Technical Note

Remnant Preservation Anterior Cruciate Ligament Reconstruction: Modified All-Inside Technique With Appendiceal Tibial Tunnel

An Van Duy Ho, M.Sc., M.D., Khoa Dinh Le, M.Sc., M.D., Thanh Nhat Le, M.Sc., M.D., Vu Anh Tran, M.Sc., M.D., and Anh Ha Nam Tang, Ph.D., M.D.

Abstract: The number of anterior cruciate ligament (ACL) ruptures treated arthroscopically has increased. In most cases, the rupture of the ligament occurs in the femoral attachment, leaving a robust stump attached to the tibia. ACL reconstruction with stump preservation might have some advantages: rapid reinnervation and revascularization of the graft. Most techniques have used an interference screw in tibial fixation, which could be more difficult to achieve the graft diameter within 8 to 10 mm in most situations. Therefore, we describe a technique for modified "all-inside" ACL reconstruction with remnant preservation using an appendiceal tibial tunnel to optimize the graft size. After tunnel drilling in anatomic positions, the ACL stump is bored centrally up to the diameter of the graft to be passed. After passing the graft from the tibial tunnel to the remnant to the femoral tunnel, adjustable loops are used to fix the femoral side and the tibial side by an appendiceal tibial tunnel.

Anterior cruciate ligament (ACL) tears are common knee injuries, particularly in sports. ACL reconstruction has become the standard treatment for these injuries.

However, approximately 43% of the cases have more than 75% of the remnant attached to the tibia.[1] The ACL remnants contain well-vascularized synovial tissues, fibroblasts, myofibroblasts, and mechanoreceptors.[2] Preservation of the robust remnant might accelerate the healing ability of the graft without causing any complications such as cyclops lesion or impingement.[3]

Recent ACL remnant preservation techniques using tibial fixation with an interference screw have resulted in a smaller graft in diameter compared with the "all-inside" graft type.[4] Graft size affects the failure risk in ACL reconstruction.[5] Therefore, we describe a technique that includes the advantages of ACL remnant preservation and the "all-inside" graft type.

From the Center of Orthopedics and Traumatology, Tam Anh Hospital, Ho Chi Minh City, Vietnam.

Received April 27, 2024; accepted July 17, 2024.

Address correspondence to An Van Duy Ho, M.Sc., M.D., Tam Anh General Hospital at Ho Chi Minh City, 2B Pho Quang Street, Ward 2, District Tan Binh, Ho Chi Minh City, Vietnam. E-mail: an.d.ho0108@gmail.com

2212-6287/24689

https://doi.org/10.1016/j.eats.2024.103217

Technique

General Preparation

The patient is supine and examined under anesthesia. A side support and a foot support are used to hold the position in 45° of hip flexion and 90° of knee flexion during arthroscopy. A tourniquet is applied to the ipsilateral proximal thigh. The operative limb is sterilized and draped.

The surgical techniques are summarized in Table 1.

Arthroscopic Examination

Anterolateral (AL) and anteromedial (AM) portals are created. A diagnostic arthroscopy is performed to identify the integrity of the posterior cruciate ligament (PCL), menisci, cartilage, and the presence of loose bodies and other pathologies and treat if needed. The type of ACL rupture is noted (Fig 1A), and the decision of remnant preservation is considered. If the remnant of the ACL is attached to the PCL surface, the remnant is released via the AM portal until PCL exposure.

Preparation of Graft

Since the pathology of the ACL is determined and the decision for reconstruction is clear, the gracilis and semitendinosus autograft from the ipsilateral limb are

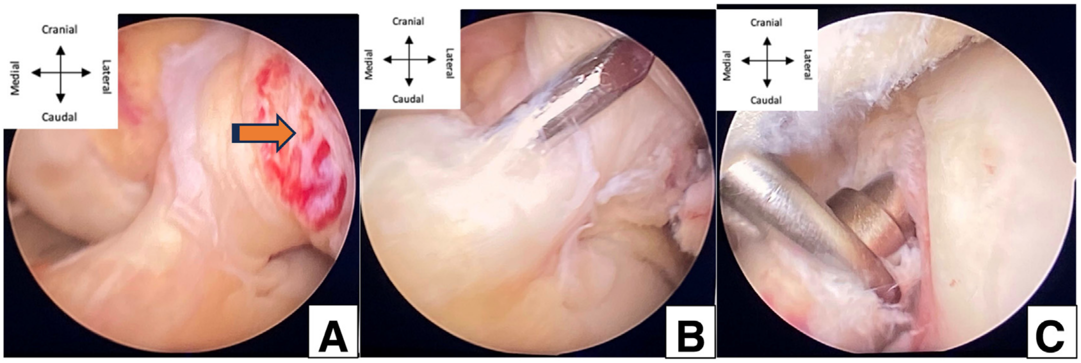

Fig 1. (A) The robust remnant in a case of femoral side rupture (orange arrow), which is a good candidate for the remnant-preserving technique. (B) Under the control of a C-type tibial aimer (RZ Guide Drill System; RZ), a K-wire is inserted into the center of the remnant through the remnant length. (C) A drill sleeve and cannulated drilling bits are used to bore the remnant. This creates a pathway to avoid the graft being stuck during pulling. Left knee, supine position with knee in 90° of flexion.

harvested. The graft is prepared in the "all-inside" fashion with adjustable loops (Power Button; Riverpoint Medical) at both ends. The desired graft size is maintained between 8 and 10 mm in diameter and 60 to 65 mm in length. Each end is tagged with Vicryl No. 2-0 (Ethicon) the last 20 mm.

Preparation of Remnant and Tunnels

By viewing via the AL portal, the knee is held at 120° of flexion. Electrocautery is used to expose the posterior wall of the lateral condyle. The anatomic femoral tunnel is determined by a femoral aimer with a proper offset guide via the AM portal. A femoral guide pin is inserted through the offset guide (RZ Guide Drill System; RZ) and drilled into the femur. An appropriate-size tunnel is then drilled in an inside-out manner (with a minimum tunnel depth of 15 mm to accommodate the graft) via the AM portal. The guide pin is retained for the remaining 4.5 mm of drilling. Drilling debris is evacuated. A femoral waiting suture (FiberWire No. 2; Arthrex) is passed. After femoral preparation, the soft tissue flap should be removed to avoid being entangled during graft passage.

The knee is returned to 90° of knee flexion. The tibial C-type drill guide (RZ Guide Drill System; RZ) with a 50° to 55° set is placed in the center of the tibial remnant. An appropriate-sized tunnel is drilled carefully in an outside-in manner to avoid violating the tibial remnant.

A K-wire is inserted through the center of the remnant along its length (Fig 1B). Cannulated drilling bits are used to gradually bore the remnant from the smaller size up to the appropriate graft size (Fig 1C).

A tibial waiting suture is passed through the remnant and recruited to the AM portal with the femoral waiting suture (Fig 2A). Then, the femoral waiting suture is looped into the tibial ones to pass the femoral suture through the remnant to the tibia.

Graft Passing and Tensioning

The graft is passed and fixed on the femoral side by an adjustable loop (Fig 2B). After tensioning the

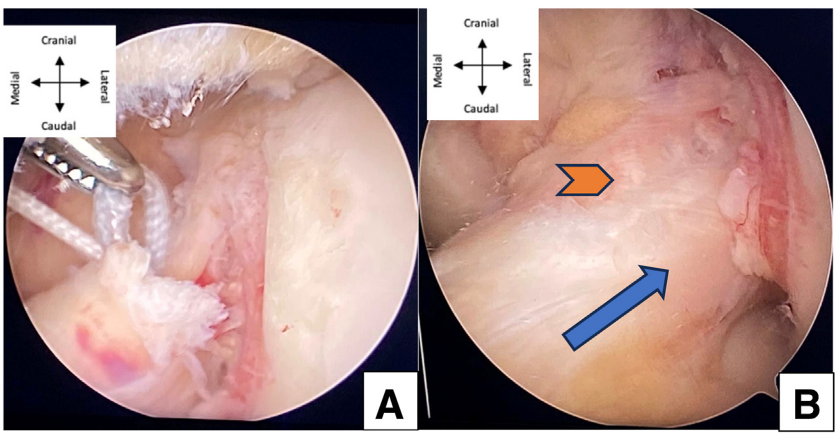

Fig 2. (A) A tibial blue waiting suture (FiberWire No. 2; Arthrex) is passed through the remnant and recruited with the femoral white waiting suture via anteromedial portal. (B) The graft is passed through the center of the remnant and tensioned. Orange arrowhead: exposed graft; blue arrow: anterior cruciate ligament remnant. Left knee, supine position with knee in 90° of flexion.

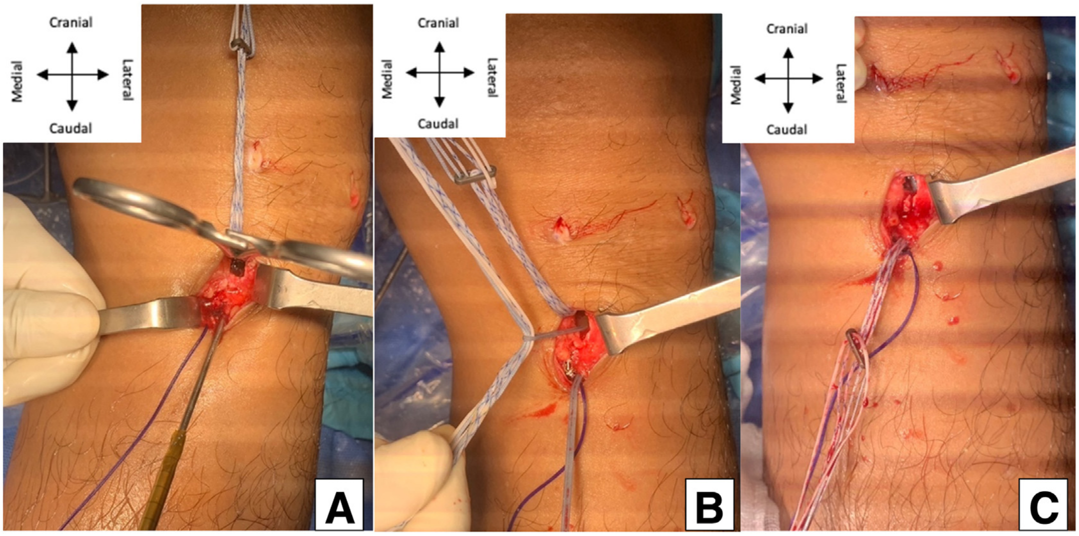

Fig 3. (A) To avoid tunnel collapse, at 1.5 to 2 cm lower than the tibial tunnel, a K-wire is drilled obliquely, aimed at the tibial tunnel with a protective Kelly clamp (Aesculap). (B) The appendiceal tunnel is drilled 4.5 mm following the K-wire to connect with the tibial tunnel, and a shuttle suture (FiberWire No. 2; Arthrex) (blue suture) is inserted via appendiceal tunnel to the tibial tunnel. (C) The tibial adjustable loop (Power Button; Riverpoint Medical) is passed from the tibial tunnel to the appendiceal tunnel and is ready to be fixed. Left knee, supine position with knee in 30° of flexion.

femoral side, cycling is performed. A Kelly clamp (Aesculap) is used to enlarge the tibial tunnel and to protect the graft. At a point 1.5 to 2 cm lower than the tibial tunnel, a K-wire is drilled obliquely aimed to the tibial tunnel. The appendiceal tunnel is drilled 4.5 mm following the K-wire (Fig 3A). The tibial adjustable loop is passed from the tibial tunnel to the appendiceal tunnel and fixed after tensioning (Fig 3 B and C).

Rehabilitation

All patients begin range-of-motion exercises using a knee hinge brace on postoperative day 1. For patients with an isolated ACL reconstruction or with associated meniscal debridement, weightbearing as tolerated is commenced on postoperative day 1. For those with associated meniscal repairs or articular cartilage repairs, weightbearing is delayed until 6 weeks postoperatively. At 3 months, strengthening exercises are initiated. At 9 months, patients undergo assessment for return to sport.

Discussion

The technique is used with the purposes of preservation of the remnant and graft size optimization. The purpose of preservation is to maintain the original biology and mechanical properties of the ACL (Table 2), which could not be obtained with a reconstruction graft. Many studies show that the ACL remnant contains a rich vascularized synovial sheet, fibroblasts, myofibroblasts, and mechanoreceptors,[2,6] Sun et al.[6] and Takahashi et al.[7] conclude that despite unchanged structure properties of the graft, remnant preservation enhances cell proliferation, revascularization, and regeneration of proprioception organs and reduces anterior translation. Kittani et al.[8] find that after the first 3 months, the number of lymphocytes, blood vessels, and nonorganized collagen fibers decreased, and fat infiltration and hyaline degeneration occurred over time. Because the decrease of mechanoreceptors is lessened when being triggered,[9] the technique should be performed within 3 months after injury, and we may recommend having a suture for retention of the remnant along with the graft.

Some studies also report equivalent or superior postoperative outcomes with the remnant preservation group.[3,9] Current literature also reports that mechanoreceptors in the ACL remnant promote reinnervation and proprioception improvement in this group.[10] On second-look arthroscopy, the remodeling graft has a hypertrophy synovium sheet covering 70% or more of the graft.[11]

There is a relationship between graft failure following anterior ACL and the graft diameter. With a hamstring graft, even if the size is equal to or less than 8 mm, Conte et al.[5] report the failure risk is 6.8 times higher. In contrast, with every 0.5- to 1-mm increment of graft diameter, the risk of failure decreases 0.79- to 0.82-fold.[12] The reports of Marchand et al.[13] show that there is no significant difference between 8 to 9 mm and 9.5 to 10 mm in graft diameter, and the risk of failure is higher with a diameter greater than 10 mm. The reason is attributed to roof impingement of the graft that is too big, resulting in collagen damage, revascularization inhibition, and low cellularity in a thick center graft.

Table 1. Surgical Pearls and Pitfalls

Pearls
- The graft is prepared in the "all-inside" fashion with adjustable loops at both ends. Desired graft size should be 8 to 10 mm in diameter and 60 to 65 mm in length.
- The best use for this technique is a femoral side rupture with a robust remnant.
- The anatomic femoral tunnel is determined by a femoral aimer with a proper offset guide.
- The appropriate-size tibial tunnel is drilled carefully in an outside-in manner.
- Cannulated drilling bits are used to gradually bore the remnant from the smaller size to the appropriate graft size.
- A Kelly clamp is used to enlarge the tibial tunnel and to protect the graft while manipulating the appendiceal tibial tunnel.
- The appendiceal tunnel is made at a point 1.5 to 2 cm lower than the tibial tunnel.

Pitfalls
- Considerable force when drilling the tibial tunnel outside-in could violate the remnant.
- Graft could be stuck during pulling due to the tunnels and the remnant.

Remnant preservation techniques have been described with a double-stranded semitendinosus or 4-stranded graft (a 2-stranded semitendinosus with a 2-standed gracilis) and fixed with a cortical button and an interference screw.[4] In this fashion, the diameter is modest. Graft preparation with the "all-inside" technique with 2 cortical buttons allows to strand the graft further, including a 5-stranded semitendinosus tendon graft and a 6-strand hamstring tendon (a 3-stranded gracilis graft combined with a 3-stranded semitendinosus graft). With a hamstring autograft equal to or greater than 8 mm, Nazari et al.[14] show that a 5- or 6-stranded graft is consistent.

This technique could be cost-saving because it does not require a special instrument for drilling a tunnel, such as a flip cutter. However, the limitation of this technique might be the modest visibility of the footprint due to the presence of the tibial remnant, operation time increase, and being technically demanding to avoid complications. The graft could be stuck during pulling due to the tunnels and the remnant. The appendiceal tunnel could collapse due to the distance to the tibial tunnel being too close. Therefore, we recommend leaving approximately 1.5 to 2 cm from the appendiceal to the tibial tunnel.

Table 2. Advantages and Disadvantages

Advantages
- Rapid reinnervation and revascularization of the graft.
- Optimal graft size with the smallest tendon harvesting in the "all-inside" fashion.
- This technique could be cost-saving due to not requiring a special instrument for drilling a tunnel, such as a flip cutter.

Disadvantages
- Modest visibility of the footprint due to the presence of the tibial remnant.
- Operation time might be increased.
- Technically demanding to avoid complication.

In conclusion, the described technique could be a promising option for ACL reconstruction. By preserving the remnant, a scaffold with intact native ACL collagen may provide early and better ligamentation of the graft. With an "all-inside" graft, this technique easily obtains the proper graft diameter, reducing the risk of failure.

Disclosures

All authors (A.V.D.H., K.D.L., T.N.L., V.A.T., A.H.N.T.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. van der List JP, Mintz DN, DiFelice GS. The location of anterior cruciate ligament tears: a prevalence study using magnetic resonance imaging. *Orthop J Sports Med* 2017;5, 2325967117709966.
2. Sonnery-Cottet B, Bazille C, Hulet C, et al. Histological features of the ACL remnant in partial tears. *Knee* 2014;21:1009-1013.
3. Wang H, Liu Z, Li Y, et al. Is remnant preservation in anterior cruciate ligament reconstruction superior to the standard technique? A systematic review and meta-analysis. *Biomed Res Int* 2019;2019:1652901.
4. Singh I, Singh A. Remnant-preserving anterior cruciate ligament reconstruction: Remnant envelope technique. *Arthrosc Tech* 2020;9:e1805-e1812.
5. Conte EJ, Hyatt AE, Gatt CJ, Dhawan A. Hamstring autograft size can be predicted and is a potential risk factor for anterior cruciate ligament reconstruction failure. *Arthroscopy* 2014;30:882-890.
6. Sun L, Wu B, Tian M, Liu B, Luo Y. Comparison of graft healing in anterior cruciate ligament reconstruction with and without a preserved remnant in rabbits. *Knee* 2013;20:537-544.
7. Takahashi T, Kondo E, Yasuda K, et al. Effects of remnant tissue preservation on the tendon graft in anterior cruciate ligament reconstruction: A biomechanical and histological study. *Am J Sports Med* 2016;44:1708-1716.
8. Kittani M, Haviv B, Shemesh S, Yaari L, Yassin M, Rath-Wolfson L. Morphological and histological changes in the human anterior cruciate ligament after rupture. *Isr Med Assoc J* 2021;23:33-37.
9. Kosy JD, Mandalia VI. Anterior cruciate ligament mechanoreceptors and their potential importance in remnant-preserving reconstruction: A review of basic science and clinical findings. *J Knee Surg* 2018;31:736-746.
10. Cho E, Chen J, Xu C, Zhao J. Remnant preservation may improve proprioception after anterior cruciate ligament reconstruction. *J Orthop Traumatol* 2022;23:22.
11. Kim MK, Lee SR, Ha JK, Ra HJ, Kim SB, Kim JG. Comparison of second-look arthroscopic findings and clinical results according to the amount of preserved remnant in anterior cruciate ligament reconstruction. *Knee* 2014;21:774-778.

12. Itoh M, Itou J, Okazaki K, Iwasaki K. Estimation failure risk by 0.5-mm differences in autologous hamstring graft diameter in anterior cruciate ligament reconstruction: A meta-analysis. *Am J Sports Med* 2024;52: 535-543.
13. Marchand JB, Ruiz N, Coupry A, Bowen M, Robert H. Do graft diameter or patient age influence the results of ACL reconstruction? *Knee Surg Sports Traumatol Arthrosc* 2016;24:2998-3004.
14. Nazari G, Barton KI, Bryant D, Getgood A, Brown CH. Five- and six-strand hamstring grafts consistently produce appropriate graft diameters for anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2021;29:2940-2947.