A Femoral Tunnel View Test During ACL Reconstruction

Eduardo Frois Temponi, M.D., M.Sc., João Newton Penido Oliveira, M.D., Luiz Fernando Machado Soares, M.D., M.Sc., and Lúcio Honório de Carvalho Júnior, M.D., Ph.D.

Abstract: Despite technologic advances in the surgical techniques for anterior cruciate ligament (ACL) reconstruction, some patients continue to have violation of the femoral cortex, commonly referred to as wall blowout. These posterior or lateral cortical breaches lead to loss of graft containment and subsequent difficulty with graft fixation. If this intraoperative error is not promptly recognized and treated, the graft is at an increased risk of premature failure. Thus, in these situations, recognizing the complication and knowing strategies for alternative or salvage fixation are of importance. This article details a simple tunnel view test realized during ACL reconstruction that would enable determining the integrity and depth of the femoral tunnel. The femoral tunnel view test is a technically straightforward and quick test able to obtain a superior view of patient anatomy to facilitate accurate tunnel integrity evaluation during ACL reconstruction.

Improvements in clinical and functional results of anterior cruciate ligament (ACL) reconstruction have been observed after anatomic reconstruction is performed.[1-4] For anatomic ACL reconstruction, there is a need to place both femoral and tibial tunnels in the center of the respective footprints, respecting the original anatomy.[1,5] Knowledge of the anatomic position of ACL attachments can improve the correct positioning and placement of the tunnel and graft.[6,7] The most common error in surgical technique of ACL reconstruction is improper tunnel placement, which may be identified in 70% to 80% of failed ACL reconstruction, specifically inappropriate femoral tunnel placement.[6,8-13] Several techniques have been developed to try to anatomically address tunnels in the setting of an ACL reconstruction; however, an anatomic positioning does not necessarily indicate maintenance of integrity of the tunnels, specifically the femoral tunnel.[10,14-17]

Although femoral tunnel misposition in an anterior location can result in rotational laxity or graft impingement, a posteriorly placed femoral tunnel may result in deleterious consequences such as a breach of the posterior femoral cortex and consequent lack of femoral graft fixation.[11,18,19] The compromising of the walls of the femoral tunnel can lead to a loss of graft containment and subsequent difficulty with fixation.[18,20] If this intraoperative error is not promptly recognized and appropriately treated, the graft is at an increased risk of premature failure.[5,13] Thus, in these situations, recognizing the complication and knowing strategies for alternative or salvage fixation are of paramount importance.[3] The true incidence of posterior wall blowout in ACL reconstruction is difficult to determine because it is unclear how often such blowouts are recognized intraoperation and treated appropriately versus how many go unrecognized.[18,20,21]

Thus, the purpose of this article was to describe a surgical tip that can lead to more consistent and anatomic views of the femoral tunnel during ACL reconstruction, and describe a simple tunnel view test realized during ACL reconstruction that would enable determining the integrity of the femoral tunnel.

From the Hospital Madre Teresa (E.F.T., J.N.P.O., L.F.M.S., L.H.C.J.); Departamento do Aparelho Locomotor, Faculdade de Medicina, Universidade Federal de Minas Gerais, Departamento de Medicina, Pontifícia Universidade Católica (L.H.C.J.), Belo Horizonte, Minas Gerais, Brazil.

The authors report that they have no conflicts of interest in the authorship and publication of this article.

The investigation was performed at the Hospital Madre Teresa, Belo Horizonte, Minas Gerais, Brazil.

Received January 25, 2017; accepted April 11, 2017.

Address correspondence to Eduardo Frois Temponi, M.D., M.Sc., Avenida Raja Gabáglia 1002, Gutierrez, 30441-070, Belo Horizonte, Minas Gerais, Brazil. E-mail: dufrois@hotmail.com

2212-6287/17114/$36.00

http://dx.doi.org/10.1016/j.eats.2017.04.003

Table 1. Indications and Contraindications of Femoral Tunnel View Test During ACL Reconstruction

Indications	Contraindications
Arthroscopic ACL reconstruction.	Lack of knowledge about arthroscopic technique
Doubt about integrity of the femoral tunnel	Realization of open reconstruction technique
Doubt about depth of the femoral tunnel	ACL remnant >50% (relative)

ACL, anterior cruciate ligament.

Surgical Technique

Patient setup

The patient is placed supine on an operative table in the standard arthroscopy position with a lateral post just proximal to the knee, at the level of the padded tourniquet, and a foot roll to prevent the hip from externally rotating and to keep the knee flexed at 90°. In this way, the knee can be moved freely throughout the full range of motion during ACL reconstruction.[22]

ACL Inside-Out Technique

The technique used is a modified one previously published and is summarized here.[22,23] Grafts were harvested with an open-ended tendon stripper, allowing the tibial insertion to be preserved, thereby improving the fixation and vascularity of the graft. Once harvested, the graft is evaluated to determine whether an 8- to 10-mm-width graft of 12 cm length can be obtained. The knee was held close to 110° of flexion to allow better visualization when the femoral tunnel was drilled. The inside-out femoral tunnel was placed 7 mm from the posterior border of the lateral femoral condyle at the 9 o'clock position for a right knee and at the 3 o'clock position for a left knee, using the ACL remnants as anatomic reference.[14-16] The tibial tunnel is made according to standard protocol. Leaving the knee at 90° of flexion, the surgeon then passes the graft from the tibia to the femur. A metallic interference screw (Arthrex, Naples, FL) of the same diameter as the tunnel and 25 mm in length was inserted in the femoral tunnel in an inside-out manner through the anteromedial portal. Tibial fixation was performed using a metallic interference screw of the same diameter as the tunnel and 25 mm in length. The graft was fixed with around 20° of knee flexion.

Femoral Tunnel View Test

The femoral tunnel view test can be used during any ACL arthroscopic reconstruction. Indication contraindication can be found in Table 1. The recommended time to realize the femoral tunnel view test is after creating the femoral tunnel during ACL reconstruction. Advantages and disadvantages are summarized in Table 2. To perform the test, the same arthroscope (4-mm HD arthroscope camera 30°; ConMed Linvatec, Largo, FL; Fig 1) used during the ACL reconstruction should be maintained. For proper and direct view of the femoral tunnel, the change from the anterolateral portal to the anteromedial portal should be done (Fig 2). After changing the portal, lens direction correction should be made for direct viewing of the femoral tunnel. Next, the introduction of the arthroscope into the anteromedial portal allows direct visualization of the femoral tunnel (Fig 3). At first, the vision is more distant, with the tunnel being observed in the background. In these initial moments, the medial femoral condyle and the ACL remnants can still be observed. The next step involves introducing the arthroscope into the femoral tunnel (Fig 4). Some difficulties may be encountered as a result of the presence of ACL remnants, although these do not prevent the direct visualization of the femoral tunnel. In cases of large remnants (>50%), maneuvering the posterior rejection of the same can be done. After viewing the femoral tunnel entrance, the arthroscope is introduced directly into the tunnel. This can be done in a delicate manner without much difficulty and resistance. With the introduction of the arthroscope, a general evaluation of all the walls of the tunnel (posterior, lateral, medial and anterior) is made by rotating the lens; this maneuver also allows the surgeon to evaluate the superficial as well as the deepest part of the tunnel. At this time, it is possible to evaluate the integrity of the femoral tunnel and the location and depth of the wall fracture in case of injury (Fig 5 and Video 1). Several variations of wall blowouts are susceptible. These may be described by their location along the femoral tunnel (i.e., deep or more proximal) or by the depth of the tunnel blowout (<3 mm, 3-5 mm, >5 mm). Finally, evaluation of depth of the femoral tunnel is made. This stage is a complementary part of the femoral tunnel view test and can be done both before and after the test with the arthroscope already in the anterolateral portal. With the introduction of a reamer of smaller diameter, the depth of the tunnel is confirmed by direct

Table 2. Advantages and Disadvantages of Femoral Tunnel View Test During ACL Reconstruction

Advantages	Disadvantages
Technically straightforward	Increased surgical time
Simple test	Damage to ACL remnants
Confirms the integrity of the femoral tunnel	
Small learning curve	
Allows assessment of the depth measurement of the femoral tunnel	
It can be used in any tunnel (femoral or tibial) and is independent of the chosen technique (in-out, out-in, all inside)	

ACL, anterior cruciate ligament.

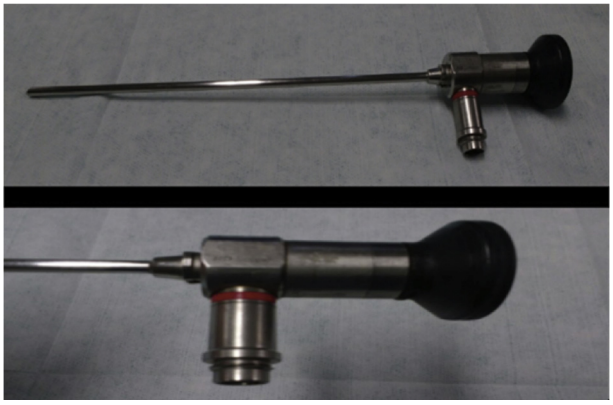

Fig 1. The 4-mm HD Arthroscope camera (30°) (ConMed Linvatec) used during ACL reconstruction. This camera is used throughout the procedure, both for the anterolateral and anteromedial portals. The top panel shows camera on low magnification and below it the highest.

visualization (Fig 6). The pearls and pitfalls of this technique are summarized in Table 3.

Discussion

Although ACL anatomy has been described by use of radiographic and cadaveric measures, it is important to understand the anatomy to easy visualize the arthroscopic landmarks.[7-9,16,24,25] Anatomic placement of the femoral and tibial tunnels is crucial to the success of ACL reconstruction.[1-4,19] Although during ACL reconstruction the anatomic positioning is objectified, the maintenance of the bone integrity of the tunnels created is not always guaranteed.[18] The advantages of the described test are that it is technically straightforward to learn and the surgeon is quickly able to obtain a superior view of patient anatomy to facilitate accurate tunnel integrity evaluation, despite this is not a common complication.[18,20,21] Although in this study it was done for integrity evaluation using an in-out technique, the test can be extrapolated to other techniques (e.g., out-in), other tunnels (e.g., tibial), and in other reconstructions (e.g., posterior cruciate ligament). The potential disadvantage of this technique is the necessity to modify the portal for direct visualization, although this does not significantly increase the time of the procedure. Another limitation is the possibility of damaging ACL remnants during arthroscopic triangulation for direct femoral tunnel view (Table 2).

When some femoral wall has been breached and the complication is immediately recognized, it may be possible to continue with planned suspensory (soft tissue grafts) or interference screw fixation (bone-tendon-bone grafts) if the cortical defect is minimal.[13,18,20,26] A posterior cortical blowout that does not extend beyond 3 to 5 mm from the entrance of the tunnel may be salvaged by slight anterior redirection of the reamer or a deeper reaming followed by the same planned

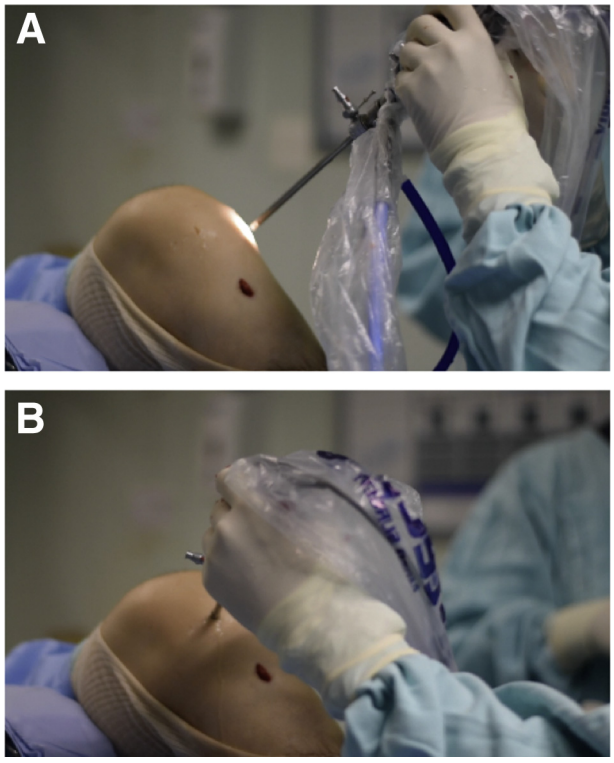

Fig 2. The patient is lying supine with the knee flexed at 110° (left knee). Photography during portal interchanging to realize the femoral tunnel view test on ACL reconstruction. For proper and direct visualization of the femoral tunnel, the surgeon must change the anterolateral portal (A) to the anteromedial portal (B). After changing the portal, lens correction is made for direct viewing of femoral tunnel (put lens parallel to articulation under direct visualization).

fixation. Prior to continuation of reaming, however, a probe should be used to assess and confirm the degree of blowout.[18,20] If posterior wall blowout is

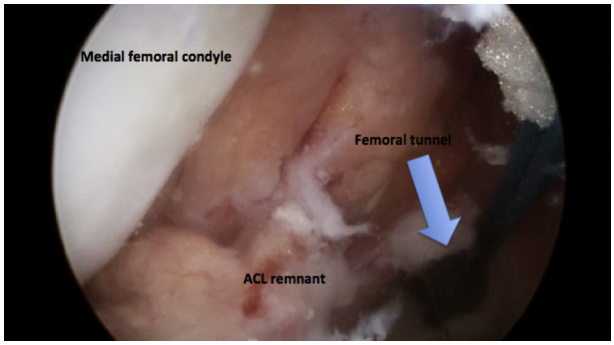

Fig 3. The patient is lying supine with the knee flexed at 110°. The left knee is shown with the first joint arthroscopic image after introduction into the anteromedial portal. After the introduction of the arthroscope into the anteromedial portal the visualization of the femoral tunnel is visualized directly (blue arrow). With primary arthroscopic visualization, on the left side the lateral femoral condyle is observed; shortly before the femoral tunnel, the remnants of the ACL (center of the image); and on the right side, the femoral tunnel already reamed.

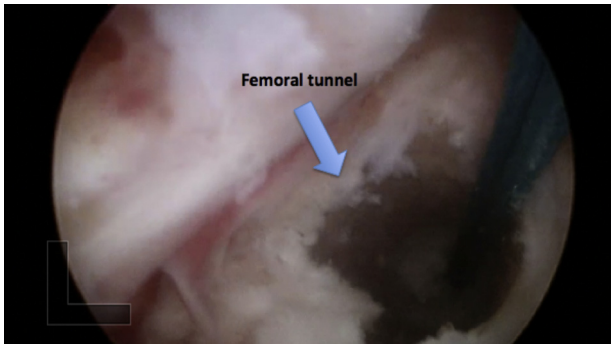

Fig 4. Entrance of the femoral tunnel through the anteromedial portal (left knee). After introduction of the arthroscope through the anteromedial portal, the surgeon must approach the arthroscope inside the femoral tunnel. Some difficulties may be encountered as a result of the presence of ACL remnants, although these do not prevent the direct visualization of the femoral tunnel.

found to be substantial, as defined by extending beyond 5 mm or involves a large circumference of the tunnel, several salvage options exists and should be used.[18,20] If posterior wall blowout is significant and the planned fixation cannot be safely completed, suspensory fixation using the lateral femoral cortex may be used.[27,28] These fixation methods are beneficial because they do not require an intact posterior cortex. Another option for femoral ACL fixation when posterior wall blowout occurs is over-the-top fixation.[29] Pearls and pitfalls are summarized in Table 3.

In summary, although complications in ACL reconstruction can cause deleterious outcomes for patients, careful planning and understanding of the surgical anatomy and tunnels can limit technical pitfalls. When complications such as femoral blowout occur, prompt recognition is imperative to ensure successful graft fixation. Femoral tunnel view test is safe and effective to provide the integrity of the femoral tunnel during ACL reconstruction without increasing considerably the surgical time and complications rate.

Fig 5. Inner part of the femoral tunnel during ACL reconstruction. After viewing the femoral tunnel entrance, the arthroscope is introduced directly into the tunnel. This can be done in a delicate way without difficulty and resistance in this inside-out reconstruction with the knee at 110°. With the introduction of the arthroscope, a general evaluation of the tunnel walls (posterior, lateral, medial, and anterior) is made, in its superficial part as well as the deepest one, evaluating the integrity of the entire tunnel.

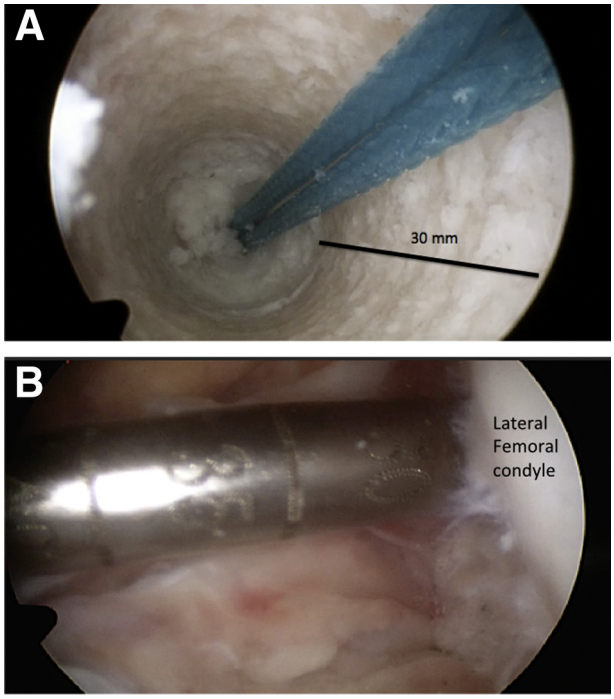

Fig 6. Evaluation of the depth of the femoral tunnel during ACL reconstruction (left knee). (A) Arthroscopic inside view of depth and (B) articular view of depth. This stage is a complementary part of the femoral tunnel view test and can be done both before and after the test. With the introduction of a reamer of smaller diameter, the depth of the tunnel is confirmed by direct visualization.

Table 3. Pearls and Pitfalls of Femoral Tunnel View Test During ACL Reconstruction

Pearls	Pitfalls
Change the arthroscope to the anteromedial portal to allow direct visualization of femoral tunnel and correct lens.	The integrity of the femoral tunnel is not a guarantee of anatomic tunnel positioning.
Gently insert the arthroscope through the medial portal into the entrance of the femoral tunnel carefully in order not to damage the ACL remnants during the course.	The remnants of the ACL may disrupt the adequate visualization of the femoral tunnel during the introduction of the arthroscope.
After the entry into the femoral tunnel, a 360° visual check may be performed by rotating the lens.	
Evaluate the walls (posterior, anterior, medial, and lateral) along the femoral tunnel.	

ACL, anterior cruciate ligament.

References

1. Wylie JD, Marchand LS, Burks RT. Etiologic factors that lead to failure after primary anterior cruciate ligament surgery. *Clin Sports Med* 2017;36:155-172.
2. Jeon YS, Choi SW, Park JH, et al. Mid-term outcomes of anterior cruciate ligament reconstruction with far anteromedial portal technique. *Knee Surg Relat Res* 2017;29:19-25.
3. Chen JL, Allen CR, Stephens TE, et al. Differences in mechanisms of failure, intraoperative findings, and surgical characteristics between single- and multiple-revision ACL reconstructions: A MARS cohort study. *Am J Sports Med* 2013;41:1571-1578.
4. Yasen SK, Borton ZM, Eyre-Brook AI, et al. Clinical outcomes of anatomic, all-inside, anterior cruciate ligament (ACL) reconstruction. *Knee* 2017;24:55-62.
5. Di Benedetto P, Di Benedetto E, Fiocchi A, Beltrame A, Causero A. Causes of failure of anterior cruciate ligament reconstruction and revision surgical strategies. *Knee Surg Relat Res* 2016;28:319-324.
6. Rayan F, Nanjayan SK, Quah C, Ramoutar D, Konan S, Haddad FS. Review of evolution of tunnel position in anterior cruciate ligament reconstruction. *World J Orthop* 2015;6:252-262.
7. Piefer JW, Pflugner TR, Hwang MD, Lubowitz JH. Anterior cruciate ligament femoral footprint anatomy: Systematic review of the 21st century literature. *Arthroscopy* 2012;28:872-881.
8. Ilahi OA, Mansfield DJ, Urrea LH 2nd, Qadeer AA. Reliability and reproducibility of several methods of arthroscopic assessment of femoral tunnel position during anterior cruciate ligament reconstruction. *Arthroscopy* 2014;30:1303-1310.
9. Pansard E, Klouche S, Vardi G, Greeff E, Hardy P, Ferguson M. How accurate are anatomic landmarks for femoral tunnel positioning in anterior cruciate ligament reconstruction? An in vivo imaging analysis comparing both anteromedial portal and outside-in techniques. *Arthroscopy* 2015;31:882-889.
10. Luthringer TA, Blackmore SA, Singh BC, Strauss EJ. The learning curve associated with anteromedial portal drilling in ACL reconstruction. *Phys Sportsmed* 2016;44:141-147.
11. Giron F, Losco M, Giannini L, Buzzi R. Femoral tunnel in revision anterior cruciate ligament reconstruction. *Joints* 2013;1:126-129.
12. Kamath GV, Redfern JC, Greis PE, Burks RT. Revision anterior cruciate ligament reconstruction. *Am J Sports Med* 2011;39:199-217.
13. Ma Y, Ao YF, Yu JK, Dai LH, Shao ZX. Failed anterior cruciate ligament reconstruction: Analysis of factors leading to instability after primary surgery. *Chin Med J (Engl)* 2013;126:280-285.
14. Han Y, Hart A, Martineau PA. Is the clock face an accurate, precise, and reliable measuring tool for anterior cruciate ligament reconstruction? *Arthroscopy* 2014;30:849-855.
15. Mehta V, Petsche T, Rawal AM. Inter- and intrarater reliability of the femoral tunnel clock-face grading system during anterior cruciate ligament reconstruction. *Arthroscopy* 2017;33:394-397.
16. Rowan FA, Marshall T, Gombosh MR, Farrow LD. Utilization of osseous landmarks for anatomic anterior cruciate ligament femoral tunnel placement. *J Knee Surg* 2017;30:359-363.
17. Ahn JH, Lee YS, Ko TS, Shin JY. Accuracy and reproducibility of the femoral tunnel with different viewing techniques in the ACL reconstruction. *Orthopedics* 2016;39:e1085-e1091.
18. Mitchell JJ, Dean CS, Chahla J, Menge TJ, Cram TR, LaPrade RF. Posterior wall blowout in anterior cruciate ligament reconstruction: A review of anatomic and surgical considerations. *Orthop J Sports Med* 2016;4:2325967116652122.
19. Westermann RW, Wolf BR, Elkins J. Optimizing graft placement in anterior cruciate ligament reconstruction: A finite element analysis. *J Knee Surg* 2017;30:97-106.
20. Rue JP, Busam ML, Detterline AJ, Bach BR Jr. Posterior wall blowout in anterior cruciate ligament reconstruction: avoidance, recognition, and salvage. *J Knee Surg* 2008;21:235-240.
21. Dave LY, Nyland J, Caborn DN. Knee flexion angle is more important than guidewire type in preventing posterior femoral cortex blowout: a cadaveric study. *Arthroscopy* 2012;28:1381-1387.
22. Sonnery-Cottet B, Freychet B, Murphy CG, Pupim BH, Thaunat M. Anterior cruciate ligament reconstruction and preservation: The single-anteromedial bundle biological augmentation (SAMBBA) technique. *Arthrosc Tech* 2014;3:e689-e693.
23. Sonnery-Cottet B, Saithna A, Cavalier M, et al. Anterolateral ligament reconstruction is associated with significantly reduced ACL graft rupture rates at a minimum follow-up of 2 years. *Am J Sports Med* 2017:363546516686057.
24. Elazab A, Lee YS, Kang SG. Femoral footprint reconstruction with a direct viewing of the posterior insertion using a trans-septal portal in the outside-in anterior cruciate ligament reconstruction. *Arthrosc Tech* 2016;5:e49-e54.
25. Luites JW, Verdonschot N. Radiographic positions of femoral ACL, AM and PL centres: Accuracy of guidelines based on the lateral quadrant method. *Knee Surg Sports Traumatol Arthrosc* July 4, 2015. [Epub ahead of print.]
26. Hua J, Liu D, Shen G, et al. Comparative evaluation of the techniques and effects of RetroButton and interference screw in anterior cruciate ligament reconstruction [in Chinese]. *Zhonghua Yi Xue Za Zhi* 2015;95:3673-3677.
27. Browning WM 3rd, Kluczynski MA, Curatolo C, Marzo JM. Suspensory versus aperture fixation of a quadrupled hamstring tendon autograft in anterior cruciate ligament reconstruction. *Am J Sports Med* 2017:363546516680995.
28. Nye DD, Mitchell WR, Liu W, Ostrander RV. Biomechanical comparison of fixed-loop and adjustable-loop cortical suspensory devices for metaphyseal femoral-sided soft tissue graft fixation in anatomic anterior cruciate ligament reconstruction using a porcine model [published online February 16, 2017]. *Arthroscopy*. doi:10.1016/j.arthro.2016.12.014.
29. Ruffilli A, Buda R, Pagliazzi G, et al. Over-the-top anterior cruciate ligament reconstruction using single- or double-strand hamstrings autograft. *Orthopedics* 2015;38:e635-e643.