Technical Note

The Push-Through Sign—Making the Decision for Selective-Bundle Anterior Cruciate Ligament Surgery

Arthur R. Bartolozzi, M.D., Aashish V. Jog, M.D., and Tyler J. Smith, D.O.

Abstract: Partial anterior cruciate ligament (ACL) tears are often difficult to diagnose and treat. Recent interest in the literature has focused on performing selective-bundle ACL reconstruction in patients with symptomatic partial ACL tears when one of the ACL bundles is intact. However, the clinical examination, magnetic resonance imaging, and arthroscopic evaluation of partial ACL tears may not correlate, and proper assessment of the integrity of the intact portion of the ACL continues to be a challenge. If a selective-bundle ACL reconstruction is performed in a patient with an apparently intact but structurally damaged individual bundle, the outcome would be compromised by leaving the damaged bundle in place. This technical note provides a description of a simple and reliable arthroscopic method to aid in the diagnosis of a partial ACL tear. The use of this method to assess remaining ligamentous tissue will assist surgeons in deciding for or against selective-bundle ACL reconstruction.

Anterior cruciate ligament (ACL) reconstruction has undergone an evolution since the science and biomechanical behavior has become more understood, and there also is increasing attention to performing single-bundle ACL reconstruction as the anatomic nuances of ACL injury are better understood. Fu et al. have emphasized that double-bundle ACL reconstruction is an anatomic concept, not simply a technique. Individual comparative studies as well as meta-analyses of randomized controlled trials indicate better biomechanical function of double-bundle reconstructions in comparison with single-bundle reconstructions; however, there is no consensus regarding superiority of functional outcomes or graft failures. Nevertheless, there remains interest in single-bundle ACL reconstruction. Attention to detail and focusing on anatomical restoration has prompted greater interest in restoring only the injured segment of the ligament. However, the diagnosis and assessment of an individual-bundle disruption or a partial ACL tear is often difficult.

DeFranco and Bach have defined a partial ACL tear by a combination of the following factors (Table 1): (1) an asymmetric Lachman test result as compared with that of the uninjured knee; (2) a negative pivot-shift test with the patient under anesthesia; (3) a low-grade KT-1000 arthrometer measurement (<3 mm); and (4) arthroscopic evidence of an ACL injury. They further indicated that an asymmetric positive pivot shift, regardless of the grade, is consistent with functional instability.

In addition, studies have suggested that results of the clinical examination, magnetic resonance imaging (MRI), and arthroscopy may be variable, may not correlate during the assessment of a partial ACL tear, and none of these diagnostic methods can be used individually to diagnose a partial ACL tear with certainty.

Furthermore, the microanatomy of the torn ACL has been documented, as has the outcome of nonoperative treatment for partial tears. The implication is that if a selective-bundle ACL reconstruction is performed in a patient with an apparently intact individual bundle, the outcome would be compromised by leaving an internally damaged but visually intact bundle in place. The purpose of this paper is to present an arthroscopic technique of identifying whether an ACL bundle that appears intact during arthroscopy is truly intact, or in other words, whether a partial ACL tear is actually partial (Table 2).
Technique

A standard operating room table with a lateral post or an arthroscopic leg holder is used for the procedure. The affected knee is prepped and draped in a standard fashion. A standard anterolateral portal is made, and a 30° arthroscope is introduced in the knee through the portal. A routine diagnostic arthroscopy is performed. After creation of a standard anteromedial working portal under direct visualization, a suction shaver is used to remove any obstructing tissue. The least possible debridement that allows inspection and evaluation of the ACL is performed using the suction shaver. The ACL can be visualized after retracting the ligamentum mucosum, when intact, medially using the probe. The ACL originates from the medial wall of the lateral femoral condyle and attaches on the anterior portion of the interspinous region of the tibia. The ACL is thus directed inferiorly, medially, and anteriorly from its attachment on the femur.

The Push-Through Sign (With Video Illustration)

To perform the push-through test, the probe is inserted through the anteromedial portal and the ACL is visualized from anterolateral portal. The tip of the probe is aligned parallel with the long axis of the visually intact bundle of the ACL, adjacent to its femoral attachment (Fig 1). Using the probe, moderate pressure is applied posteriorly in an attempt to push the probe through the ACL tissue. Care must be taken to avoid excessive or uncontrolled pressure, as the probe may pass through the ACL posteriorly and cause injury to structures of the posterior knee. If the probe passes through the tissue, it is considered a positive push through sign (Fig 2, Video 1, first part). This would indicate that although the bundle is visually intact, there is structural damage and therefore not functionally intact. If moderate pressure applied to the probe does not result in the probe passing through the tissue, this is considered a negative push through sign (Figs 3 and 4). This would indicate that the bundle is

Table 1. Criteria for Defining a Partial ACL Tear (DeFranco and Bach10)

| Criterion                                                                 |
|---------------------------------------------------------------------------|
| An asymmetric Lachman test result as compared with that of the uninjured knee |
| A negative pivot-shift test with the patient under anesthesia             |
| A low-grade KT-1000 arthrometer measurement (≤3 mm)                       |
| Arthroscopic evidence of an anterior cruciate ligament injury             |

ACL, anterior cruciate ligament.

Table 2. Key Points

| Point                                                                 |
|---------------------------------------------------------------------|
| It is difficult to assess the integrity of remaining ACL fibers in the case of a partial tear. |
| Consideration must be given to thoroughly evaluating the remnant anteromedial or posterolateral bundle arthroscopically in the event that the MRI and/or physical examination indicates that a partial tear may be present. |
| The positive push-through sign is an indication of insufficient or incompetent remnant tissue to perform a selective-bundle reconstruction |

ACL, anterior cruciate ligament; MRI, magnetic resonance imaging.
both visually and structurally intact. It is important to keep the probe aligned parallel to the long axis of the ACL fibers, as positioning the probe perpendicularly may result in a false-negative sign. Additional tips regarding the push-through sign can be found in Table 3. To summarize, the probe cannot be passed through the tissue with moderate pressure in a healthy, structurally intact ACL (Video 1, second part).

Discussion

Selective-bundle ACL reconstruction for partial tears has gained interest in the past several years. However, clinical examination, MRI, and routine arthroscopic evaluation may not be able to provide a detailed and proper assessment of the integrity of the ACL. As a result, determining which partial ACL tears truly involve only a single bundle continues to be a challenge. There are circumstances in which clinical examination, MRI, and diagnostic arthroscopy suggest there is a partial tear with one intact bundle. However, the visually intact bundle may have significant structural damage, compromising its function. If a selective-bundle ACL reconstruction is performed in this scenario, there is a high risk of failure and revision surgery.

We have developed a method that can be used during arthroscopy to evaluate the structural integrity of the individual bundles in cases of partial ACL tear. This technique presents a simple, reliable, and easily reproducible method to aid in the diagnosis of a partial ACL tear. Other advantages of the technique are that it does not add any increased cost, no special equipment is required, and it is not time-consuming or disruptive to operative workflow (Table 4). Limitations of the technique are that it cannot be used for bony avulsions of the ACL, and the test does not provide information regarding the microarchitecture of the bundle (Table 5). A positive push-through sign indicates that the visually intact bundle is weak, has structural damage, and implies that it is actually torn. A negative push-through

Table 3. Tips
When the ligament remaining appears intact, it is helpful to view it from several positions such as the standard lateral and medial parapatellar portals.

Begin applying the probe pressure just adjacent to the femoral attachment, as most ACL injuries occur closer to the femoral side.

When performing arthroscopy of the knee in cases in which the ACL is normal, take the opportunity to carefully probe the ACL in line with the longitudinal axis to get an appreciation of what an intact ligament feels like.

If the probe tip is pushed perpendicular to the fibers and not longitudinally, it can result in a false-negative push through sign.

ACL, anterior cruciate ligament.

Table 4. Advantages of the Technique
It presents a method of assessment of ligament integrity
It is not time consuming
It does not require any special equipment
It is reliable and reproducible
It is safe and does not compromise any further surgical steps
against selective-bundle ACL reconstruction. Surgeons during diagnostic arthroscopy and ACL is intact. Thus, the push-through test is a useful tool for a sign indicates that the bundle is strong, functional, and intact. Thus, the push-through test is a useful tool for determining the integrity of the ACL. It is useful only in cases of interstitial tears of the ACL or tears at the remaining tissue but not the microarchitecture. It is only applicable as a component of a comprehensive evaluation to assess the situation for appropriateness of selective-bundle reconstruction. A negative sign must be accompanied with a physical exam suggesting single bundle injury.

| **Table 5. Limitations and Risks of the Technique** |
|---------------------------------------------------|
| It assesses only the apparent quantity and apparent integrity of the remaining tissue but not the microarchitecture. It is useful only in cases of interstitial tears of the ACL or tears at the attachment sites of the ACL and not in cases of bony avulsions of the ACL. |
| If the probe is pushed in an uncontrolled fashion, it may slide too posterior and cause injury. |
| Using the push through sign is only part of a thorough assessment of the remaining ACL tissue. It is only applicable as a component of a comprehensive evaluation to assess the situation for appropriateness of selective-bundle reconstruction. A negative sign must be accompanied with a physical exam suggesting single bundle injury. |

References

1. Fu FH, Araujo PH, Lin A. Double-bundle ACL reconstruction with use of a single tibial tunnel: A technique or an anatomic concept? *J Bone Joint Surg* 2011;93:e121.
2. Goldsmith MT, Jansson KS, Smith MD, Engebretsen L, LaPrade RF, Wijdicks CA. Biomechanical comparison of anatomic single- and double-bundle anterior cruciate ligament reconstructions: An in vitro study. *Am J Sports Med* 2013;41:1595-1604.
3. Xu M, Gao S, Zeng C, et al. Outcomes of anterior cruciate ligament reconstruction using single-bundle versus double-bundle technique: Meta-analysis of 19 randomized controlled trials. *Arthroscopy* 2013;29:357-365.
4. Zhang Y, Xu C, Dong S, Shen P, Su W, Zhao J. Systemic review of anatomic single- versus double-bundle anterior cruciate ligament reconstruction: Does femoral tunnel drilling technique matter? *Arthroscopy* 2016;32:1887-1904.
5. Järvelä S, Kiekara T, Suomalainen P, Järvelä T. Double-bundle versus single-bundle anterior cruciate ligament reconstruction: A prospective randomized study with 10-year results. *Am J Sports Med* 2017;45:2578-2585.
6. Maeyama A, Hoshino Y, Kato Y, et al. Anatomic double bundle ACL reconstruction outperforms any types of single bundle ACL reconstructions in controlling dynamic rotational laxity. *Knee Surg Sports Traumatol Arthrosc* 2018;26:1414-1419.
7. Gobbi A, Whyte GP. Anatomic double-bundle and single-bundle ACL reconstruction after ACL rupture did not differ for quality of life at 2 years. *J Bone Joint Surg* 2019;101:943.
8. Mohtadi NG, Chan DS. A randomized clinical trial comparing patellar tendon, hamstring tendon, and double-bundle ACL reconstructions: Patient-reported and clinical outcomes at 5-year follow-up. *J Bone Joint Surg* 2019;101:949-960.
9. Siebold R, Fu FH. Assessment and augmentation of symptomatic anteromedial or posterolateral bundle tears of the anterior cruciate ligament. *Arthroscopy* 2008;24:1289-1298.
10. DeFranco MJ, Bach BR. A comprehensive review of partial anterior cruciate ligament tears. *J Bone Joint Surg Am* 2009;91:198-208.
11. Lintner DM, Kamaric E, Moseley JB, Noble PC. Partial tears of the anterior cruciate ligament: Are they clinically detectable? *Am J Sports Med* 1995;23:111-118.
12. Van Dyck P, De Smet E, Veyser J, et al. Partial tear of the anterior cruciate ligament of the knee: Injury patterns on MR imaging. *Knee Surg Sports Traumatol Arthroscopy* 2012;20:256-261.
13. Noyes F, Mooar L, Moorman C, McGinniss G. Partial tears of the anterior cruciate ligament. Progression to complete ligament deficiency. *J Bone Joint Surg Br* 1989;71-B:825-833.
14. Adachi N, Ochi M, Uchio Y, Sumen Y. Anterior cruciate ligament augmentation under arthroscopy, *Arch Orthop Trauma Surg* 2000;120:128-133.
15. Ochi M, Adachi N, Uchio Y, et al. A minimum 2-year follow-up after selective anteromedial or posterolateral bundle anterior cruciate ligament reconstruction. *Arthroscopy* 2009;25:117-122.
16. Park SY, Oh H, Park SW, Lee JH, Lee SH, Yoon KH. Clinical outcomes of remnant-preserving augmentation versus double-bundle reconstruction in the anterior cruciate ligament reconstruction. *Arthroscopy* 2012;28:1833-1841.
17. Chia Z-Y, Chee JN, Bin-Abd-Razak HR, Lie DT, Chang PC. A comparative study of anterior cruciate ligament reconstruction with double, single, or selective bundle techniques. *J Orthop Surg* 2018;26:230949901877312.
18. Hu J, Qu J, Xu D, Zhang T, Zhou J, Lu H. Clinical outcomes of remnant preserving augmentation in anterior cruciate ligament reconstruction: A systematic review. *Knee Surg Sports Traumatol Arthrosc* 2014;22:1976-1985.
19. Matsushita T, Kuroda R, Nishizawa Y, et al. Clinical outcomes and biomechanical analysis of posterolateral bundle augmentation in patients with partial anterior cruciate ligament tears. *Knee Surg Sports Traumatol Arthrosc* 2017;25:1279-1289.
20. Nakamae A, Ochi M, Deie M, et al. Clinical outcomes of second-look arthroscopic evaluation after anterior cruciate ligament augmentation: Comparison with single- and double-bundle reconstruction. *Bone Joint J* 2014;96-B:1323-1332.
21. Papalia R, Franceschi F, Zampogna B, Tecame A, Maffulli N, Denaro V. Surgical management of partial tears of the anterior cruciate ligament. *Knee Surg Sports Traumatol Arthrosc* 2014;22:154-165.
22. Shaikh H, Rahmamei-Azar AA, Fu FH. Anterior cruciate ligament augmentation for one-bundle tears. *Op Tech Orthop* 2017;27:43-51.
23. Song G-Y, Zhang H, Zhang J, et al. The anterior cruciate ligament remnant: To leave it or not? *Arthroscopy* 2013;29:1253-1262.
24. Yazdi H, Torkaman A, Ghahramani M, Moradi A, Nazarian A, Ghorbanhoseini M. Short term results of anterior cruciate ligament augmentation in professional and amateur athletes. *J Orthop Traumatol* 2017;18:171-176.
25. Yoo Y-S, Song SY, Yang CJ, Ha JM, Kim YS, Seo Y-J. A comparison between clinical results of selective bundle and double bundle anterior cruciate ligament reconstruction. *Yonsei Med J* 2016;57:1199.