Management of Partial Tears of the Anterior Cruciate Ligament: A Review of the Anatomy, Diagnosis, and Treatment

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ABSTRACT

Partial anterior cruciate ligament (ACL) tears comprise an estimated 10% to 27% of isolated ACL injuries. Partial ACL tears may be challenging to clinically diagnose. We reviewed relevant studies focusing on the anatomy, diagnosis, imaging, and treatment of a partial injury with the goal of providing guidance to clinicians. Although a comprehensive patient history, thorough clinical examination, and imaging studies are helpful in arriving at a diagnosis, the benchmark for diagnosis remains visualization and examination of the ACL at the time of knee arthroscopy. Currently, limited data exist about the long-term outcomes of nonsurgical treatment. Some studies demonstrate that younger, active patients have the risk of progressing to a complete ACL rupture with conservative treatment. The decision to proceed with surgery is based on careful history and physical examination findings that suggest either a "functional" or "nonfunctional" ACL. Surgical treatment consists of augmenting the intact bundle with a selective bundle reconstruction versus a traditional ACL reconstruction. Selective bundle reconstruction has limited data available but is an option. The best evidence supports traditional ACL reconstruction for the surgical management of patients with documented nonfunctional partial tears of the ACL.

Partial anterior cruciate ligament (ACL) tears are observed in 10% to 27% of isolated ACL injuries.[1,2] Several treatment options exist ranging from nonsurgical treatment, partial ACL reconstruction (also referred to as ACL augmentation or selective bundle reconstruction), to full reconstruction.[3,4] We aim to provide a basis for diagnosing partial ACL ruptures that include a careful history, physical examination, and review of imaging studies. The decision to proceed with surgery is based on careful history and physical examination findings that suggest either a "functional" or "nonfunctional" ACL coupled with individualized consideration of the athlete's age, sport, and desired level of activity. The current evidence-based treatment options and surgical techniques are presented.

Anatomy

The ACL is one of the two major intra-articular fibrous ligaments that provides rotational and translational stability to the knee. The structure comprises fibroblasts situated in primarily type I and III collagen with small amounts of type IV collagen at the insertion sites.[5] The ACL attachment is considered a direct ligament bone insertion type and contains four distinct histological zones: (1) ligament, (2) uncalcified fibrocartilage, (3) calcified fibrocartilage, and (4) bone. The ACL inserts in the posterior-medial aspect of the lateral femoral condyle and extends distal and anterior to insert in an area just anterior to the intercondylar eminence of the tibia. Anatomically, the ACL is divided into two bundles: the anteromedial bundle (AMB) and posterolateral bundle (PLB) with distinct footprints on the femur and tibia with their name derived from the tibial insertion site. The long axis of the ACL is directed anteriorly, medially, and distally because it originates from the femur and externally rotates on itself approximately 90° as it approaches the tibial surface.[6,7] Fascicles of the AMB originate at the most anterior and proximal aspect of the femoral attachment and insert at the anteromedial aspect of the tibial attachment. Conversely, the fascicles of the PLB originate at the posterodistal aspect of the femoral attachment and insert at the posterolateral aspect of the tibial attachment.[7] The ACL increases in size distally, resulting in a wider insertional footprint on the tibia with the PLB comprising more fascicles, resulting in a more robust bundle.

The two bundles also vary in function. The AMB is largely isometric, whereas the PLB is anisometric. In extension, the AMB appears as a flat band and the PLB of the ligament is taut. With progressive flexion, the AMB tightens and the PLB loosens (Figure 1).[9] The AMB is primarily responsible for resisting the anterior translation of the tibia in knee flexion, whereas the PLB resists rotation, hyperextension, and anterior translation of the tibia in extension.[8] The AMB primarily provides anterior restraint of the tibia in knee flexion, and the PLB provides rotatory restraint in extension. It is thought that an anteriorly directed force to the tibia with the knee in flexion would more likely injure the AMB, whereas a similar force with the knee in extension would be more likely to injure the PLB.[10]

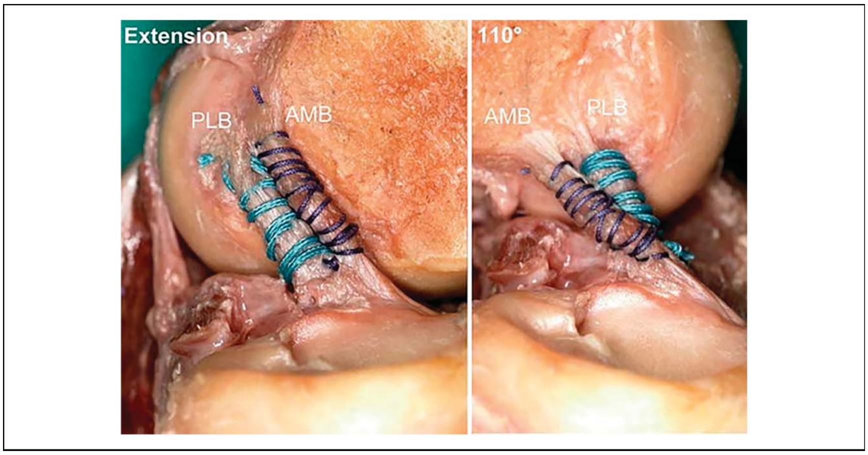
The ACL is innervated by nerve fibers originating from the posterior articular branches of the tibial nerve that penetrate the posterior joint capsule. These branches relay information from mechanoreceptors that serve a proprioceptive function to provide the afferent arc for knee postural signaling changes.[8] The ACL receives its blood supply from the middle genicular artery. It pierces the posterior capsule, passing through an aperture existing in the oblique popliteus ligament near the lateral femoral condyle.[8] When the artery penetrates the joint, it ramifies and provides branches to the ACL with greater blood flow to the proximal origin compared with the distal insertion.[11]

History and Physical Examination

A partial ACL tear may occur from a cutting or pivoting injury but may differ in its presentation from a complete rupture. A specific injury is frequently associated with the onset of symptoms; however, patients may present with vague reports and state that their knee simply “feels different” than the other one after an insult to the knee.[12] Alternatively, the patient may describe an injury followed by overt symptoms of instability and an inability to cut and pivot more consistent with a complete ACL rupture.[13,14]

If patients are seen in the acute postinjury period, the knee frequently demonstrates an effusion. The Lachman examination often elicits moderate anterior laxity compared with the contralateral side, with a delayed, but firm, end point.[3] Pivot shift test of grades 2 and 3 are more commonly associated with complete ACL rupture, whereas partial ruptures are more likely to be graded at 0 or 1. Some patients may have a positive pivot glide without an overt pivot shift.[15] A pivot glide is defined as an abnormal, gentle sliding reduction of the tibia when the tibia is held in maximal internal rotation with a valgus load applied at the knee as it is brought into flexion from full extension.[12] The Lever sign, a more recently described test, involves placing a fulcrum under the supine patient’s calf and applying a downward force to the quadriceps. If the ACL is intact, the patient’s heel will raise off the table (Figure 2). The Lever sign is reported as being 100% sensitive for partial ACL tears compared with only 42% sensitivity for the Lachman test and 19% for the anterior drawer test.[17] Jarbo et al[16] noted an overall accuracy of the Lever sign to be 77%, with no difference in sensitivity or specificity, whereas the patient was awake or under anesthesia and that the test remained reliable regardless of patient sex and level of trainee performing the maneuver. An arthrometer (such as the KT-1000, -2000, etc) quantitates anterior tibia translation for comparing side-to-side knee laxity. The normal expected difference is less than 3 mm.[18] A shortcoming of

Figure 1



Radiograph showing the anatomy of the anteromedial and posterolateral bundles of the anterior cruciate ligament. **A,** With the knee in extension the posterolateral bundle (PLB) is taut and the anteromedial bundle (AMB) is relatively lax. **B,** As the knee moves into flexion the AMB becomes taut and spirals around the PLB while it relaxes. (Adapted with permission from Duthon VB, Barea C, Abrassart S, Fasel JH, Fritschy D, Menetrey J: Anatomy of the anterior cruciate ligament. *Knee Surg Sports Traumatol Arthrosc* 2006;14:204-213.) Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

Figure 2

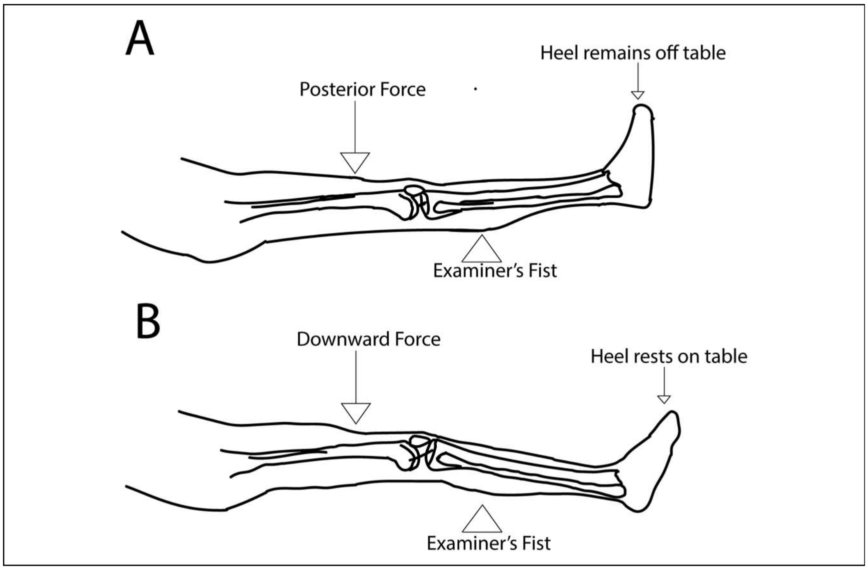
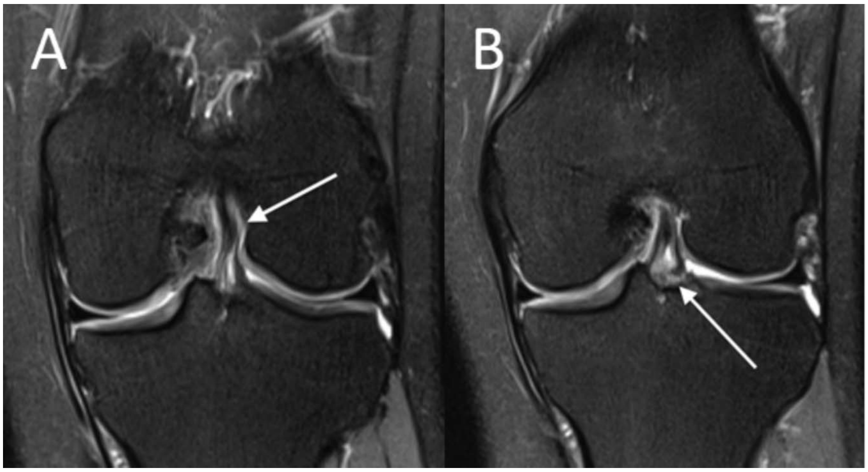


Illustration showing the Lever sign. **A**, As a posterior directed force is applied to the distal thigh by the examiner with their fist under the calf, the heel will lift off the table in the case of an intact anterior cruciate ligament. **B**, If the anterior cruciate ligament is functionally ruptured, the heel will remain resting on the table with a similarly directed force. (Adapted with permission from Jarbo KA, Hartigan DE, Scott KL, Patel KA, Chhabra A: Accuracy of the Lever Sign test in the diagnosis of anterior cruciate ligament injuries. *Orthop J Sports Med* 2017;5:2325967117729809.) Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

the device is that it is unable to test rotational laxity. Given the differing functions of the ACL bundles, Siebold and Fu[14] contend that an isolated tear of the PLB would be more likely to result in a positive pivot shift test, whereas an isolated tear of the AMB would be more likely to result in a positive Lachman or anterior drawer test.

The primary determinate for treatment selection for a patient with a partial tear of the ACL is dependent on whether the ACL is functionally competent. A

Figure 3



Photographs of coronal T2-weighted magnetic resonance images of the right knee in a collegiate soccer player. **A**, The “gap” sign is highlight by the white arrow. The gap sign represents a femoral avulsion of the posterolateral bundle. **B**, The “footprint” sign demonstrates increased signal at the site of the posterolateral bundle tibial insertion the correlates with a tear. The patient was treated nonsurgically and returned to play in the same season.

Table 1. Reported Sensitivity and Specificity of Magnetic Resonance Imaging Signs for Diagnosing Partial Anterior Cruciate Ligament Ruptures

	Sensitivity	Specificity	Sensitivity (Experienced)	Specificity (Experienced)
Footprint sign	75	80	70	97
Gap sign, axial	52	53	45	53
Gap sign, coronal	72	68	64	83
Both signs	57	83	45	97
Either signs	82	58	79	73

Experienced is defined as a practicing radiologist or orthopaedic surgeon.[22]

functional partial tear of the ACL would be defined as one in which the athlete can return to play with confidence in their knee and minimal to no laxity on physical examination after appropriate rehabilitation. A nonfunctional partial tear would be one in which the athlete is unable to return to play because of symptomatic instability when attempting more demanding sporting activities or evidence of overt laxity on physical examination. An ACL reconstruction or augmentation procedure is recommended to those patients who are unable to return to the desired level of activity with symptoms and examination findings associated with a nonfunctional partial ACL tear. Pivoting contact sport participation (eg, soccer, rugby, basketball, and football) and aged 20 years or younger have been found to be notable risk factors for progression to a complete rupture versus athletes involved in noncontact sport and those older than 20 years of age.[19]

Imaging

Radiographic assessment of partial ACL tears presents a challenge as well. A standard knee radiographic series evaluates potential osseous injury in the knee. The success of stress radiographs is limited. Lateral stress radiographs of the knee are reported to be predictive of ACL rupture, but a systematic review of 12 different techniques did not demonstrate superiority of any one technique.[20] A stress devise (Telos Stress Device) was predictive of a complete rupture of the ACL with a mean 9.1 mm of anterior tibial translation relative to the femur compared with 5.2 mm in a partially ruptured ACL on stress.[3] The complexity of the device and the need to radiograph both knees limit the clinical utility of this device. Magnetic resonance imaging (MRI) of the knee is most commonly used to differentiate between a normal and an abnormal ACL but is less reliable in determining and categorizing partial tears.[21]

Table 2. **Outcomes of Nonsurgical Treatment of Partial Anterior Cruciate Ligament Tears**

Study	Year	Patients	Follow-up (mos)	Outcome (Lysholm)	Return to Sport (%)[a]	Persistent Instability (%)
McDaniel[26]	1976	9	15 (3-37)	Unreported	89	11
Odensten et al[27]	1985	21	70 ± 22	93 ± 6	Unreported	14
Kannus and Jarvinen[25]	1987	41	96 ± 28	85 ± 18	66	78
Sandberg and Balkfors[28]	1987	29	36 (12-60)	94	100	62
Noyes et al[29]	1989	32	67 (24-110)	Other	21	38
Buckley et al[30]	1989	25	49 (8-88)	(28% excellent, 32% good)	44	52
Fruensgaard and Johannsen[31]	1989	41	17 (12-22)	88 (45-100)	49	51
Barrack et al[23]	1990	35	41 (8-88)	(23% excellent, 29% good)	40	83
Sommerlath et al[32]	1992	19	144 (108-180)	93 (51-100)	32	9
Bak et al[13]	1997	56	63 (24-152)	86 (52-100)	30	23

[a]Return to sport at the same level.

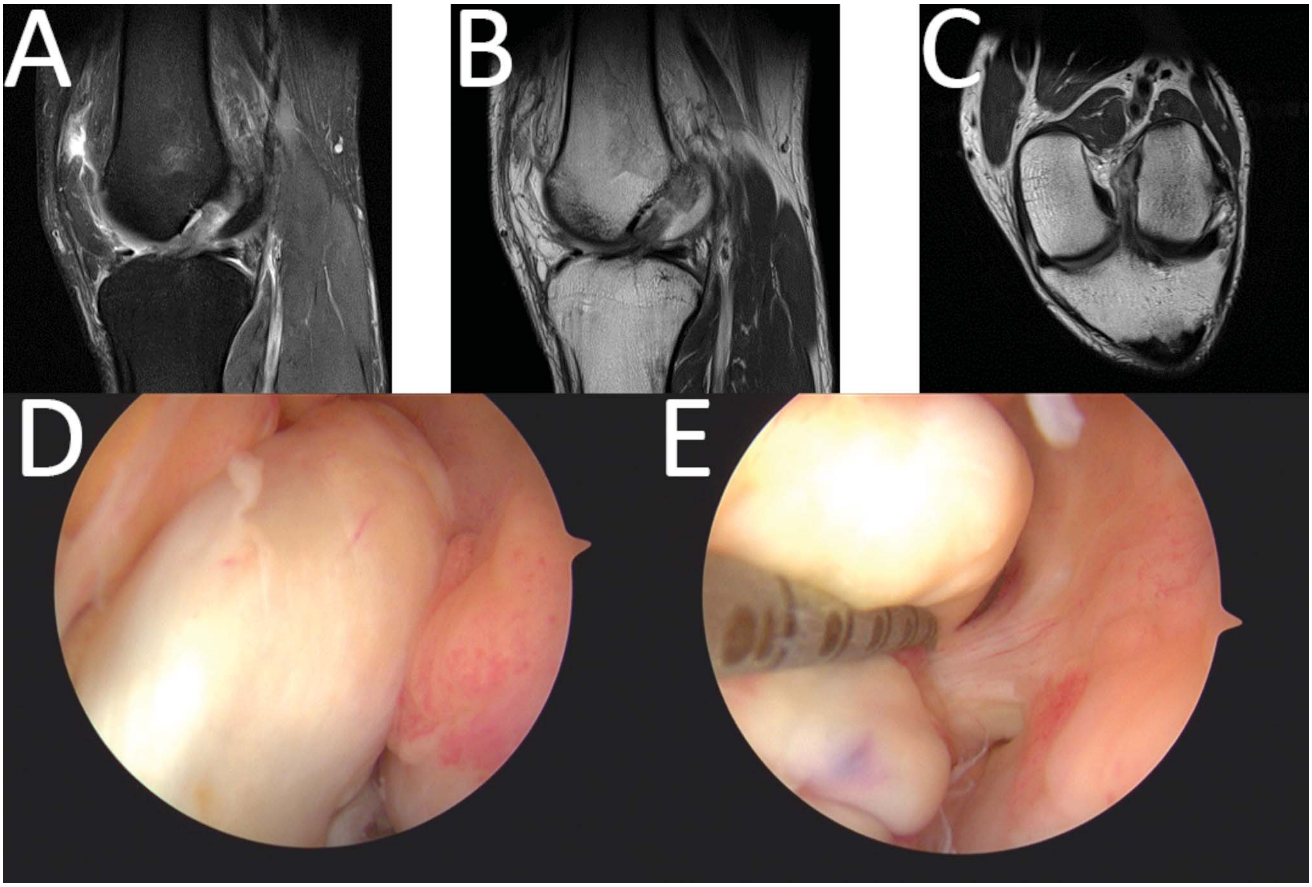
Increased T2 signal within the ACL, diffuse ACL thickening and disorganization suggests a partial tear. Oblique imaging in the coronal, sagittal, and axial planes may help delineate the nature of the injury further. Volokhina et al[22] recently described two signs found on routine MRI sequences to help identify an isolated tear of the PLB: the "gap" sign and the "footprint" sign. The "gap" sign is described as an increased signal on water-sensitive sequences between the lateral femoral condyle and the proximal aspect of the ACL as seen on coronal and axial images (Figure 3, A).[22] The "footprint" sign is seen on coronal images with increased signal correlating with an avulsion or compromised area of the PLB tibial insertion (Figure 3, B).[22] The sensitivity and specificity of these signs are found in Table 1. Even with suspicion, MRI accuracy for partial ACL tears is 25% to 53% and markedly challenging for the radiologist.[21] The standard for diagnosis remains intraoperative confirmation in the setting of a stable knee examination.

Treatment and Outcomes

Nonsurgical treatment with rehabilitation is indicated for clinically stable and functional knees as determined by history and physical examination. A typical candidate for nonsurgical treatment would be a patient with a negative pivot shift and anterior tibial translation of less than 5 mm on KT compared with the contralateral side with an ability to participate at the same level of sport.[19] The success rate of nonsurgical treatment is highly variable in young, active patients. After 1.5 to 3.5 years of follow-up, 14% to 56% progressed to complete ruptures.[2,13,23,24] When comparing nonsurgical treatment of partial and complete ACL tears, Barrack et al[23] showed that partial ACL injuries treated nonsurgically did significantly better than complete ACL injuries regarding meniscal tears, subsequent ACL reconstruction and clinical scores. An early study of ACL tears treated conservatively by Kannus and Järvinen[25] showed that at an average 8-year follow-up, complete tears of the ACL resulted in greater instability and radiographic evidence of joint degeneration than conservatively treated partial tears by the International Knee Documentation Committee (IKDC) scores and radiographic evaluation. Outcomes of nonsurgical treatment of partial ACL tears is summarized in Table 2.

A specific proposed rehabilitation protocol has not been be found in the literature. As part of their proposed treatment algorithm of partial ACL tears, Sonnery-Cottet and Colombert suggest 3 months of conservative treatment consisting of immobilization and rehabilitation in patients with a differential knee laxity of <4 mm and retesting of differential laxity at 3 months. If the patient remains stable, they may return to sporting activity at that time.[33] A brief period of immobilization is recommended to decrease pain and effusion, followed by a functional rehabilitation program that focuses on maintaining motion and strength before progressing to sport-specific activity, as tolerated under the careful guidance and instruction of a physical therapist. The timing of return to sport will be variable among athletes and typically allow for return to sport in 6 to 12 weeks if the athlete remains asymptomatic through the rehabilitation process.

Figure 4



Photograph of sagittal T1- and T2-weighted and coronal oblique T2-weighted magnetic resonance images with arthroscopic images of a partial anterior cruciate ligament (ACL) tear in the left knee. **A**, Sagittal T2-weighted image showing partial ACL tear. **B**, Sagittal T1-weighted image showing partial ACL tear. **C**, Coronal T1-weighted image showing partial ACL tear with both intact fibers and bunching torn fibers. **D**, Arthroscopic image with bunching of the torn fibers (corresponding to the bulge in panel **C**) and avulsion off the wall. **E**, Arthroscopic image upon probing with few remaining anteromedial bundle fibers intact. The ACL was then reconstructed.

The likelihood of a partial tear to heal without surgical intervention is low. Synovial fluid limits the normal ligament healing process through a fibrin scaffold replaced by fibroblasts and collagen fibers.[34] Because the middle geniculate artery supplies the ACL from its proximal origin to the distal insertion, the capacity for healing may be further limited based on tear location with the expectation that distal tears may have less capacity to heal than proximal.[35] The limited healing potential of the ACL without surgical intervention is the primary reason for considering reconstruction for a nonfunctional partial ACL tear.

Current investigations into the use of biologics to supplement nonsurgical treatment have attempted to use platelet rich plasma (PRP) or growth factors injected intrasubstance to form a fibrin clot to promote healing in a manner similar to other ligamentous injuries. The results from these studies are limited and variable. In a cohort of 19 professional soccer players with a partial tear treated with PRP, 18 were able to return to play in an average of 15.33 weeks.[36] Only one of these players progressed to a complete rupture. Meanwhile, a return to play rate of 78% was reported for athletes treated with PRP injection at the 5-year follow-up.[24] A limited study examined arthroscopically assisted placement of autologous conditioned plasma within the ligament after partial tearing of the ACL without repair.[37] Out of a pool of 24 patients, the authors reported a failure of treatment in 3 (12.5%). Two patients sustained a rerupture leading to ACL reconstruction and another patient required reoperation because of a symptomatic cartilage defect. Return to sport in this study group occurred at an average of 4.8 months. In those treated by this manner, functional outcomes were reported as good to excellent as measured by IKDC subjective, Lysholm, Tegner, and Cincinnati scores. Notably, patients with a complete tear of at least one bundle were excluded from the study. Further follow-up and better study design are needed to consider biologics as a recommended treatment option.

Surgical Technique

Clinical examination, preoperative imaging studies, and arthroscopic findings at the time of surgery all converge to influence the surgical decision-making process. Arthroscopic examination of the ACL includes careful inspection of the ACL (Figure 4, D and E). Owing to its position primarily behind the AMB in 90° of flexion, the PLB may be better visualized and probed in the Figure 4 position.[14] Probing of the ligament may identify intraligamentous failure with laxity in a bundle that may otherwise seem intact and can be examined with intraoperative stress testing. Based on the arthroscopic findings, a decision is then made to proceed with selective débridement and augmentation versus total débridement of the ACL and standard reconstruction surgery. This decision is affected by both the amount and quality of remaining fibers after selective débridement along with surgeon preference.

The optimal approach to surgical treatment of partial ACL tears is unclear. Some authors advocate for selective repair rather than single bundle reconstruction. A recent prospective cohort study of ACL repair and marrow stimulation for partial tears, followed by 50 patients for a mean of 10 years (5 to 14 years).[38] The authors reported an 80% survival at 5 years and 73% survival at 10 years with good to excellent preservation of the Tegner activity scores. These patients were narrowly selected within 4 weeks of the injury, increased laxity with Lachman testing, and MRI confirmation of partial tearing.[38] The patient cohort and tear types amenable to repair have limited data and are being refined. Murray et al recently published 2-year outcome data after bridge-enhanced ACL repair for the treatment of complete ACL rupture in which an extracellular matrix scaffold was incorporated into the repair site to help facilitate end-to-end healing of the ligament with promising results similar to those of reconstruction with quadrupled hamstring autograft.[39] Although this has not specifically been studied in the partially torn ACL group, it could represent an effective treatment strategy for this injury.

Selective single-bundle reconstruction offers some theoretical advantages over a traditional ACL reconstruction. In one of the few studies comparing single-bundle augmentation and ACL reconstruction in the setting of a partial ACL tear, Ochi et al[40] reported on improved proprioception of the knee using a Cybex II dynamometer according to the Skinner method following single-bundle augmentation versus dual bundle reconstruction. The Skinner method requires the patient to reproduce a set degree of flexion, and inaccuracies are tallied between the injured and uninjured leg.[40] Improved proprioception is postulated to be secondary to retained mechanoreceptors present in the intact bundle. The vascularity of the intact bundle is also proposed to accelerate the healing process of the reconstructed bundle.[35] Finally, although initial graft strength is entirely reliant on instrumented fixation strength in standard ACL reconstruction, an intact bundle provides improved early strength of the ACL graft that could allow for an accelerated rehabilitation.[35]

Several techniques describe selective reconstruction of the AMB or PLB. Selective reconstruction follows the principles of anatomic double-bundle reconstruction and seeks to restore the individual bundle anatomy and function without damaging the intact bundle. All-inside, over-the-top, transtibial and anteromedial femoral tunnel drilling techniques have all been described with good success, as summarized in Table 3.[2,12,42,44] Buda et al prospectively randomized partial ACL tears to selective bundle anatomic reconstruction versus selective bundle nonanatomic reconstruction by an over-the-top technique with no notable differences in outcomes identified at the final follow-up between the two techniques.[49] The authors did find that reconstruction of the PLB led to markedly higher IKDC subjective and objective scores with lower side-to-side KT-1000 differences when compared with reconstruction of the AMB.

Studies comparing selective bundle augmentation versus traditional reconstruction in the setting of a partial thickness tear are limited. Pujol et al performed a multicenter randomized study with a 1-year follow-up comparing the treatment of AM bundle tear by selective AM bundle reconstruction versus standard anatomic single-bundle reconstruction discovered improved postoperative differential laxity in the selective AM bundle reconstruction group of 1.2 mm compared with 1.9 mm in the standard ACL reconstruction group that was noted to be statistically significant. No differences in functional outcome scores was found (Table 4).[41] Chia et al[45] compared the outcomes of double, single, and selective bundle techniques and found no differences in outcome at the 2-year follow-up regarding functional outcome scores, laxity, and retear rate. Adachi et al published a case-control study comparing selective

Table 3. **Comparisons of Outcomes for Different ACL Augmentation Techniques; All Studies Included Both Anteromedial and Posterolateral Bundle Injuries**

Study	Year	Patients	LOE	Follow-up (mos)	Surgical Technique	Complication Outcomes	Graft Failure
Adachi et al[41]	1999	40	3	38 (24-66)	Over-the-top	No complications	None
Ochi et al[42]	2006	17	3	None	Transtibial	No complications	None
Ochi et al[40]	2009	45	3	35 (24-55)	Transtibial	No complications	None
Yazdi et al[12]	2015	56	3	19.3 (12-37)	All-inside	No complications	None
Matsushita et al[44]	2017	68	4	35.1 ± 16.4	Anteromedial	No complications	None
Perelli et al[39]	2019	76	4	85 (65-110)	Femoral retro-reaming	4 (15%) dissatisfied patients	2 (2.6%)
Buda et al[45]	2013	52	4	Up to 60	Over-the-top and outside-in	2 (3.8%) standard ACL reconstruction	1 (1.9%)

ACL = anterior cruciate ligament, LOE = level of evidence

bundle augmentation in partial ACL tears to standard ACL reconstruction in complete ACL rupture with findings of superior position sense as measured with use of a Cybex II dynamometer and diminished side-to-side anterior translation measured by KT-2000. Functional outcome scores between the two groups were noted to be similar.[47] Inaccuracy of joint position sense of the standard reconstruction group was 1.7° compared with 0.7° in the selective bundle augmentation group. Side-to-side anterior translation was measured to be 1.8 mm in the reconstruction group compared with 0.7 mm in the augmentation group.[47]

During selective ACL débridement, it is imperative to preserve the intact bundle. Careful dissection with the shaver in parallel motions to the fibers and dissection with an arthroscopic biter can aid in bundle protection (Table 5). The intact bundle faces an additional risk of injury at the time of drilling, particularly with the tibial tunnel. One helpful maneuver during this step is the use of a curet to help protect the intact bundle as the drill pierces the proximal tibia.[35]

After diagnostic arthroscopy and selective débridement, the decision must then be made to proceed with selective bundle augmentation or standard ACL reconstruction. Common grafts for ACL augmentation include a doubled or tripled semitendinosus autograft. If needed, this can be supplemented with gracilis autograft to obtain a graft of appropriate size. Use of a bone-patellar tendon-bone autograft has been described as well.[48] To avoid overstuffing the notch or potential development of a cyclops lesion, a graft that is less than 8 mm in diameter has been recommended, whereas Rao et al[35] suggested an even smaller graft size of 6.5 mm. The graft size differs from a complete ACL reconstruction because a native bundle remains. Graft fixation strategies are similar to those of standard ACL reconstruction and primarily include the use of interference and/or suspensory fixation.

To optimally place the augmentation bundle, the target bundle footprint should be clearly defined and prepared. Viewing through a transpatella tendon portal or an accessory anteromedial portal can help improve visualization of the footprint. Vermersch et al[48] evaluated femoral tunnel placement in single-bundle augmentation versus standard ACL reconstruction and noted optimal tunnel position in only 37.5% of ACL augmentation surgeries compared with 68.9% in standard full ACL reconstructions. They postulated that difficulty placing their tunnel guide with intact fibers in the way and less than adequate visualization may have led to these results.[49]

Conversion from selective bundle augmentations to standard ACL reconstruction could occur at several steps during surgery. The most obvious would be at the time of diagnostic arthroscopy and the discovery of a complete rupture of the ACL or incompetence of the remaining bundle. For this reason, it is important to perform the diagnostic arthroscopy before graft harvest when considering bundle augmentation. In addition, conversion to a traditional ACL reconstruction could be precipitated by iatrogenic causes when debriding the torn bundle or while drilling the tunnels. Should this occur after semitendinosus graft harvest, the gracilis could be additionally harvested to create a 4-strand hamstring graft and tunnel-drilling strategy changed to accommodate a traditional single-bundle reconstruction or used separately with an additional tunnel as a double-bundle reconstruction.

Table 4. Studies Comparing the Outcomes of Single Bundle Augmentation Versus Double Bundle Reconstruction in 20- to 30-Year-Old Adults Participating in Sport

		ACL Augmentation Group						ACL Reconstruction Group					
Study	Year	n	IKDC Objective Scores	n	IKDC Subjective Scores	Side-to-Side Laxity (mm)	Differential Anterior Laxity	n	IKDC Objective Scores	n	IKDC Subjective Scores	Side-to-Side Laxity (mm)	Differential Anterior Laxity
Adachi et al[41]	1999	40	A	na	na	0.7 ± 1.8	na	40	A	na	na	1.8 ± 2.1	na
			B	na					B	na			
			C	na					C	na			
Pujol et al[46]	2012	29	A	17	86.17	na	1.24	25	A	15	85.67	na	1.87
			B	9					B	6			
			C	3					C	3			
Total		120						167					

ACL = anterior cruciate ligament, IKDC = International Knee Documentation Committee, na = not applicable
Adachi et al and Pujol et al found a significant difference in graft laxity between the augmented and reconstructed groups. Adachi et al performed a Level III, retrospective case-control study with 2-year follow-up. Pujol et al performed a Level II, prospective randomized cohort with 1-year follow-up. Chia et al performed a Level III retrospective cohort study with 2-year follow-up.

Table 5. Intraoperative Techniques in Selective Bundle Augmentation

Intraoperative Consideration
Perform diagnostic arthroscopy before graft harvest
Use of shaver in parallel motion to the fibers of the anterior cruciate ligament
Dissection with arthroscopic biter
Protect intact bundle with curet during tunnel drilling
Doubled or tripled semitendinosus autograft
Reduced graft size of 6.5-8.0 mm
Clearly define target bundle footprint

Postoperatively, patients may follow an accelerated rehabilitation protocol that focuses on regaining full motion and restoration of hamstring and quadriceps strength along with the principles of pelvifemoral rehabilitation. Early postoperative bracing treatment is left to the discretion of the treating surgeon. In the absence of concomitant meniscal or cartilage injuries, patients are immediately weight bearing. They are progressed through isometric and closed chain exercise programs with advancing to additional strengthening, plyometrics, and sport-specific drills. A functional sport assessment is completed at 6 months, and patients are typically released to play at approximately 8 to 9 months with adequate performance, strength, control, and confidence. Currently, no studies have investigated the effects of electrical muscle stimulation or blood flow restriction therapy on the recovery of this patient cohort; however, the modalities are promising.[43]

Traditional single-bundle ACL reconstruction offers several advantages as well. Perhaps most appealing is the reproducibility of the procedure by many surgeons already comfortable with the technique and the ability to maintain similar rehabilitation protocols in all patients. In the studies reviewed already, no notable differences were observed in functional outcomes measures in patients treated by this technique. Notable differences were noted in laxity and functional position sense, but they were small in magnitude.[41,42,47]

Surgical Outcomes

Three studies have investigated the outcomes of partial ACL injuries treated with a selective single bundle augmentation technique versus a standard ACL reconstruction (Table 3). All of these studies found the single bundle augmentation group had less laxity compared with the contralateral side when compared with the traditional double bundle technique. One study reported their result as a ratio of injured to uninjured side, whereas two studies reported the measured distance.[41,46,49] Two of the studies reported that the single bundle augmented group reported higher subjective IKDC scores versus the double bundle cohort; however, no difference was noted in the objective IKDC scores for the cohorts.[46,49] The limited number of studies, short follow-up times ranging from 6 months to 2 years, and small number of patients treated limits the application of the data.

Summary

Partial ACL tears may present as a challenging diagnosis based on clinical and radiographic findings. A definitive diagnosis can only be made by diagnostic arthroscopy. In young, active individuals expecting to return to sporting activities, the decision to pursue surgical stabilization procedures should be tailored to the patient's injury pattern and complemented by the treating surgeon's preferences. Although theoretical advantages are seen with selective-bundle ACL augmentation procedures, no clear and convincing evidence exists to demonstrate selective ACL augmentation as superior to a standard ACL reconstruction to treat a nonfunctional partial ACL tear. The surgeon should select the technique based on their familiarity with the procedure and a thorough discussion with the patient.

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