from revision reconstructions demonstrate similar findings with previous meniscectomies and chondral defects, particularly trochlear, negatively affecting outcomes at 2-year follow-up.[4]

Table 3

Summary of Conclusions (Levels of Evidence)
Lateral meniscal tears are more often associated with acute, primary ACL tears and occur less frequently in chronic ACL tears and failed reconstructions (III)
Increasing time from injury and increasing episodes of instability result in higher rates of chondral defects and medial meniscal tears (II, III)
Meniscal tears and previous partial meniscectomies have higher associations with corresponding compartmental chondral defects in both primary and revision ACL reconstructions (II)
Failed ACL reconstructions have higher rates of chondral injury than primary cases, which partially depends on meniscal integrity. Rates of patellofemoral chondrosis are higher in revision cases (II)
Benign neglect of stable meniscal tears in association with ACL reconstruction leads to generally acceptable outcomes; however, medial meniscal tears left in situ are associated with higher revision surgery rates than lateral tears (9.5%-16.3% versus 3.0%-5.8%).[3,4] Detailed outcomes comparing treatment modalities in specific tear subtypes are generally lacking.
Success rates for repair of unstable, nondegenerative meniscal tears is high, with better survival rates with inside-out techniques compared with all-inside techniques (III, IV)
Emerging biomechanical and clinical data suggest that meniscal deficiency negatively affects graft integrity after ACL reconstruction; however, this area needs further long-term clinical validation (III, IV)
Successful patient-reported outcomes have been demonstrated with multiple treatment modalities for chondral defects,[4] as well as benign neglect,[3] when performed in conjunction with ACL reconstruction. However, the current level of evidence and volume of literature are insufficient for clear treatment recommendations (II)
The presence of chondral defects consistently results in lower intermediate-to-long-term patient-reported outcomes. Lateral meniscal tears in general have less negative effect on outcomes than do medial meniscal tears. (I, II)

ACL = anterior cruciate ligament

Summary

Optimizing long-term outcomes in treating ACL tears with associated chondral and meniscal pathology requires an understanding of both the natural history of specific pathology and the results of various treatment modalities. Despite insights gained from numerous studies on this subject, the complex, multifactorial nature of this pathology results in continued management questions. The presence of high-grade chondral defects is consistently associated with worse patient-reported outcomes.[2,6,11,39] However, intact menisci may lessen this effect, and a clearly superior treatment modality of these defects is lacking, with benign neglect remaining a viable option.[8,35] Results related to meniscal tear types and treatment are also unclear, and further high-level studies are needed regarding specific tear subtypes, modern repair techniques, the effect of tears, and/or insufficiency on long-term stability. Existing data suggest that lateral meniscal tears in general may have acceptable results obtained with both aggressive and conservative treatment modalities in primary reconstructions,[6,32,33,39] whereas medial meniscal tears may be more prone to relatively inferior outcomes and/or higher rates of revision surgery regardless of treatment modality.[6,21,25,30,32,39] However, in revision cases, previous lateral or medial meniscal resections are associated with higher rates of chondral injury and worse overall outcomes due in part to increased patellofemoral involvement.[4,14,15] Despite these observations, further study is needed to elucidate the complex factors involved in optimizing patient outcomes in the setting of ACL insufficiency with concomitant meniscal or chondral injury.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 6 and 38 are level I studies. References 2, 3, 4, 5, 10, 14, 15, 29, 37, and 39 are level II studies. References 1, 8, 9, 13, 21, 22, 23, 27, 30, 32, 33, 34, 35, and 36 are level III studies. References 7, 11, 12, and 26 are level IV studies.

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

1. Kluczynski MA, Marzo JM, Bisson LJ: Factors associated with meniscal tears and chondral lesions in patients undergoing anterior cruciate ligament reconstruction: A prospective study. *Am J Sports Med* 2013;41:2759-2765.

2. Røtterud JH, Sivertsen EA, Forssblad M, Engebretsen L, Arøen A: Effect of meniscal and focal cartilage lesions on patient-reported outcome after anterior cruciate ligament reconstruction: A nationwide cohort study from Norway and Sweden of 8476 patients with 2-year follow-up. *Am J Sports Med* 2013;41:535-543.

3. Granan LP, Bahr R, Lie SA, Engebretsen L: Timing of anterior cruciate ligament reconstructive surgery and risk of cartilage lesions and meniscal tears: A cohort study based on the Norwegian National Knee Ligament Registry. *Am J Sports Med* 2009;37:955-961.

4. **MARS Group: Meniscal and articular cartilage predictors of clinical outcome after revision anterior cruciate ligament reconstruction. *Am J Sports Med* 2016;44:1671-1679.**

5. 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.

6. **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.**

7. Brophy RH, Zeltser D, Wright RW, Flanigan D: Anterior cruciate ligament reconstruction and concomitant articular cartilage injury: Incidence and treatment. *Arthroscopy* 2010;26:112-120.

8. Widuchowski W, Widuchowski J, Koczy B, Szyluk K: Untreated asymptomatic deep cartilage lesions associated with anterior cruciate ligament injury: Results at 10- and 15-year follow-up. *Am J Sports Med* 2009;37:688-692.

9. Chhadia AM, Inacio MC, Maletis GB, Csintalan RP, Davis BR, Funahashi TT: Are meniscus and cartilage injuries related to time to anterior cruciate ligament reconstruction? *Am J Sports Med* 2011;39:1894-1899.

10. Røtterud JH, Sivertsen EA, Forssblad M, Engebretsen L, Arøen A: Effect of gender and sports on the risk of full-thickness articular cartilage lesions in anterior cruciate ligament-injured knees: A nationwide cohort study from Sweden and Norway of 15 783 patients. *Am J Sports Med* 2011;39:1387-1394.

11. Shelbourne KD, Gray T: Results of anterior cruciate ligament reconstruction based on meniscus and articular cartilage status at the time of surgery: Five- to fifteen-year evaluations. *Am J Sports Med* 2000;28:446-452.

12. Shelbourne KD, Gray T: Anterior cruciate ligament reconstruction with autogenous patellar tendon graft followed by accelerated rehabilitation: A two to nine year follow-up. *Am J Sports Med* 1997;25:786-795.

13. Granan LP, Inacio MC, Maletis GB, Funahashi TT, Engebretsen L: Sport-specific injury pattern recorded during anterior cruciate ligament reconstruction. *Am J Sports Med* 2013;41:2814-2818.

14. Brophy RH, Wright RW, David TS, et al: Association between previous meniscal surgery and the incidence of chondral lesions at revision anterior cruciate ligament reconstruction. *Am J Sports Med* 2012;40:808-814.

15. Borchers JR, Kaeding CC, Pedroza AD, Huston LJ, Spindler KP, Wright RW; MOON Consortium and the MARS Group. Intra-articular findings in primary and revision anterior cruciate ligament reconstruction surgery: A comparison of the MOON and MARS study groups. *Am J Sports Med* 2011;39:1889-1893.

16. Musahl V, Citak M, O'Loughlin PF, Choi D, Bedi A, Pearle AD: The effect of medial versus lateral meniscectomy on the stability of the anterior cruciate ligament-deficient knee. *Am J Sports Med* 2010;38:1591-1597.

17. 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.

18. **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.

19. Shybut TB, Vega CE, Haddad J, et al: Effect of lateral meniscal root tear on the stability of the anterior cruciate ligament-deficient knee. *Am J Sports Med* 2015;43:905-911.

20. Frank JM, Moatshe G, Brady AW, et al: Lateral meniscus posterior root and meniscofemoral ligaments as stabilizing structures in the ACL-deficient knee: A biomechanical study. *Orthop J Sports Med* 2017;5.

21. Shelbourne KD, Benner RW, Nixon RA, Gray T: Evaluation of peripheral vertical nondegenerative medial meniscus tears treated with trephination alone at the time of anterior cruciate ligament reconstruction. *Arthroscopy* 2015;31: 2411-2416.

22. Shelbourne KD, Carr DR: Meniscal repair compared with meniscectomy for bucket-handle medial meniscal tears in anterior cruciate ligament-reconstructed knees. *Am J Sports Med* 2003;31:718-723.

23. Shelbourne KD, Dersam MD: Comparison of partial meniscectomy versus meniscus repair for bucket-handle lateral meniscus tears in anterior cruciate ligament reconstructed knees. *Arthroscopy* 2004;20: 581-585.

24. Rothermich MA, Cohen JA, Wright R: Stable meniscal tears left in situ at the time of arthroscopic anterior cruciate ligament reconstruction: A systematic review. *J Knee Surg* 2016;29:228-234.

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

26. 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.

27. 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.

28. Bhatia S, LaPrade CM, Ellman MB, LaPrade RF: Meniscal root tears: Significance, diagnosis, and treatment. *Am J Sports Med* 2014;42:3016-3030.

29. Liu X, Zhang H, Feng H, Hong L, Wang XS, Song GY: Is it necessary to repair stable ramp lesions of the medial meniscus during anterior cruciate ligament reconstruction? *Am J Sports Med* 2017;45:1004-1011.

30. Duchman KR, Westermann RW, Spindler KP, et al: The fate of meniscus tears left in situ at the time of anterior cruciate ligament reconstruction: A 6-year follow-up study from the MOON cohort. *Am J Sports Med* 2015;43:2688-2695.

31. Westermann RW, Duchman KR, Amendola A, Glass N, Wolf BR: All-inside versus inside-out meniscal repair with concurrent anterior cruciate ligament reconstruction: A meta-regression analysis. *Am J Sports Med* 2017;45:719-724.

32. LaPrade CM, Dornan GJ, Granan LP, LaPrade RF, Engebretsen L: Outcomes after anterior cruciate ligament reconstruction using the Norwegian Knee Ligament Registry of 4691 patients: How does meniscal repair or resection affect short-term outcomes? *Am J Sports Med* 2015;43:1591-1597.

33. Shelbourne KD, Roberson TA, Gray T: Long-term evaluation of posterior lateral meniscus root tears left in situ at the time of anterior cruciate ligament reconstruction. *Am J Sports Med* 2011;39:1439-1443.

34. Parkinson B, Robb C, Thomas M, Thompson P, Spalding T: Factors that predict failure in anatomic single-bundle anterior cruciate ligament reconstruction. *Am J Sports Med* 2017;45:1529-1536.

35. Shelbourne KD, Jari S, Gray T: Outcome of untreated traumatic articular cartilage defects of the knee: a natural history study. *J Bone Joint Surg Am* 2003;85-A(suppl 2): 8-16.

36. Lattermann C, Jacobs CA, Reinke EK, et al: Are bone bruise characteristics and articular cartilage pathology associated with inferior outcomes 2 and 6 years after anterior cruciate ligament reconstruction? *Cartilage* 2017;8:139-145.

37. Røtterud JH, Sivertsen EA, Forssblad M, Engebretsen L, Årøen A: Effect on patient-reported outcomes of debridement or microfracture of concomitant full-thickness cartilage lesions in anterior cruciate ligament-reconstructed knees: A nationwide cohort study from Norway and Sweden of 357 patients with 2-year follow-up. *Am J Sports Med* 2016;44:337-344.

38. Dunn WR, Wolf BR, Harrell FE Jr, et al. Baseline predictors of health-related quality of life after anterior cruciate ligament reconstruction: A longitudinal analysis of a multicenter cohort at two and six years. *J Bone Joint Surg Am* 2015;97:551-557.

39. Gudas R, Gudaitė A, Mickevičius T, et al: Comparison of osteochondral autologous transplantation, microfracture, or debridement techniques in articular cartilage lesions associated with anterior cruciate ligament injury: A prospective study with a 3-year follow-up. *Arthroscopy* 2013;29:89-97.