

Partial Tears of the Anterior Cruciate Ligament: Diagnosis and Treatment

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Abstract

In sports medicine, diagnosis and treatment of partial tears of the anterior cruciate ligament (ACL) continue to be difficult. Partial tears of the ACL are common, representing 10% to 28% of all ACL tears. As our understanding of the anatomy of the native ACL improves, our accuracy in diagnosing these injuries increases. The advent of magnetic resonance imaging (MRI) and recognition of injury patterns have more clearly delineated the pathoanatomy in a majority of these cases.

Natural history studies following patients with these injuries have demonstrated that fewer than 50% of patients return to their preinjury activity level. Several studies have also documented that progression to complete rupture is a common outcome for patients who want to return to an active lifestyle.

Treatment options include conservative modalities (eg, activity modification, functional rehabilitation, functional bracing) and surgery (eg, thermal shrinkage of remaining ACL, complete reconstruction, newer techniques to augment or reconstruct the damaged portion of the native ligament). Studies comparing conservative treatments with more aggressive operative interventions are required to fully evaluate the efficacy of these treatments.

Anterior cruciate ligament (ACL) injuries are common. An estimated 80,000 to 250,000 ACL injuries occur yearly, with the majority of these in athletes between ages 15 and 25.^{1,2} The Centers for Disease Control and Prevention³ estimated that approximately 100,000 ACL reconstructions are performed annually in the United States. Partial tears of the ACL, though not as common as complete tears, may account for 10% to 28% of all ACL injuries, but the epidemiologic data regarding this entity are not as clearly defined.⁴

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The natural history of complete ACL ruptures has been well defined and often reported in the literature.^{5,6} Typically, patients who sustain a complete ACL tear report symptomatic instability with pivoting sports or strenuous activity. Patients diagnosed with partial tears of the ligament have a less predictable outcome. Although many continue to experience instability, many do not, and identifying both groups can be challenging. In addition, diagnosing partial tears and tailoring treatment to individual patients can be difficult, as there are no clear treatment guidelines.

In this review, we focus on ACL anatomy, diagnosis and treatment of partial ACL tears, and outcomes and new treatment techniques.

ANATOMY OF THE ACL

The two-bundle concept of the ACL was introduced by Palmer⁷ in 1938 and expanded on by Girgis and colleagues⁸ in 1975. Each described the ACL as having an anteromedial (AM) component and a posterolateral (PL) component on the basis of the insertion of each individual bundle into the tibial surface. In 1991, Amis and Dawkins⁹ further elucidated that the ACL has an intermediate (IM) bundle with anatomical and biomechanical properties very similar to those of the AM bundle. The

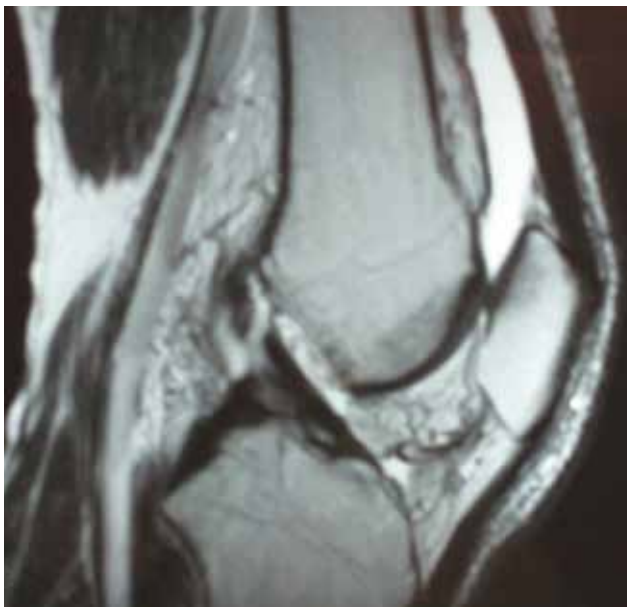


Figure 1. Sagittal magnetic resonance imaging shows focal increased signal intensity within substance of anterior cruciate ligament. Patient had acute partial tear of anterior cruciate ligament compromising anteromedial bundle, with intact posterolateral bundle (see Figure 2).

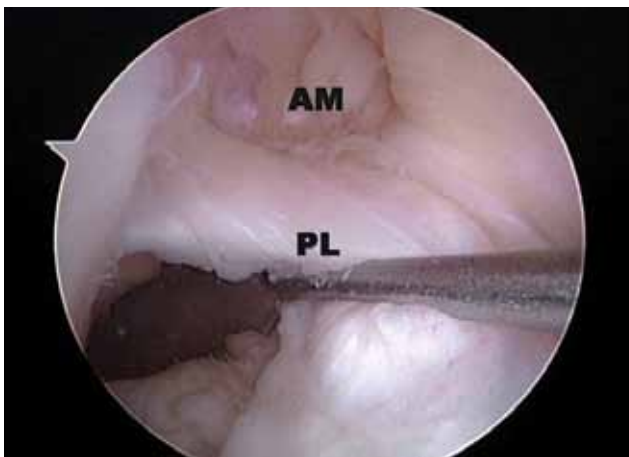


Figure 2. Arthroscopic picture of partial anterior cruciate ligament injury. In this patient, posterolateral (PL) bundle was intact, and anteromedial (AM) bundle was torn and scarred within notch.

ACL has a microstructure of collagen bundles of multiple types (predominantly type I) and a complex matrix of proteins, glycoproteins, glycosaminoglycans, and elastic systems.¹⁰ On the macroscopic level, the ligament originates on the lateral femoral condyle and courses obliquely through the knee joint lateral and posterior to medial and anterior, inserting into a broad area on the tibial plateau. The cross-sectional diameter of the ligament varies along its course, from 44 mm² at the midsubstance to nearly 3 times that at the origin and the insertion.^{11,12} Total ligament length is 31 to 38 mm and can vary by as much as 10% during normal knee range of motion.¹³ The ACL is innervated by posterior articular branches of the tibial nerve and receives most of its blood supply from branches of the middle geniculate artery.

The dual-bundle anatomy of the ACL has biomechanical and clinical implications and may provide insight into the precise pathoanatomy of partial ACL tears. In a biomechanical study, Gabriel and colleagues¹⁴ found that the PL bundle is tightest in extension and relaxes as the knee is flexed, and the AM bundle is relaxed in extension and tightens as the knee approaches 60° of flexion. In a cadaveric study, all specimens demonstrated the dual-bundle anatomy; in addition, the motion pattern of the ACL demonstrated that the AM and PL bundles are oriented parallel with the knee extended and twist around each other as the knee is flexed.^{15,16} These anatomical and biomechanical dynamics may affect the ligament while it is being injured. Depending on the flexion angle of the knee and the force applied, there is a different strain produced within each component of the ACL, and this strain may produce a partial ligamentous disruption of the AM bundle, the PL bundle, or both.

DIAGNOSIS OF PARTIAL ACL TEARS

Diagnosis of partial ACL tears can be challenging. Often, clinical examination findings can be subtle, and radiographic studies may not reveal significant pathology. The most accurate diagnosis is achieved by integrating patient

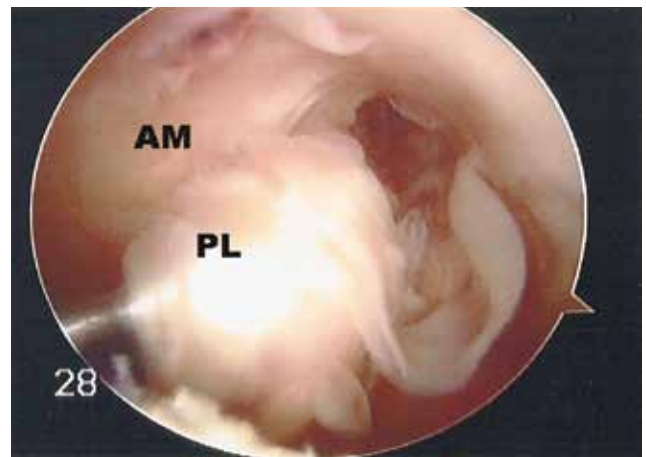


Figure 3. Arthroscopic picture of partial anterior cruciate ligament injury. In this patient, anteromedial (AM) bundle was intact, and posterolateral (PL) bundle was avulsed off femur.

history, physical examination findings, imaging studies, and routine orthopedic follow-up.

Patient History

ACL injuries typically occur in patients who participate in activities that require running, jumping, or cutting. The classic scenario is a young athlete who sustains a noncontact pivoting injury while the foot is planted and the knee is slightly flexed. The ensuing injury may be characterized as a “pop” or buckling of the knee with eventual swelling from a traumatic hemarthrosis. The history from a partial disruption of the ACL can be as classic as the scenario presented, or more nebulous in presentation. Some patients remember a specific traumatic event, as in a complete tear, but many others report a minor event in which the knee felt as if it shifted or rolled. Some patients report they returned to competitive play later that same game or within a week after being injured. In rarer cases, patients report minor pain with certain activity but report no specific injury. Perhaps one of the most important components of taking the history is to ask the patient about the degree of morbidity from the injury and about similar injuries that may have occurred since the sentinel event. In addition, the patient should be asked about any prior treatment for the problem and about the success of that treatment.

Physical Examination

The physical examination is very similar to that for most knee injuries. The knee is first inspected for any bruising or contusion that may indicate a more serious injury. The knee is checked for an effusion. If one is present, causing discomfort that impedes the physical examination, it should be aspirated. (Maffulli and colleagues,¹⁷ who performed a study involving 106 athletes who each presented with an acute hemarthrosis of the knee, found that the ACL was partially disrupted in 28 of these patients and completely ruptured in 43, as determined by arthroscopy.) Range of motion is assessed. Limited motion may

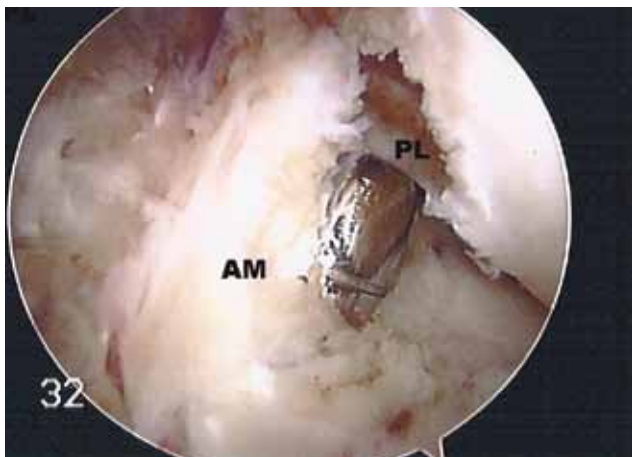


Figure 4. Anatomical reconstruction technique. Tunnel dilator exited tibial tunnel for posterolateral (PL) insertion.

indicate concomitant meniscal pathology, though this is not a common finding with partial ACL tears. Locking of the knee or a block to extension may be the result of interposition of a partial ACL tear (as was observed by Chun and colleagues¹⁸; Finsterbush and colleagues¹⁹ found locking in a significant number of patients with partial ACL tears, the majority resulting from fat pad adhesion and fibrosis to the damaged stump). The knee is then examined for any tenderness or swelling along the joint line. The ligamentous examination is performed, and its findings compared with those of the contralateral extremity. The knee is first checked for varus or valgus instability at both 0° and 30°. The Lachman and pivot shift test are then performed. It is important to determine whether the patient is guarding or contracting the hamstrings, which could hinder detection of any subtle differences. Seldom do patients have a positive anterior drawer test, as the secondary stabilizers (medial meniscus and posteromedial corner) are usually preserved with this injury. The examination may conclude with the KT-1000 (or KT-2000) arthrometer test and comparison of its finding with that of the unaffected extremity. (Liu and colleagues²⁰ evaluated the KT-2000 test with varying degrees of ACL disruption, ranging from mild, or a half-tear of one bundle, to severe, or a complete tear of one bundle and half of another, and found that mild and moderate injuries produced only small changes in the anterior tibial translation at different force levels.) A normal KT finding does not preclude an injury to a portion of the ACL and is no substitute for a good physical examination. To date, no study has correlated the degree of tibial translation or disruption of the ACL with functional status or need for operative intervention.

Imaging Studies

Plain radiographs are routinely used to look for associated pathology (all patients) and to document status of the physes (adolescents). Radiographs include bilateral anteroposterior flexion weight-bearing views, a lat-

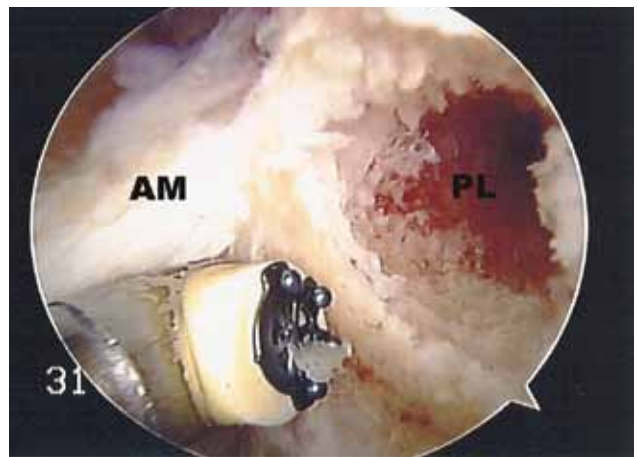


Figure 5. Femoral tunnel was drilled for posterolateral graft. Anteromedial (AM) origin on femur visible just posterior to posterolateral (PL) tunnel.

eral view of the involved knee, and bilateral merchant or sunrise views. All radiographs are inspected for soft-tissue swelling, effusion, fracture, and overall alignment. Paramount to determining prognosis is examining for joint space narrowing that may be indicative of degenerative changes. Any patient with evidence of knee arthrosis is further studied with a long cassette film to determine alignment.

In patients with suspected complete or partial ACL tears, obtaining magnetic resonance imaging (MRI) of the knee is customary. MRI is also useful in detecting any chondral injury or meniscal pathology. For accurate diagnosis when partial tears are suspected, often it is necessary to review the MR images with an experienced musculoskeletal radiologist. In a recent MRI–arthroscopy comparison study, Duc and colleagues²¹ found that 4 partial tears were incorrectly diagnosed by MRI, and the authors concluded that paracoronal images may be useful in equivocal cases. Earlier, Umans and colleagues²² found that MRI may not be sensitive enough to accurately diagnose partial ACL tears; in this scenario, the sensitivity of MRI was .4 to .75, and the specificity was .62 to .89. Lawrance and colleagues²³ found that, compared with arthroscopy, MRI diagnosed only 1 of 9 partial ACL tears.

Some investigators have attempted to determine ways to increase the diagnostic accuracy of conventional imaging. Adding oblique coronal images to the standard knee MRI and using a 4-point grading scale for ACL injuries (intact, low-grade partial, high-grade partial, complete tear) were found to significantly increase diagnostic accuracy.²⁴ Chen and colleagues²⁵ delineated criteria that assist clinicians in making accurate diagnoses and found that an empty notch sign, a wavy ACL, a bone contusion, and posterior horn of the lateral meniscus tears are suggestive of complete ACL injury. A residual straight and tight ACL fiber seen on at least one image and a focal increase in ACL signal intensity in the acute setting are suggestive of partial

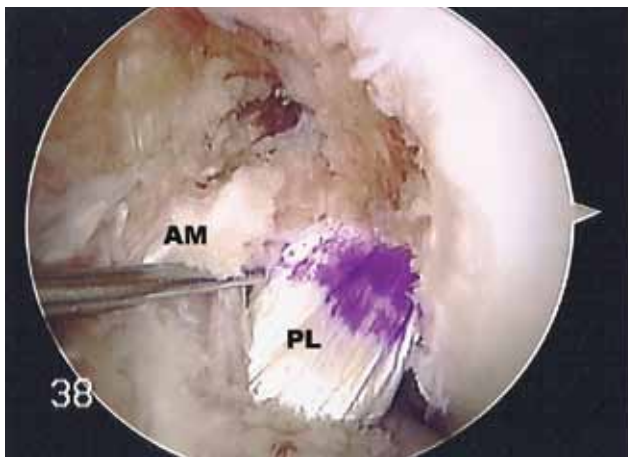


Figure 6. Posterolateral (PL) graft was passed, and anatomical augmentation procedure for partial anterior cruciate ligament disruption was complete.

ACL tears (Figures 1, 2). Studies also have shown that a lateral bone bruise is highly suggestive of an ACL injury. Murphy and colleagues²⁶ found that only 1 of 6 patients diagnosed with a partial ACL tear by MRI had a bone contusion. Zeiss and colleagues²⁷ found that 12% of partial ACL tears were accompanied by a bone contusion on MRI, whereas 72% of complete ruptures had this finding; in addition, 80% of the partially torn ACLs with a bone contusion went on to complete rupture within 6 months after the study date. These findings provide some prognostic signs that may assist orthopedists in determining appropriate treatment.

TREATMENT

Nonoperative Treatment

Treatment of partial ACL tears depends entirely on making an accurate diagnosis and determining degree of impairment. For some patients with partial tears, little morbidity is associated with the injury, and knee stability may be adequate for participation in sports and for all activities of daily living. Treatment in this scenario is largely supportive: recommending that the patient take the time to recover from the initial injury and, after rehabilitation, to make a gradual return to sport. Assessing which patients require more aggressive treatment can be challenging. Various factors are taken into consideration: age, activity level, degree of laxity on physical examination, associated injuries, and symptomatic instability. Most clinicians would agree that symptomatic and debilitating instability requires a more aggressive approach, likely in the form of operative intervention. Unfortunately, most patients with a partial ACL tear fall on the opposite end of the continuum from complete ACL rupture, with more subtle physical examination findings, and may not have effusion, laxity, or other significant findings on examination. Counseling patients in this regard can be difficult, and a literature review revealed conflicting outcomes in the natural history of this injury.

Odensten and colleagues²⁸ prospectively followed 21 patients with partial ACL tears for 6 years and found that only 3 ACLs were unstable at most recent follow-up, with all patients achieving good or excellent results. They concluded that the course of a partial tear is benign and that long-term results are good. Sommerlath and colleagues²⁹ evaluated 22 acute partial ACL tears, 3 of which were repaired initially, and found at long-term follow-up (9-15 years) that no patient required ACL reconstruction. All 22 patients had decreased their activity level, and more than half showed signs of osteoarthritis. The study authors concluded that conservative treatment is effective for this condition. Buckley and colleagues³⁰ evaluated 25 patients with partial ACL tears at intermediate follow-up and found that 60% had good or excellent results. Only 44% of patients had resumed sports at their preinjury levels; 72% reported activity-related symptoms. There was no correlation between ultimate outcome and percentage of ligament tear at arthroscopy, length of follow-up, or age at injury. In perhaps one of the best long-term studies, Bak and colleagues³¹ followed 56 patients with isolated partial ACL tears for a mean of 5.3 years. Sixty-two percent of patients in this series reported good or excellent knee function; however, only 30% of patients resumed their preinjury activities. Barrack and colleagues³² reported on a series of 35 patients with partial tears and found that 52% had good or excellent results, significantly better than the natural history of complete ruptures in the series. Fritschi and colleagues³³ found that 18 of 43 patients with partial ACL tears progressed to complete rupture by 5-year follow-up. Noyes and colleagues³⁴ reported similar results in their series: 38% of patients with partial tears progressed to complete rupture. The authors also identified several risk factors for tear progression: degree of initial tear, subtle increase in anterior translation, and reinjury with giving way.

Our integrated approach to managing a partial ACL tear is to discuss the risks for complete rupture and give patients an opportunity to pursue an initial course of nonoperative treatment. There have been no studies of the efficacy of bracing or neuromuscular proprioceptive rehabilitation in preventing complete rupture within the setting of a partial ACL tear. Mandelbaum and colleagues³⁵ recently found an 88% reduction in noncontact ACL injury at 1 year and a 74% reduction at 2 years with a preventive rehabilitation program in female soccer athletes. Although this study and studies like it are aimed at preventing an initial complete ACL rupture, they could have implications for preventing a complete tear in the setting of a partial ACL tear. A functional knee brace is often prescribed to restore the athlete's confidence, but Swirtun and colleagues³⁶ found no objective evidence supporting use of a brace in patients with acute ACL tears. At short-term follow-up, however, patients in that study reported a sense of increased stability wearing the brace. Earlier, Kocher and colleagues³⁷ found fewer sub-

sequent knee injuries in braced professional skiers than in nonbraced professional skiers.

Future nonoperative interventions may be aimed at identifying patients who can cope with partial (or complete) tears of the ACL. In a recent review, Herrington and Fowler³⁸ concluded that laxity measurements and International Knee Documentation Committee (IKDC) ratings are incapable of predicting the functional status of the ACL-deficient patient. Lysholm-Gillquist scores, Knee Outcome Survey–Sports Activity Scale (KOS-SAS) and Activities of Daily Living Scale (KOS-ADLS) scores, and Global Knee Function scores are better tools for distinguishing ACL copers from noncopers. It is anticipated that, with more clinical studies, we will become better at identifying patients who can cope with partial ACL tears, and perhaps we will be able to offer more aggressive treatment to patients who cannot cope.

Operative Treatment

When conservative management fails and patients continue to experience instability, operative intervention is often required. Partial tears that progress to complete rupture are routinely treated with standard ACL reconstruction. There is debate as to which management strategy is optimal for cases in which some ACL fibers remain. In a majority of patients, intermediate- and long-term failure rates for repair of completely or partially torn ACLs have been high.³⁹ There has been recent interest in enhanced primary repair, a technique that uses biological scaffolds to enhance primary repair, but the *in vivo* success of this technique is still being investigated.⁴⁰ Steadman and colleagues⁴¹ reported good results with use of the healing response technique in skeletally immature patients with complete ACL disruptions, and these results may have implications for partial ligamentous disruption in this age cohort. In a recent study by Lamar and colleagues,⁴ 10 of 13 patients were successfully treated with thermal shrinkage of the ACL in partial tears involving less than 50% of the native ligament. Indelli and colleagues⁴² reported that 96% of knees in their series were normal or near normal (IKDC A/B) after using thermal modification for partial ACL tears, with only 1 failure at 2-year follow-up. We do not perform thermal shrinkage for partial ACL tears, as recent reports have demonstrated a high failure rate as well as graft complications in patients with native and reconstructed ligaments, respectively.^{43,44} Our current strategy is anatomical reconstruction aimed at restoring the damaged portion of the native ACL. This strategy is similar to the technique reported by Buda and colleagues⁴⁵: using hamstring autograft in augmentation surgery to reconstruct the damaged portion of the ACL in partial ACL deficiency. At final, 5-year follow-up, 45 of their 47 patients (95.7%) had good or excellent results, with no recurrence of ligamentous laxity. Although our techniques are similar in principle, we use femoral bone tunnels (used in standard ACL reconstructions) instead of the over-the-top technique of Buda and colleagues. Our

approach reflects the anatomical principle of reconstructing the damaged bundle, AM or PL, which may be all that is necessary to restore knee function and stability (Figures 3–6). For patients with symptomatic instability and partial tears involving both bundles, a standard single-bundle ACL reconstruction can be performed with anatomical placement of the graft.

SUMMARY

In sports medicine, diagnosis and treatment of partial tears of the ACL continue to be difficult. Understanding ACL anatomy has helped to clarify these injuries and has been implemented as a treatment strategy recently. Although the history and physical examination of patients with partial ACL tears may be similar to those of patients with complete ligamentous disruption, often the symptoms are vague and the physical examination not confirmatory of the injury. MRI, though useful, has not been as sensitive as arthroscopy in detecting partial ACL tears, but the addition of oblique and coronal sequences and the detection of a bone bruise can significantly improve diagnostic accuracy.

Treatment of partial tears continues to be controversial. Although natural history studies have demonstrated satisfactory knee function at follow-up, significant declines in activity level and return to preinjury activity level have been noted by most investigators. In addition, in most series, risk for progression to complete rupture has been reported to be almost 40%. A treatment program that can be tailored to individual needs and activity levels is warranted. Neuromuscular proprioceptive training has shown promise in preventing ACL injury and may be useful in preventing progression to complete rupture. Functional knee bracing is another option for patients who want to forgo surgical intervention. For patients who continue to experience instability or who progress to complete rupture, augmentation surgery and standard ACL reconstruction remain viable treatment alternatives.

AUTHORS' DISCLOSURE STATEMENT

The authors report no actual or potential conflict of interest in relation to this article.

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