Ultrasound-Guided Percutaneous Reconstruction of the Anterolateral Ligament: Surgical Technique and Case Report

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Abstract

The first noted description of the anterolateral ligament (ALL) is often attributed to Dr. Paul Segond (1879). Segond described a "fibrous, pearly band showing extreme amounts of tension during forced internal rotation" that was responsible for an avulsion at the lateral aspect of the proximal tibia. In 2013, Dr. Steven Claes confirmed the presence of the ALL as the band of tissue detailed by Segond. Recent biomechanical studies have shown that the ALL is a vital stabilizer during internal rotation of the knee. Its contribution to stability during rotational kinematics has been proven to exceed that of the anterior cruciate ligament (ACL). Using the concept of the wheel and axle biomechanical formulas, the ACL endures 6 times greater forces during internal rotation in an ALL-deficient knee.

With the recent anatomic and biomechanical findings, the necessity of a technique for reconstruction of the ALL has become increasingly important. The novel use of ultrasound intraoperatively allows for the exact anatomic reconstruction of the lost ligament by identifying the exact anatomic location of both the origin and insertion of the ALL. This article describes a technique for an ultrasound-guided percutaneous reconstruction of the ALL and a case report on one of our patients who required the reconstruction of his ALL.

Restoring native kinematics of the knee has been a primary goal of anterior cruciate ligament (ACL) procedures. Double-bundle ACL reconstruction, compared to single-bundle, has been hypothesized to more effectively re-establish rotational stability by re-creating the anatomic ACL, but has not yet proven to result in better clinical outcomes.[1]

In 1879, Dr. Paul Segond described a "fibrous, pearly band" at the lateral aspect of the knee that avulsed off the anterolateral proximal tibia during many ACL injuries.[2] The role of the lateral tissues in knee stability and their relationship with ACL pathology has attracted noteworthy attention in recent time. There have been multiple studies presenting an anatomical description of a structure at the anterolateral portion of the knee with definitive femoral, meniscal, and tibial attachments, which helps control internal rotational forces.[3-7] Claes and colleagues[4] later found that band of tissue to be the anterolateral ligament (ALL) and determined its injury to be pathognomonic with ACL ruptures.

The ALL is a vital static stabilizer of the tibio-femoral joint, especially during internal tibial rotation.[8-10] In their report on ALL and ACL reconstruction, Helito and colleagues[11] acknowledge the necessity of accurate assessment of the lateral structures through imaging to determine the presence of extra-articular injury. Musculoskeletal diagnostic ultrasound has been established as an appropriate means to identify the ALL.[12]

Ultrasound can accurately determine the exact

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Authors' Disclosure Statement: Dr. Hirahara reports that he receives support from Arthrex as a consultant, royalties, and research support. Mr. Andersen reports no actual or potential conflict of interest in relation to this article.

Table 1. **Indications/Contraindications for Anterolateral Ligament Reconstruction**

Indications	Contraindications
Positive ultrasound diagnosis of ALL damage	Moderate to severe arthritic changes
Grade III pivot shift test in an ACL-deficient knee	Significant bone defects
Grade I-II pivot shift test in an ACL-intact knee	Persistent ACL insufficiency
Clinical instability	

Abbreviations: ACL, anterior cruciate ligament; ALL, anterolateral ligament.

anatomic location of the origin and insertion of the ALL. Reconstruction of the ALL could yield better patient outcomes for those who experience concurrent ACL/ALL injury. Here we present an innovative technique for an ultrasound-guided percutaneous method for reconstruction of the ALL and report on a patient who had underwent ALL reconstruction.

Surgical Indications

All patients undergo an ultrasound evaluation preoperatively to determine if the ALL is intact or injured. Our experience has shown that when ultrasound evaluation reveals an intact ALL, the pivot shift has never been a grade III. Our indications for a combined ACL and ALL reconstruction are a positive ultrasound diagnosis of an ALL tear, and a grade III pivot shift test in an ACL-deficient knee or a grade I-II pivot shift test in an ACL-intact knee (**Table 1**). The ACL cannot be left insufficient if the patient is to have a successful ALL reconstruction.

Surgical Technique

For a demonstration of this technique, see the video that accompanies this article online at www.amjorthopedics.com.

The pivot shift test is conducted under anesthesia to determine whether an ALL reconstruction is required. The patient is placed in a supine position with the knee flexed at 30°, at neutral rotation, and without any varus or valgus stress. The knee is prepped and draped under sterile conditions. Under ultrasound guidance, the origin and insertion of the ALL are identified and marked with an 18-gauge spinal needle (**Figure 1**).

A No. 15 blade is used to make a small incision centered on each spinal needle. The spinal needle is replaced with a 2.4-mm drill pin (**Figure 2**). A 90° hemostat is used to establish a plane under the iliotibial (IT) band between the 2 incisions to pass a looped FiberWire suture (Arthrex) for passage of the graft and FiberTape (Arthrex). The FiberTape acts as an internal brace. A socket 22 mm in length is drilled using a 5.0-mm cannulated reamer over each drill pin. A 4.5-mm semitendinosus graft was prepared with a collagen-coated FiberTape attached to a 5.5-mm BioComposite Vented SwiveLock

Figure 1. Intraoperative identification of the femoral and tibial attachments of the anterolateral ligament under ultrasound guidance. The attachments are then marked with a spinal needle for accurate, anatomic placement of the guide pins.

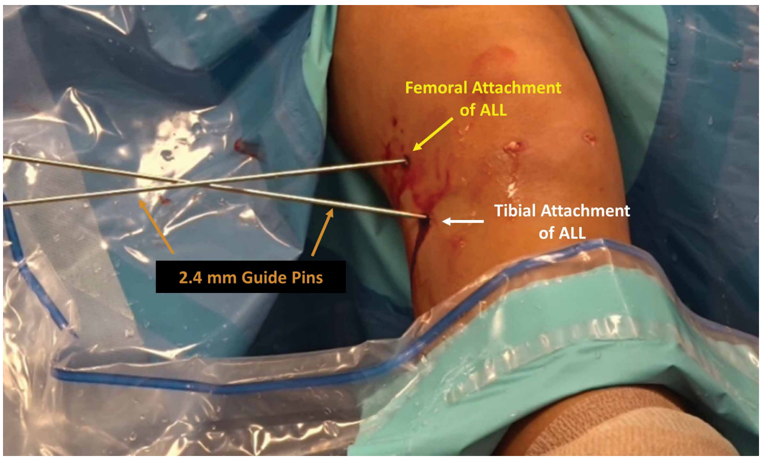

Figure 2. Intraoperative position of the femoral and tibial 2.4-mm guide pins (orange arrows). The locations of the guide pins are at the anatomic site of the femoral (yellow arrow) and tibial (white arrow) attachments of the anterolateral ligament. The 5.0-mm cannulated reamer is used to drill the sockets for anchor placement.

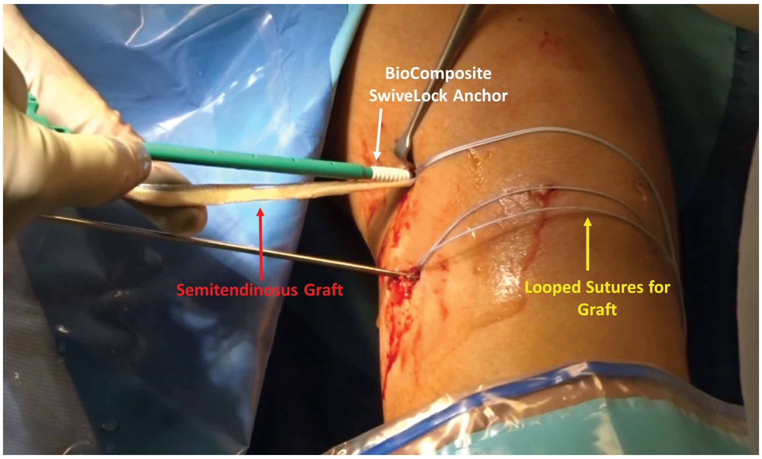

Figure 3. Intraoperative insertion of the BioComposite SwiveLock anchor (Arthrex) (white arrow) at the femoral attachment. The semitendinosus graft (red arrow) is attached to the anchor prior to fixation. The looped, passing suture (yellow arrow) is then used to pull the construct through the plane created underneath the iliotibial band for distal attachment.

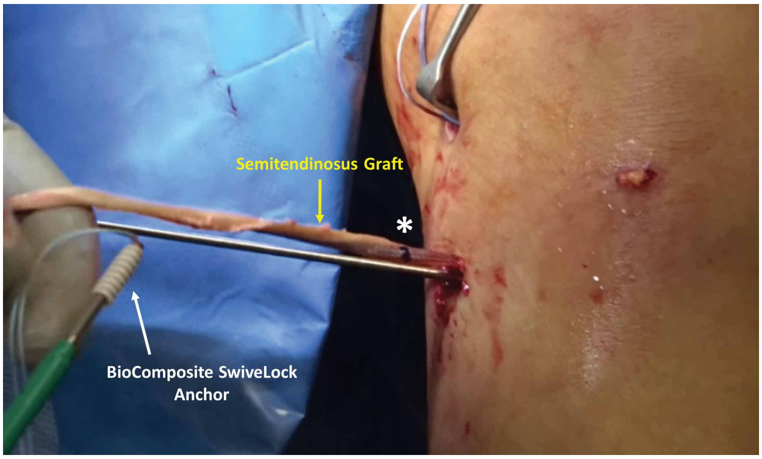

Figure 4. Intraoperative preparation for distal fixation of the semitendinosus graft (yellow arrow). The length of the BioComposite SwiveLock anchor (Arthrex) (white arrow) is marked directly on the graft (white asterisk). The anchor is then attached to the graft at the mark (white asterisk) for appropriate tibial fixation and tensioning.

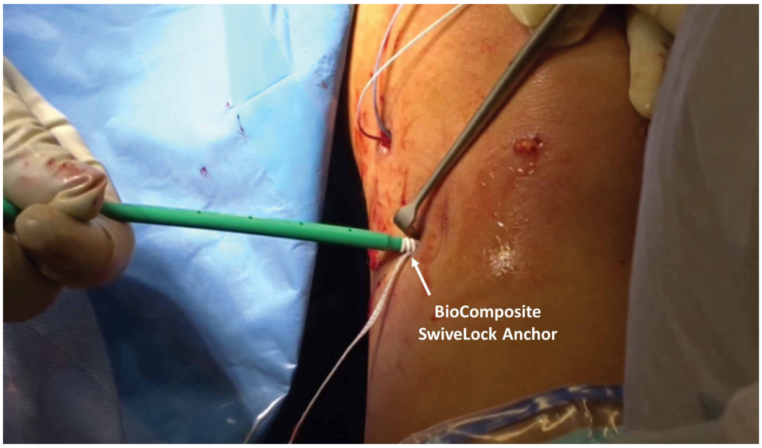

Figure 5. Intraoperative fixation of the tibial BioComposite SwiveLock anchor (Arthrex) (white arrow). Once this anchor is secured, the reconstruction is completed. Range of motion and instability are tested to ensure proper tensioning of the construct.

anchor (Arthrex) and fixed into the femoral socket (**Figure 3**).

The graft and FiberTape are then passed under the IT band to the distal incision. Using the length of the BioComposite SwiveLock anchor as a guide, a mark is made on the graft after tensioning the construct in line with the leg, distal to the tibial drill pin (**Table 2**, **Figure 4**). The second 5.5-mm BioComposite SwiveLock anchor is attached to the FiberTape and graft at the mark. The rest of the graft is resected. The BioComposite SwiveLock anchor, graft, and FiberTape are fixed into the tibial socket, completing the reconstruction (**Figure 5**). Passive range of motion should then be checked to ensure the construct is not overtensioned.

Rehabilitation

Rehabilitation following an ALL procedure is similar to traditional ACL rehabilitation with an added emphasis on minimizing rotational torque of the tibia in the early stages. Our protocol allows for early weight-bearing and minimal use of assistive devices (ie, immobilizer brace and crutches) because an internal brace is performed on every ALL reconstruction. The protocol emphasizes full range of motion and linear power with a progression to lateral and rotational activities. This enables the client to begin rehabilitation within 1 week and regain normal daily function quickly. Return to heavy lifting, physical activity, and sports is delayed until after 6 months to allow for the graft maturity and integration, which takes quite a while, as grafts are weakest after 6 weeks.[13] When patients return to sports and activity, a brace is used for up to 1 year postoperatively to limit shearing forces inherent in pivoting and cutting.

Case Report

In January 2013, a 17-year-old male soccer player suffered an ACL rupture of his right knee. Later that spring, he had an ACL reconstruction with an allograft. Twelve months postoperatively, the patient returned, saying that he felt much better; however, anytime he tried to plant his foot and rotate over that fixed foot, his knee felt unstable. The physical examination revealed both negative Lachman and anterior drawer tests but a I+ pivot shift test. A magnetic resonance imaging (MRI) examination revealed an intact ACL graft. A diagnostic ultrasound evaluation revealed a distal ALL injury. After discussing the risks, benefits, and goals with the patient, we opted for a diagnostic arthroscopy and a percutaneous, ultrasound-guided reconstruction of the ALL.

Table 2. **Anterolateral Ligament Reconstruction Tips/Pearls**

Evaluate pivot shift under anesthesia prior to reconstruction
Knee positioned at 30° flexion and neutral rotation without any varus or valgus stress
Use ultrasound to guide placement of spinal needles
Use 90° hemostat for establishing plane under iliotibial band and for the FiberWire (Arthrex) passing suture
Use FiberTape (Arthrex) with graft as an internal brace
Use length of BioComposite SwiveLock (Arthrex) as a guide to mark graft for tibial placement

Table 3. **Advantages/Disadvantages of Ultrasound-Guided Anterolateral Ligament Reconstruction**

Advantages	Disadvantages
Accurate preoperative assessment	Required proficiency in ultrasound use
Easy graft passage and placement	Controversy over exact femoral attachment location
Re-establish normal rotational kinematics	
Reliable and anatomic socket placement	
Reliable graft measurement	
Percutaneous and minimally invasive procedure	

Postoperatively, the patient did very well. One week after surgery, he returned, saying he felt completely stable and demonstrated by repeating the rotation of his knee. The patient continued to have no issues until he returned 13 months post-ALL surgery, complaining of a recent injury that had caused the return of his feelings of instability. An MRI evaluation showed an intact ACL graft and the possibility of a ruptured ALL. Fifteen months after the initial ALL reconstruction, we proceeded with surgery. At arthroscopy, the patient was found to have a pivot shift of I+ and an intact ACL graft. The ALL was reconstructed again using an allograft, internal brace, and bone marrow concentrate. At 13 months post-ALL reconstruction revision, the patient had no complaints.

Discussion

Reconstruction of the ALL is aimed to restore anatomic rotational kinematics. Sonnery-Cottet and colleagues[14] have reported promising initial results in their 2-year follow-up study of combined ACL and ALL reconstruction outcomes. This surgical technique includes use of an internal brace, which negates the necessity for external support devices and allows for earlier mobilization of the joint. A reconstruction of the ALL, performed concurrently with the ACL, does not add recovery time, but could prevent postsurgical complications and improve rehabilitation by eliminating rotational instability that presents in some ACL-reconstructed patients.

Sonnery-Cottet and colleagues[15] state that their arthroscopic identification of the ALL can help to cultivate a "less invasive and more anatomic" reconstruction. The use of musculoskeletal ultrasound allows our technique to utilize a completely noninvasive imaging tool that allows proper establishment of ALL anatomy prior to the procedure. The entirety of the ALL is easily identifiable,[4,12] which has proven to be shortcoming of MRI evaluation.[15-17] Accurate preoperative assessment of the lateral structures is necessary in ACL-deficient individuals.[11,15] Sonography also provides a means of accurate guidance and socket creation, without generating large incisions.

If the ALL is responsible for internal rotatory stability as asserted, the structure should exhibit biomechanical properties during movement. In their study on the function of the ligament, Parsons and colleagues[9] established the inverse relationship between the ALL and ACL during internal rotation. As their cadaveric knees were subjected to an internal rotatory force through increasing angles of flexion, the contribution of the ALL towards stability significantly increased while the ACL declined. Helito and colleagues[8] and Zens and colleagues[10] have demonstrated length changes of the ligament through varying degrees of flexion and internal rotation. Their reports indicate greater tension during knee movements, coinciding with the description of increasing ALL stability contribution by Parsons and colleagues.[9] Kennedy and colleagues[7] conducted a pull-to-failure test on the ALL. The average failure load was 175 N with a stiffness of 20 N/mm, illustrating the structure is a candidate for most traditional soft tissue grafts. The biomechanical evidence of the structural properties of the ALL confirms its importance in knee function and the necessity for its reconstruction.

With the understanding that ACL contributes to rotatory stability to some extent, the notion begs the question of how a centrally located ligament is able to prevent excessive rotation in a structure with a large relative radius. Biomechanically, with such a small moment arm, the ACL would experience tremendous stress when a rotatory force is applied. The same torque applied to a more superficial structure, with a greater moment, would sustain a large reduction in the applied force. The concept of a wheel and an axle should be considered. The equation is $F_1 \times R_1 = F_2 \times R_2$. We measured on a cadaveric knee the distance from the center of rotation to the ACL and the ALL, finding the radii were 5 mm and 30 mm, respectively. Taking these measurements, we would then expect the force experienced on the axle (ACL) to be 6 times greater than what would be experienced on the periphery of the wheel (ALL). The ALL (wheel) has a significant biomechanical advantage over the ACL (axle) in controlling and enduring internal rotatory forces of the knee. This would imply that if the ALL were damaged and not re-established, the ACL would experience a 6 times greater force trying to control internal rotation, which would result in a significantly increased chance of failure and rupture.

While there is a degree of dissent on the presence of the ALL, a number of studies have classified the tissue as an independent ligamentous structure.[3-7] While there is disagreement on the precise location of the femoral attachment, there is a consensus on the location of the tibial and meniscal attachments. Claes and colleagues[4] originally outlined the femoral attachment as anterior and distal to the origin of the fibular collateral ligament (FCL), which is the description this technique follows. Since Claes and colleagues'[4] report, many have investigated the ligament's femoral origin with delineations ranging from posterior and proximal[3,5,7] to anterior and distal.[6,16-18]

The accurate, noninvasive nature of the musculoskeletal ultrasound prior to any incisions being made makes this technique innovative and superior to other open surgical techniques or those that require fluoroscopy. This is the greatest advantage of the procedure (**Table 3**). Not only does the use of ultrasound make this specific operation exceptional, but its practice is widely applicable. To date, this is the only ultrasound-guided reconstruction of any kind and can serve as a template for not only ALL procedures, but many other procedures as well.

Conclusion

The ALL has been determined to play an integral role in the rotational stability of the knee. In the setting of instability and insufficiency, reconstruction will lead to better patient outcomes for concurrent ACL/ALL injuries and postsurgical rotatory instability following ACL procedures. This innovative technique utilizes ultrasound to ascertain the precise anatomical attachments of the ALL prior to the operation. The novel nature of this ultrasound-guided reconstruction has the potential to be applicable in many other surgical procedures.

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Acknowledgement: The authors acknowledge Robert Asuncion, DPT, Kyle Yamashiro, DPT, and Terry Weiner for their contributions to this article.

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Am J Orthop. 2016;45(7):418-422, 460.

References

1. Suomalainen P, Järvelä T, Paakkala A, Kannus P, Järvinen M. Double-bundle versus single-bundle anterior cruciate ligament reconstruction: A prospective randomized study with 5-year results. *Am J Sports Med.* 2012;40(7):1511-1518.
2. Segond P. Recherches cliniques et expérimentales sur les épanchements sanguins du genou par entorse. *Progrés Médical.* 1879;6(6):1-85. French.
3. Caterine S, Litchfield R, Johnson M, Chronik B, Getgood A. A cadaveric study of the anterolateral ligament: re-introducing the lateral capsular ligament. *Knee Surg Sports Traumatol Athrosc.* 2015;23(11):3186-3195.
4. Claes S, Vereecke E, Maes M, Victor J, Verdonk P, Bellemans J. Anatomy of the anterolateral ligament of the knee. *J Anat.* 2013;223(4):321-328.
5. Dodds AL, Halewood C, Gupte CM, Williams A, Amis AA.

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The anterolateral ligament: Anatomy, length changes and association with the segond fracture. *Bone Joint J.* 2014;96-B(3):325-331.

6. Helito CP, Demange MK, Bonadio MB, et al. Anatomy and histology of the knee anterolateral ligament. *Orthop J Sports Med.* 2013;1(7):2325967113513546.
7. Kennedy MI, Claes S, Fuso FA, et al. The anterolateral ligament: An anatomic, radiographic, and biomechanical analysis. *Am J Sports Med.* 2015;43(7):1606-1615.
8. Helito CP, Helito PV, Bonadio MB, et al. Evaluation of the length and isometric pattern of the anterolateral ligament with serial computer tomography. *Orthop J Sports Med.* 2014;2(12):2325967114562205.
9. Parsons EM, Gee AO, Spiekerman C, Cavanagh PR. The biomechanical function of the anterolateral ligament of the knee. *Am J Sports Med.* 2015;43(3):669-674.
10. Zens M, Niemeyer P, Ruhhamer J, et al. Length changes of the anterolateral ligament during passive knee motion: A human cadaveric study. *Am J Sports Med.* 2015;43(10): 2545-2552.
11. Helito CP, Bonadio MB, Gobbi RG, et al. Combined intra- and extra-articular reconstruction of the anterior cruciate ligament: the reconstruction of the knee anterolateral ligament. *Arthrosc Tech.* 2015;4(3):e239-e244.
12. Cianca J, John J, Pandit S, Chiou-Tan FY. Musculoskeletal ultrasound imaging of the recently described anterolateral ligament of the knee. *Am J Phys Med Rehabil.* 2014;93(2):186
13. Adams JE, Zobitz ME, Reach JS, et al. Rotator cuff repair using an acellular dermal matrix graft: An in vivo study in a canine model. *Arthroscopy.* 2006;22(7):700-709.
14. Sonnery-Cottet B, Thaunat M, Freychet B, Pupim BHB, Murphy CG, Claes S. Outcome of a combined anterior cruciate ligament and anterolateral ligament reconstruction technique with a minimum 2-year follow-up. *Am J Sports Med.* 2015;43(7):1598-1605.
15. Sonnery-Cottet B, Archbold P, Rezende FC, Neto AM, Fayard JM, Thaunat M. Arthroscopic identification of the anterolateral ligament of the knee. *Arthrosc Tech.* 2014;3(3):e389-e392.
16. Helito CP, Helito PV, Costa HP, et al. MRI evaluation of the anterolateral ligament of the knee: assessment in routine 1.5-T scans. *Skeletal Radiol.* 2014;43(10):1421-1427.
17. Helito CP, Demange MK, Helito PV, et al. Evaluation of the anterolateral ligament of the knee by means of magnetic resonance examination. *Rev Bras Orthop.* 2015;50(2):214-219.
18. Helito CP, Demange MK, Bonadio MB, et al. Radiographic landmarks for locating the femoral origin and tibial insertion of the knee anterolateral ligament. *Am J Sports Med.* 2014;42(10):2356-2362.