Hamstring Graft Preparation Techniques for Anterior Cruciate Ligament Reconstruction

Gustavo Vinagre, M.D., Nicholas I. Kennedy, M.D., Jorge Chahla, M.D., Ph.D., Mark E. Cinque, M.S., Zaamin B. Hussain, B.A., Morten L. Olesen, M.D., and Robert F. LaPrade, M.D., Ph.D.

Abstract: Anterior cruciate ligament reconstruction is one of the most commonly performed procedures in orthopaedics, with more than 125,000 performed in the United States per year. There are several reconstruction graft choices that can be used to reconstruct the native anterior cruciate ligament, with autograft hamstring tendons being one of the most commonly used. Preparation of a hamstring autograft varies depending on patient characteristics and physician preference. The purpose of this Technical Note is to describe in detail different variants of hamstring graft preparation techniques that are commonly used in practice.

Anterior cruciate ligament (ACL) injuries are one of the most common injuries in orthopaedics, especially in the young and athletic populations. Given the importance of its biomechanical function, ACL tears are commonly addressed surgically.[1] Although there is consensus among surgeons that most ACL injuries require surgical resolution, there is still controversy surrounding different technical aspects of the reconstruction, such as graft choice.

Reconstruction autograft versus allograft, specific graft type (hamstring, patellar tendon, quadriceps), and graft preparation all vary according to surgeons' preferences, patients' needs/expectations, or grafts' characteristics.[2-4] Although some of these considerations have been addressed in previously published outcome studies, such as autograft versus allograft, with numerous studies showing the superiority of an autograft in terms of patient-reported outcomes, decreased failure rate, and return to sport,[5-8] other aspects of the graft election remain unclear. Graft types, particularly hamstring (Table 1) and patellar tendon grafts, have shown good results, and there is no strong evidence demonstrating the superiority of either graft type.[9,10]

Another variable, which has been reported to have an effect on graft strength and longevity, is graft size. According to Conte et al.,[11] grafts less than 8 mm in diameter are a risk factor for poor patient outcomes, with an increase in failure rates, particularly in patients younger than 20 years.[12] This is of particular importance in hamstring autograft procedures because hamstring tendons, specifically in younger female population, tend to be insufficient and more prone to failure.[13] Therefore, to address this issue, techniques that involve increasing hamstring graft thickness by folding the graft on top of itself have been developed.[14,15] The purpose of this Technical Note is to describe in detail different variants of hamstring graft preparation techniques that are commonly used in practice.

Surgical Technique

Graft Harvest

For hamstring tendon autografts, the semitendinosus (ST) and/or gracilis (GC) can be harvested from the

From The Steadman Clinic (R.F.L.); Steadman Philippon Research Institute (N.I.K., J.C., M.E.C., Z.B.H., R.F.L.), Vail, Colorado, U.S.A.; Clínica Universidad de Navarra (G.V.), Pamplona, Navarra, Spain; and Orthopedic Research Laboratory, Aarhus University Hospital (M.L.O.), Aarhus, Denmark.

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Address correspondence to Robert F. LaPrade, M.D., Ph.D., Steadman Philippon Research Institute, The Steadman Clinic, 181 West Meadow Drive, Suite 400, Vail, CO 81657, U.S.A. E-mail: drlaprade@sprivail.org

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Table 1. Advantages and Disadvantages of Hamstring Autografts

Advantages	Disadvantages
• Easy to harvest • No anterior knee pain • Large sectional area • Cosmetic (smaller incision) • Lower donor site morbidity • Comparable strength to native ACL • Fast graft acquisition • Easy graft passage • Less risk of Cyclops syndrome • Custom individualized graft length and diameter • Used if patellar chondropathy; patellar pain; elderly patients; patients with kneeling activities; patients involved in jumping; aesthetic concerns; revision surgery after BTB reconstruction • Imaging (MRI) and arthroscopic evaluation of the ACL remnant dimensions help to plan the ACL reconstruction graft • In high-performance athletes with patellar misalignment: 2 semitendinosus tendons of each knee (avoid residual muscle tears)	• More difficult graft fixation/ prolonged ligamentization of the graft • Soft-tissue healing • Hematoma • Increased risk of infection (compared with BTB) • Graft size can be unpredictable • Complex graft preparation • Decreased flexion strength • Weakening of ACL agonists • Decreased internal rotation strength • Graft laxity • Instrumented (KT) laxity • Tunnel widening • Saphenous nerve injury • Not suitable for certain athletes who rely on their hamstring muscles (medial instability) • Less stiffness than the native ACL • Risk of residual muscle tearing (biceps femoris and semimembranosus)

ACL, anterior cruciate ligament; BTB, bone–patellar tendon–bone; MRI, magnetic resonance imaging.

surgical side or the contralateral side. A vertical anteromedial incision at the level of the tibial tubercle is used to expose the sartorius fascia and pes anserine bursa, which covers the hamstring tendons. An incision in the sartorial fascia allows the exposure of the tendons. The tendons are identified and then placed individually through an open tendon stripper and released from its muscular attachment proximally while flexing the knee and advancing the stripper in a proximal direction. Each tendon is identified according to the muscle belly pattern and harvest position: GC is above and proximal to ST and has a rounded-shaped muscular belly; the ST is below and distal to GC and has a U-shaped muscular belly (Fig 1).

Graft Preparation

The graft preparation and configuration is easily done in a graft preparation station (Arthrex, Naples, FL) (Video 1). The graft is loaded in a cortical suspensory adjustable-length device (ENDOBUTTON CL ULTRA, Smith & Nephew, Andover, MA), and high-strength sutures are used (FiberWire No. 2 Curved Needle, Arthrex; FiberLoop No. 2 Braided Straight Needle, Arthrex).

Removal of excess muscular tissue from each tendon graft is performed, and unstable portions of the tendon are removed. If ST and GC tendons are harvested, they should be twisted in a reverse orientation in order that the proximal end of the ST is adjacent to the distal end of the GC graft and vice versa.[18]

The graft(s) are evaluated in a graft preparation station on the back table, and measurements of length of each harvested tendon(s) are made to determine which graft preparation is more suitable for that specific ACL reconstruction. The graft configuration is then simulated (folded) to determine the appropriate graft length and diameter.

Other pearls and pitfalls should be taken into account in the surgical graft preparation technique for obtaining an optimal hamstring graft (Table 2).

Graft Configuration

Two-Strand Graft Preparation

With One Tendon (Either GC or ST). The tendon is loaded in a suspensory device with the middle portion of the tendon in the clamp (Fig 2; Video 1). The 2 free ends of the graft are folded on top of one another, and are stitched together with a nonabsorbable suture trying to equalize both the ends of the graft. The graft is whipstiched in the distal site of the graft.

Three-Strand Graft Preparation (If the Tendon Is Very Thick but Very Short)

With One Tendon (Either GC or ST). The tendon is folded to effectively divide the tendon into 3 equal parts (Fig 3; Video 1). The ends of each fold are marked. One-third of the tendon is loaded in a suspensory device

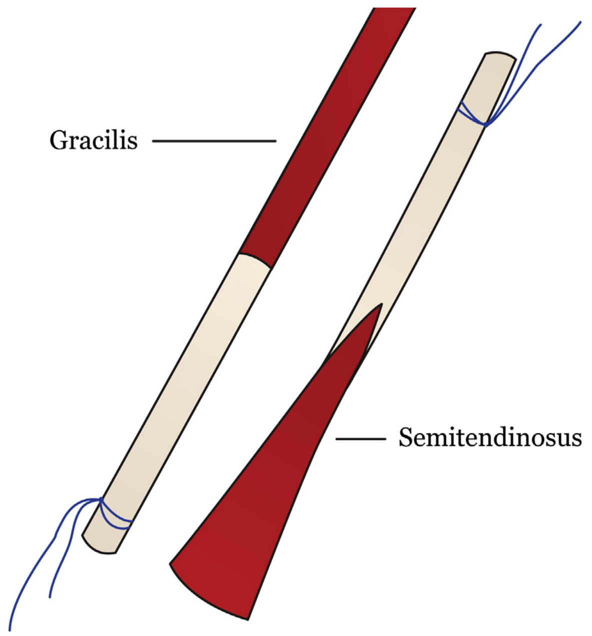

Fig 1. Identification of the gracilis and semitendinosus tendon according to muscular belly shape and anatomic location. The gracilis tendon is above and proximal to semitendinosus and has a rounded-shaped muscular belly, whereas the semitendinosus is below and distal to the gracilis and has a U-shaped muscular belly.

Table 2. Pearls and Pitfalls of the Hamstring Graft Technique for ACL Reconstruction

Pearls	Pitfalls
• Evaluation of the length and diameter of the first harvested tendon (usually semitendinosus) can avoid harvesting another tendon • The use of a proper graft station with measures, clamping fixation, and tensioning system is mandatory for a correct hamstring preparation technique • Evaluation and planification of each type of graft preparation technique is better according to hamstring anatomy and measurements to prepare a customized and individualized graft according to patient needs and anatomy • Suturing the tendon ends is essential to avoid any slippage or loosening of the stiches. The whipstitch pattern is also important for traction forces • Proper tensioning during and after graft preparation is needed before implantation	• Hamstring graft preparation might be challenging for surgeons who are untrained • Avoid mismatch of the tunnel and graft diameter and length • Cycle the knee after femoral fixation (before tibial fixation) to avoid residual laxity • Avoid fixing the suspensory device on the external aspect of the illiotibial band • After femoral and tibial fixation, be careful when cutting the suspensory device sutures to avoid to flip the device

ACL, anterior cruciate ligament; BTB, bone−patellar tendon−bone.

according to the marks. A stitch in each end of the tendon is made with a nonabsorbable suture. The needle is then passed through the 2 other strands of the graft. The same procedure is then repeated at the other end.

Four-Strand Graft Preparation

With One Tendon (Either GC or ST). Either a GC or a ST tendon is loaded in a suspensory device (Fig 2; Video 1). The free ends of the graft are whipstiched together with a nonabsorbable suture. A nonabsorbable suture is passed in the middle, and the tendons are folded. The needle is passed through the proximal part, grabbing and tensioning the distal part with the nonabsorbable suture. Sutures are reinforced in the distal site of the graft.

This technique can also be used with 2 suspensory devices for an all-inside ACL reconstruction.[16]

With Two Tendons (GC and ST or a ST Cut in Half). Both tendons are loaded in a suspensory device in a reverse orientation. A nonabsorbable suture is passed twice around the 4 free ends of the graft. The graft is whipstiched distally with a nonabsorbable suture.

Five-Strand Graft Preparation (If the Tendon Is Thin With Triple Bundle)

With One Tendon (Either GC or ST—Triple Bundle) and Another Tendon (GC or a ST—Double Bundle). Three-strand graft preparation is done with 1 tendon. The other tendon is loaded in a suspensory device (in the middle) (Video 1). A stich is made in the end of the 5 strands. The 5-strand graft is then whipstiched from proximal to its distal end.

Six-Strand Graft Preparation (If the Tendon Is Thin With Quadruple Bundle)

With Two Tendons (GC and ST). Each tendon is divided into 3 equal parts (Fig 4). The ends of each fold are marked. A stich is placed into both ends of the tendons with a nonabsorbable suture. One-third of each tendon is loaded in a suspensory device according to the marks. The needle of each end of both strands is then passed through the other 2 strands. The same procedure is repeated for the other end of the tendons.

Another way for 6-strand graft preparation is to use a 4-strand graft with 1 tendon and load another tendon as a 2-strand graft or to use 2 suspensory devices for an all-inside ACL reconstruction.[17]

Eight-Strand Graft Preparation

With Two Tendons (GC and ST). Both tendons are loaded in a suspensory device. The free ends of the

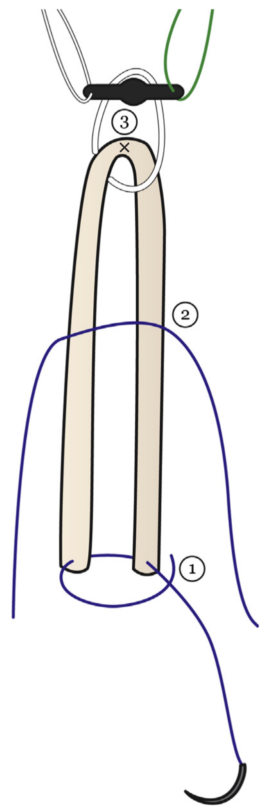

Fig 2. Two-strand and 4-strand graft preparation with 1 tendon. (1) Both ends of the tendon are sutured together. In 4-strand graft preparation, (2) a nonabsorbable suture is passed in the middle and the tendons are folded. (3) The needle is passed through the proximal part, grabbing and tensioning the distal part with the nonabsorbable suture.

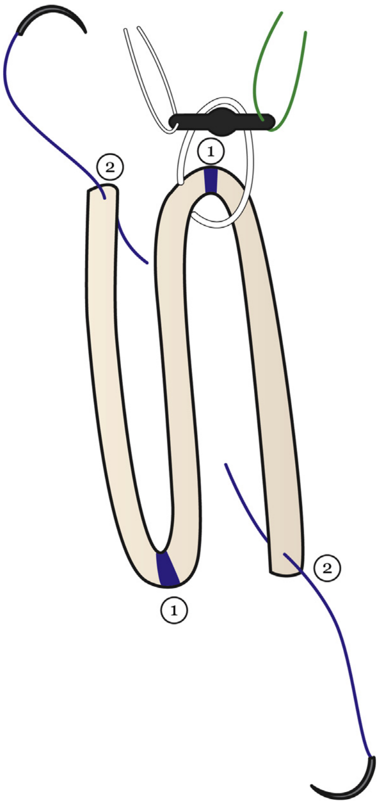

Fig 3. Three-strand graft preparation with 1 tendon. The tendon is divided into 3 equal parts. (1) The ends of each fold are marked. One-third of the tendon is loaded in a suspensory device according to the marks. (2) A stich in each end of the tendon is made with a nonabsorbable suture. The needle is then passed through the 2 other strands of the graft. The same procedure is then repeated at the other end.

grafts are whipstiched together with a nonabsorbable suture (Fig 5). A nonabsorbable suture is passed in the middle and the tendons are folded. The needle is passed through the proximal part, grabbing and tensioning the distal part with the nonabsorbable suture. Sutures are reinforced in the distal site of the graft.

This technique can also be performed with 2 suspensory devices for an all-inside ACL reconstruction.[18]

Discussion

Our Technical Note describes commonly used graft preparation techniques available for hamstring autografts. There are quite a few options for graft type, which have been shown to have good subjective and objective outcomes.

Although numerous studies have shown the superiority of an autograft compared with an allograft in regard to subjective outcomes, graft failure rate, and return to sport, there are far fewer studies comparing types of autografts.[3,5-8] Comparative studies between a patellar tendon and a hamstring tendon that have been performed to date have failed to show clinically significant differences in failure rate, subjective outcome scores, or return to sport.[19-21] Sajovic et al.[22] in a prospective study on 64 patients (32 patellar tendon, 32 hamstring) with minimum 11 years of follow-up showed no difference in the failure rate or subjective outcomes. However, they did show an increased prevalence of pivot shift and signs of osteoarthritis in the patellar tendon group.[22] Because numerous studies have shown equivalence with shorter term outcomes such as return to sport and graft failure, longer follow-up studies are needed for comparing rates of osteoarthritis and long-term outcome scores.

Numerous different hamstring preparation techniques have been described in the literature.[9,23] There is, however, a scarcity of studies looking at superiority within hamstring graft types. Conte et al.[11] showed that graft size, specifically the hamstring autograft (>8 mm in diameter), led to significantly improved results. Furthering the argument that larger graft size leads to improved outcomes, the study by Dai et al.[9] showed that a 6-strand hamstring tendon autograft had decreased pivot shift, less graft failure rate, and

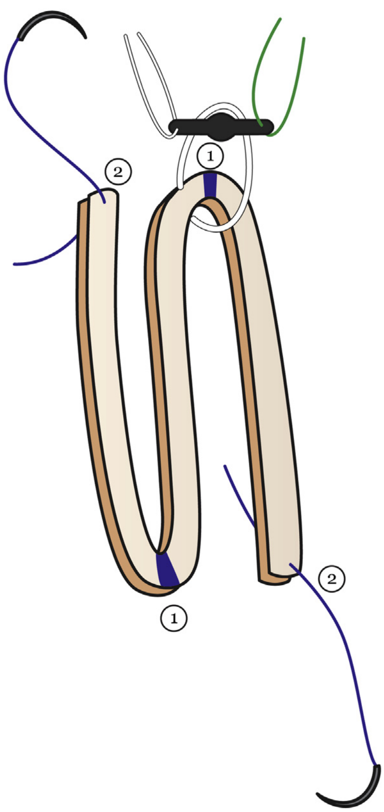

Fig 4. Six-strand graft preparation with 2 tendons. The tendons are divided into 3 equal parts. (1) The ends of each fold are marked. One-third of each tendon is loaded in a suspensory device according to the marks. (2) A stitch in each end of both tendons is made with a nonabsorbable suture. The needle is then passed through the 4 other strands of the graft. The same procedure is then repeated at the other end.

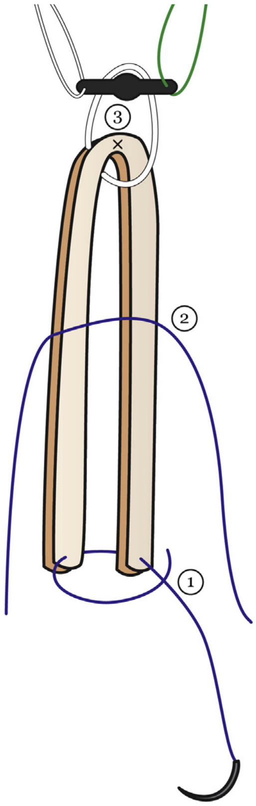

Fig 5. Eight-strand graft preparation with 2 tendons. (1) Both ends of both tendons are sutured together. (2) A nonabsorbable suture is passed in the middle and the tendons are folded. (3) The needle is passed through the proximal part of both tendons, grabbing and tensioning the distal part with the nonabsorbable suture.

improved KT-1000 outcomes when compared with a patellar tendon autograft. Although studies like these help to make the argument that larger graft size with more strands may lead to increased anteroposterior stability, they do not say anything regarding long-term outcomes, and rates of osteoarthritis. It is possible that a larger graft could overcrowd intra-articular spaces changing joint kinematics, which could increase rates of arthrofibrosis or osteoarthritis.

In conclusion, we recommend the use of any of the described hamstring graft preparation techniques as long as they meet minimum diameter requirements, and are also appropriately fitted for the patient. Further biomechanical studies as well as long-term outcome studies should be performed comparing different hamstring autograft techniques. These studies should also address how different sized grafts affect patients of different ages and stature.

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