Technical Note

# Bone—Patellar Tendon—Bone Augmentation With Gracilis Tendon: The Bone—Patellar Tendon—Bone Plus Technique

Giancarlo Giurazza, M.D., Mohammed Lahsika, M.D., Jae-Sung An, M.D., Alice Nlandu, M.D., Carlos Ferreira, M.D., Diogo Sousa, M.D., Thais Dutra Vieira, M.D., and Bertrand Sonnery-Cottet, M.D., Ph.D.

**Abstract:** The bone—patellar tendon—bone (BPTB) autograft or allograft is a well-established option for primary or revision anterior cruciate ligament (ACL) reconstruction. However, although the length and width of the graft are relatively consistent, its thickness is unpredictable and can impact the biomechanical properties of the ACL graft. This technical note describes a technique for arthroscopic ACL reconstruction called the "BPTB-plus" technique, which consists of a BPTB graft augmented by the gracilis tendon.

Despite significant advancements in anterior cruciate ligament (ACL) reconstruction, graft failure remains a significant concern, with up to 28% of patients experiencing this complication at 10 years of follow-up.[1] Although there are some concerns regarding the safety and effectiveness of allografts in ACL revision surgery, recent studies have shown that they are a safe and effective alternative to autografts when fresh and frozen.[2] ACL revision using a bone—patellar tendon—bone (BPTB) graft is a well-established technique[3] that has been shown to have excellent outcomes. However, it is important to note that although the length and width of BPTB grafts are fairly consistent and predictable, their thickness can vary greatly and may have a significant impact on the biomechanical properties of the grafts in both the short term and long term.[4,5] To address this issue, previous authors have suggested graft augmentation with an internal brace.[6-10] However, the future evolution of a synthetic intra-articular implant is unknown. As an alternative, we propose a technique for biological augmentation of BPTB allograft, called the "BPTB-plus" technique. This technique involves the use of a BPTB graft supplemented with an ipsilateral or contralateral gracilis tendon autograft, thus combining the benefits of the 2 graft types: The BPTB allograft provides excellent initial fixation and reduces the risk of donor-site morbidity, while the gracilis tendon autograft maximizes graft size, improves overall graft strength, and provides biological advantages.

*From Centre Orthopédique Santy, FIFA Medical Centre of Excellence, Groupe Ramsay-Générale de Santé, Hopital Privé Jean Mermoz, Lyon, France.*

*Received October 23, 2023; accepted February 3, 2024.*

*Address correspondence to Thais Dutra Vieira, M.D., Centre Orthopedique Santy, 24 Avenue Paul Santy, 69008, Lyon, France. E-mail: thaisdutravieira@hotmail.com*



*2212-6287/231530*
*https://doi.org/10.1016/j.eats.2024.102981*

## Surgical Technique

This technical note describes a revision arthroscopic ACL reconstruction using BPTB allograft augmented with contralateral gracilis autograft with traditional outside-in drilling and press-fit femoral fixation, as previously described[3] (Video 1). This same technique may also be used in the case of primary surgery and BPTB autograft of insufficient thickness. Pearls and pitfalls are described in Table 1, and advantages and disadvantages are presented in Table 2.

### BPTB Allograft Evaluation

The BPTB allograft is examined to confirm sufficient length, width, and thickness. In the example in Video 1, the patellar tendon length and width were 45 mm and 10 mm, respectively. On the other hand, its thickness was only 3 mm, inadequate to the patient's size (Fig 1). To augment the graft, because the patient's first ACL reconstruction was performed with ipsilateral hamstring

**Table 1.** Pearls and Pitfalls

| |
|---|
| Pearls |
| The tendinous part of the BPTB graft is whipstitched to the 2-folded gracilis graft to solidify the 2 grafts. This suture is then passed into the distal and proximal patellar holes to ensure optimal graft grip during traction. |
| The gracilis tendon is passed into the tibial plug hole at its midpoint: in this way, its extremities do not interfere with the femoral press-fit fixation and can be used during distal traction of the patellar bone block. |
| Pitfalls |
| Insufficiency of the allograft should be noted prior to starting the surgical procedure so that both legs can be prepared and draped in case of previously harvested ipsilateral hamstring tendons. |

BPTB, bone—patellar tendon—bone.

**Table 2.** Advantages and Disadvantages

| |
|---|
| Advantages |
| Augmentation with gracilis tendon optimizes the BPTB graft size in case the autograft harvested or allograft obtained is insufficient. |
| The techniques offers a biological alternative for the internal brace, without the risk of graft stress shielding or overconstraint of the joint. |
| If an allograft is used, augmentation with an autologous tendon protects it during the longer revascularization and remodeling phases, potentially enhancing and accelerating them. |
| The techniques represents a cost-effective solution via augmentation with autologous tissue and press-fit femoral fixation. |
| Disadvantages |
| It is necessary to prepare and drape both legs in case of unavailability of ipsilateral hamstring tendons. |
| A longer operative time is required. |
| There is a risk of donor-site morbidity associated with gracilis harvest. |

BPTB, bone—patellar tendon—bone.


**Fig 1.** Bone—patellar tendon—bone allograft. The patellar tendon length is 45 mm; width, 10 mm; and thickness, 3 mm. (PBB, patellar bone block; PT, patellar tendon; TBB, tibial bone block.)

**Fig 2.** Patient positioning. The patient is placed in the supine position on the operating table; for both knees, a lateral support is placed at the level of a padded tourniquet, and a foot roll is positioned to stabilize the knees when flexed at 90°.

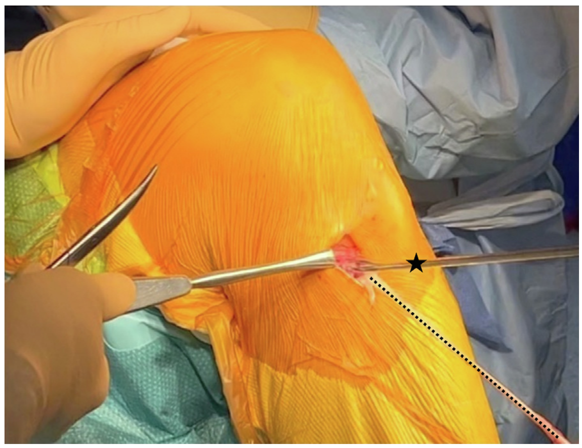

**Fig 3.** Harvest of contralateral gracilis (dotted line) in left knee: medial view. The gracilis is harvested with an open-ended tendon stripper (Pigtail Hamstring Tendon Stripper) (star) through a 2-cm vertical incision over the pes anserinus distal insertion.

tendons, we decided to proceed with a contralateral gracilis tendon harvest.

## Patient Positioning

The patient is placed in the supine position on the operating table, with a lateral support at the level of a padded tourniquet and a foot roll positioned to stabilize

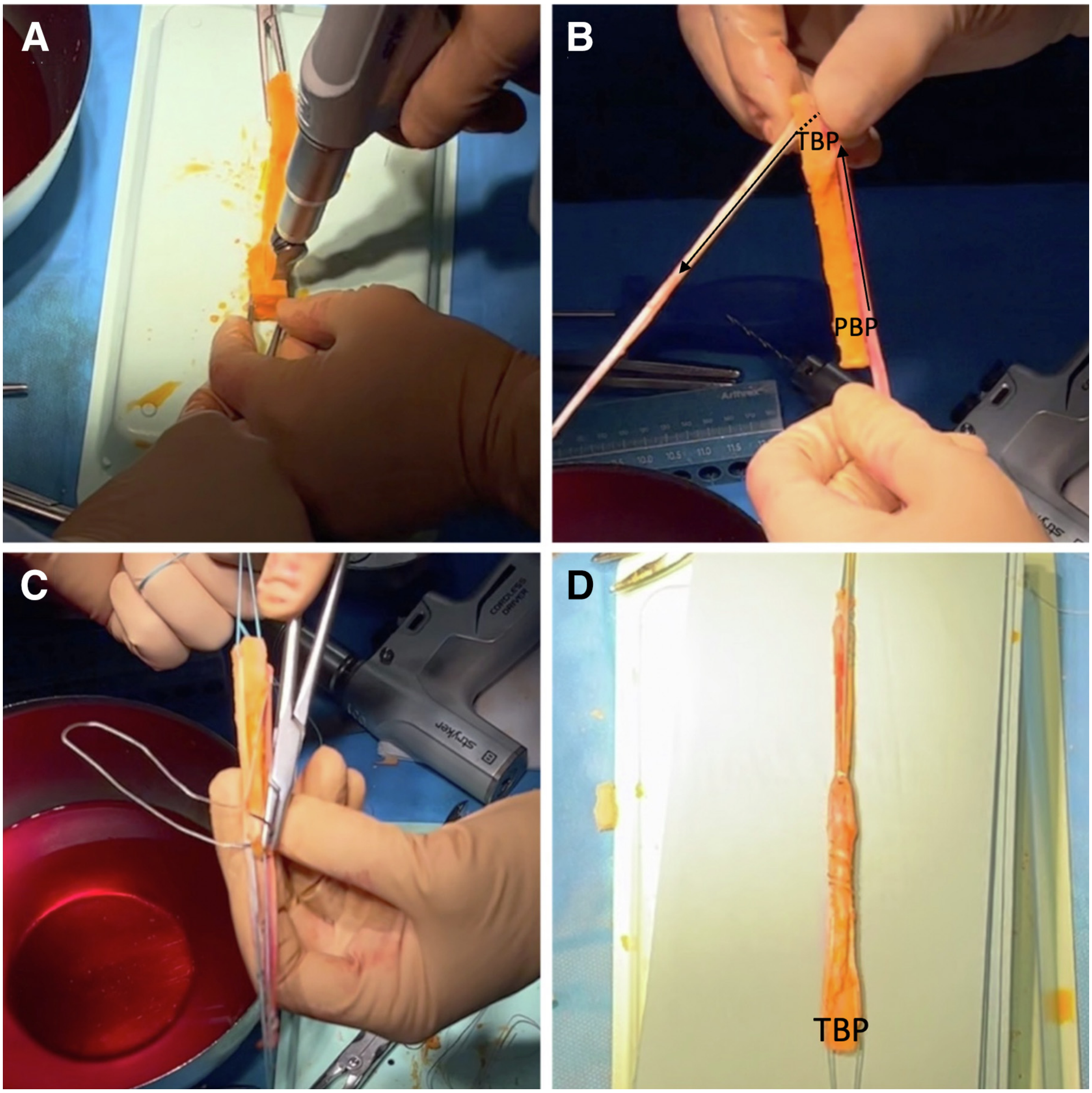


**Fig 4.** Graft preparation. (A) The patellar bone block is cut to create a 9 × 15-mm bone plug, and the tibial bone block is cut to create a trapezoidal 9 to 11 × 20-mm bone plug. Two 2-mm drill holes are made in the patellar bone block, and one 3.2-mm drill hole is made in the tibial bone block. (B) The gracilis tendon is threaded through the tibial bone block at its midpoint. (C) A No. 3 suture (Mersilene) is threaded into the distal 2-mm hole in the patellar plug and into the 2-mm hole in the tibial plug. The proximal and distal holes of the patellar plug are threaded with a No. 2 suture (Polysorb); then, the suture is used to whipstitch the tendinous part of the bone—patellar tendon—bone (BPTB) graft to the 2-folded gracilis graft and is passed back to the distal and proximal holes of the patellar bone block and knotted. (D) Final preparation: BPTB-plus hybrid graft with BPTB allograft augmented with 2-stranded autologous gracilis. The arrow indicates the gracilis tendon graft, and the dotted line indicates the gracilis tendon graft through the tibial bone plug (TBP) tunnel. (PBP, patellar bone plug.)

the knee flexed at 90° (Fig 2). Both legs are prepared and draped.

## Contralateral Gracilis Harvest

The gracilis is harvested from the contralateral leg with an open-ended tendon stripper (Pigtail Hamstring Tendon Stripper; Arthrex, Naples, FL) through a 2-cm vertical incision over the pes anserinus distal insertion (Fig 3). The attachment site is cut, and the hamstring tract is infiltrated with local anesthetic (20 mL of ropivacaine, 7.5 mg/mL) to improve postoperative analgesia. The gracilis tendon is whipstitched at both extremities.

## Graft Preparation and Diagnostic Arthroscopy

The patellar bone block is cut to create a 9 × 15-mm bone plug, and the tibial bone block is cut to create a trapezoidal 9 to 11 × 20-mm bone plug. Two 2-mm drill holes are made in the patellar bone block, and one 3.2-mm drill hole is made in the tibial bone block

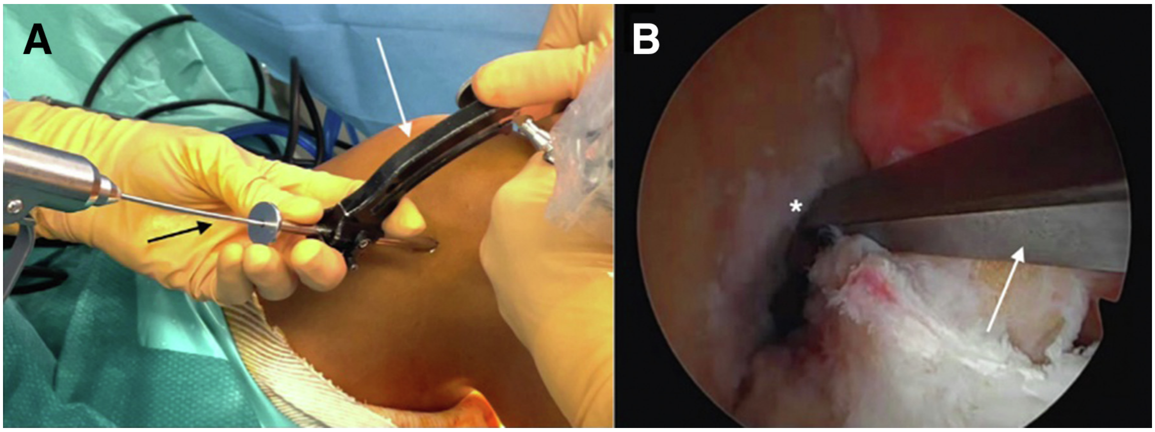


**Fig 5.** Femoral tunnel in right knee. (A) Lateral view. The femoral outside-in guide (white arrow) position on the lateral femoral cortex is chosen to avoid convergence with the previous anterior cruciate ligament tunnel and with the LEAP fixation, and a guidewire (black arrow) is inserted. (B) Arthroscopic view. The guide (arrow) is positioned at the femoral origin (asterisk) of the anteromedial bundle of the anterior cruciate ligament. (LEAP, lateral extra-articular procedure.)

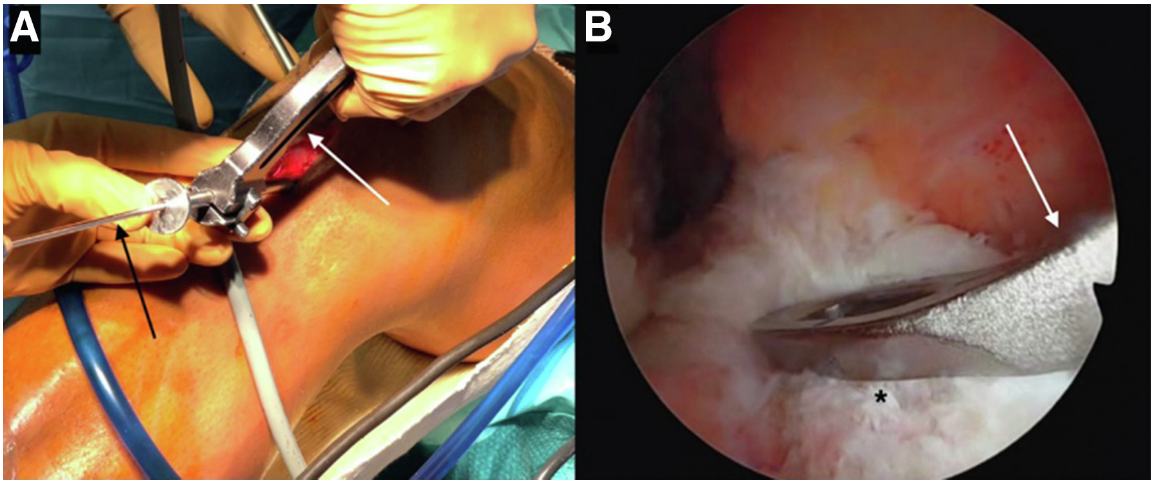


**Fig 6.** Tibial tunnel in right knee. (A) Medial view. The tibial anterior cruciate ligament guide (white arrow) is set at 65°, and a guidewire (black arrow) is inserted. (B) Arthroscopic view. The guide (arrow) is positioned over the anterior cruciate ligament footprint (asterisk).

(Fig 4A). The gracilis tendon is then threaded through the latter at its midpoint, thus creating the BPTB-plus "hybrid" graft: a BPTB allograft augmented with 2-stranded autologous gracilis (Fig 4B). A No. 3 suture (Mersilene; Ethicon, Somerville, NJ) is threaded into the distal 2-mm hole in the patellar plug and into the 2-mm hole in the tibial plug. The proximal and distal holes of the patellar plug are threaded with a No. 2 suture (Polysorb; Covidien, Mansfield, MA); then, the suture is used to whipstitch the tendinous part of the BPTB graft to the 2-folded gracilis graft (Fig 4C), passed back to the distal and proximal holes of the patellar bone block, and knotted (Fig 4D). This configuration allows the 2 grafts to solidify and allows the use of the gracilis extremities, along with the traction sutures, to pull the bone block during subsequent graft passage. The junction between the tendon and bone is then marked with a sterile marker pen to ensure the bone blocks are positioned correctly after graft passage. High anterolateral and anteromedial portals are established, and diagnostic arthroscopy is performed. Any meniscal or chondral lesions are addressed before the ACL reconstruction.

### Femoral Tunnel Creation

The femoral outside-in ACL guide (Arthrex) is placed intra-articularly at the femoral origin of the anteromedial bundle via the anteromedial portal and on the lateral femoral cortex at a point that allows avoidance of convergence with the previous ACL tunnel and subsequent lateral extra-articular procedure tunnel, as previously described.[11,12] A guidewire is inserted, and the correct position is confirmed arthroscopically. Subsequent sequential drilling from 6 to 10 mm is performed

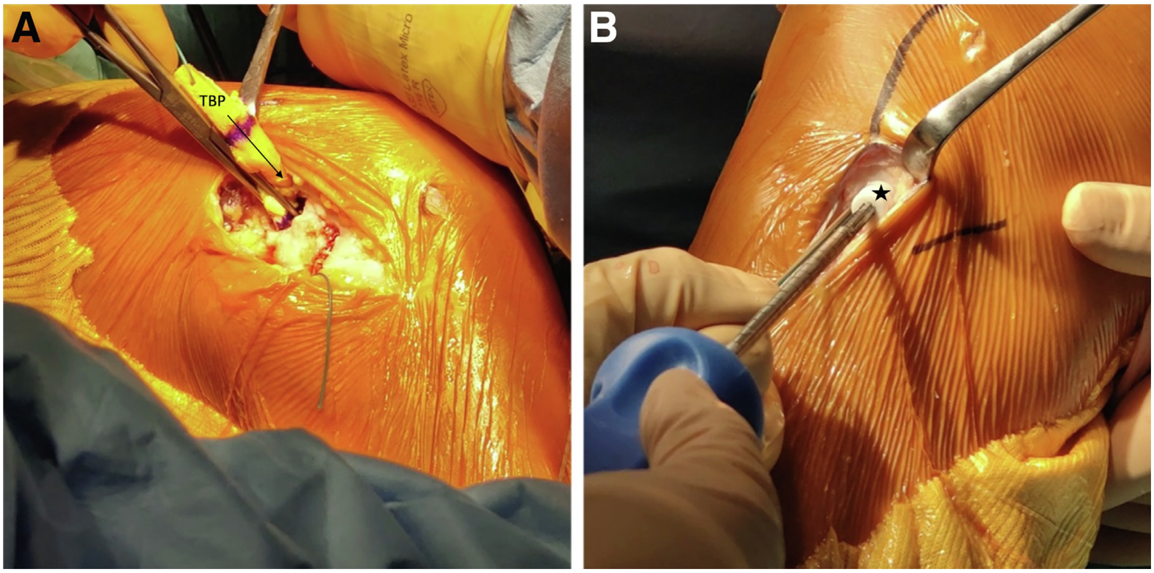


**Fig 7.** Graft passage and fixation in right knee. (A) Lateral view. The patellar bone block is inserted through the femoral tunnel using a clamp to guide graft passage, and the tibial bone block is inserted in the femoral tunnel with the cortex face facing posteriorly. (B) Medial view. Tibial fixation is achieved using an interference screw (BioComposite) with the knee in 30° of flexion. The arrow indicates the graft passage direction; the star indicates the interference screw at the tibial tunnel. (TBP, tibial bone plug.)

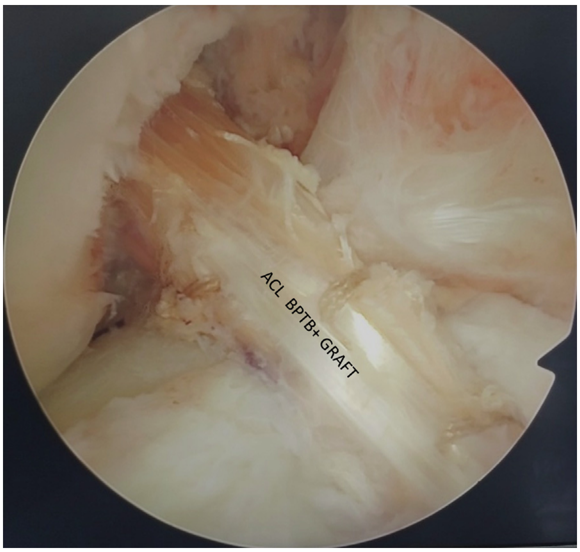


**Fig 8.** Arthroscopic view of right knee. Evaluation of graft, confirming proper placement of bone block and absence of impingement. (ACL, anterior cruciate ligament; BPTB, bone–patellar tendon–bone.)

with cannulated reamers. The lateral aperture of the tunnel is then reamed to 11 mm for press-fit fixation[3] (Fig 5).

## Tibial Tunnel Creation

The tibial ACL guide (Arthrex) is set at 65° and introduced through the anteromedial portal to position the guidewire at the center of the original ACL footprint. Then, the tibial tunnel is established with sequential reaming, starting with a 6-mm reamer and then upsizing to a 9-mm reamer once the position is confirmed (Fig 6).

## Graft Passage and Fixation

A No. 2 passing suture (Polysorb) is delivered from the tibial tunnel and then through the femoral tunnel for antegrade passage of the graft. Next, the sutures from the patellar bone block are threaded through the passing suture loop, and the patellar bone block is guided through the femoral tunnel using a clamp. With the tibial bone block inserted in the femoral tunnel with the cortex face facing posteriorly, the traction sutures along with the gracilis extremities are pulled distally by the surgical assistant while the surgeon lightly hammers the bone block using an impactor until press-fit fixation is achieved. The previously marked bone-tendon junction is identified arthroscopically to ensure proper placement of the bone block and to prevent impingement. To ensure full passage of the graft, the sutures of the patellar bone block and gracilis extremities are manually tensioned while the knee is cycled through full flexion and extension several times. Tibial fixation is achieved using an interference screw (FastThread BioComposite interference screw; Arthrex) with the knee in 30° of flexion (Fig 7), and the excess of the gracilis extremities is cut. Final arthroscopic evaluation confirms proper placement of the bone block and absence of impingement (Fig 8).

## Postoperative Rehabilitation

Postoperative rehabilitation begins with brace-free, full weight bearing and progressive range-of-motion exercises, with restriction of range of motion to 0° to 90° for 6 weeks in patients undergoing meniscal repair. Early rehabilitation focuses on maintaining full extension and performing quadriceps activation exercises. Return to sports is allowed at 4 months for nonpivoting sports, 6 months for pivoting noncontact sports, and 8 to 9 months for pivoting contact sports.

## Discussion

Many graft types have been described for revision ACL reconstruction. BPTB graft is one of the most commonly used[3] because it provides several advantages, including faster graft integration[13] and the possibility of filling previous enlarged anatomic tunnels.[14] Despite this, one of the drawbacks of BPTB autografts or allografts is that although their length and width are fairly consistent and predictable, their thickness can vary greatly. Many studies have shown a linear correlation between graft size and risk of failure.[4,5] For instance, Magnussen et al.[5] found that grafts of 8 mm or less in diameter are associated with higher revision rates. To address this issue, one potential solution could be graft augmentation with an artificial internal brace, a well-established technique mainly described for ACL repair,[15] as well as repair and reconstruction of extra-articular ligaments in various parts of the body, such as the ulnar collateral ligament of the thumb[16] and the lateral ankle ligaments.[17] Although there is limited literature on the use of suture tape in ACL reconstruction, it has been proposed as a technique to protect the ligament during the healing and graft maturation phase,[6-10] which is particularly advantageous for young active patients and individuals with smaller graft diameters.[7,9] Furthermore, the healing process for allografts takes longer than that for autografts, which in turn reduces the ability of the former to withstand the tensile forces caused by the knee joint's motion.[6,18]

As an alternative, the currently presented BPTB-plus technique involves the use of a BPTB graft supplemented with a gracilis tendon autograft. The harvest of the gracilis tendon, while preserving the semitendinosus, allows donor-site morbidity to be minimized[19] and offers both mechanical and biological advantages. In fact, in addition to maximizing allograft size and strength, this technique also protects the graft during the revascularization and remodeling phases, potentially enhancing and accelerating these phases. To summarize, this biological augmentation of a BPTB graft offers a simple, quick, and low-morbidity solution to the common problem of BPTB autografts or allografts of insufficient thickness.

## Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: J-S.A. receives funding grants from Arthrex. B.S-C. reports a consulting or advisory relationship with Arthrex. All other authors (G.G., M.L., A.N., C.F., D.S., T.D.V.) 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. Jordan MJ, Doyle-Baker P, Heard M, Aagaard P, Herzog W. A retrospective analysis of concurrent pathology in ACL-reconstructed knees of elite alpine ski racers. *Orthop J Sports Med* 2017;5:2325967117714756.
2. Condello V, Zdanowicz U, Di Matteo B, et al. Allograft tendons are a safe and effective option for revision ACL reconstruction: A clinical review. *Knee Surg Sports Traumatol Arthrosc* 2019;27:1771-1781.
3. Levy Y, Gousopoulos L, Hopper GP, et al. Anterior cruciate ligament reconstruction using bone-patella tendon-bone autograft with press-fit femoral fixation: The original Chambat technique. *Arthrosc Tech* 2022;11:e1889-e1895.
4. Rahardja R, Zhu M, Love H, Clatworthy MG, Monk AP, Young SW. Factors associated with revision following anterior cruciate ligament reconstruction: A systematic review of registry data. *Knee* 2020;27:287-299.
5. Magnussen RA, Lawrence JTR, West RL, Toth AP, Taylor DC, Garrett WE. Graft size and patient age are predictors of early revision after anterior cruciate ligament reconstruction with hamstring autograft. *Arthroscopy* 2012;28:526-531.
6. Smith PA, Bley JA. Allograft anterior cruciate ligament reconstruction utilizing internal brace augmentation. *Arthrosc Tech* 2016;5:e1143-e1147.
7. Bachmaier S, Smith PA, Bley J, Wijdicks CA. Independent suture tape reinforcement of small and standard diameter grafts for anterior cruciate ligament reconstruction: A biomechanical full construct model. *Arthroscopy* 2018;34:490-499.
8. Smith PA, Bradley JP, Konicek J, Bley JA, Wijdicks CA. Independent suture tape internal brace reinforcement of bone-patellar tendon-bone allografts: Biomechanical assessment in a full-ACL reconstruction laboratory model. *J Knee Surg* 2020;33:1047-1054.
9. Aboalata M, Elazab A, Halawa A, Imhoff AB, Bassiouny Y. Internal suture augmentation technique to protect the anterior cruciate ligament reconstruction graft. *Arthrosc Tech* 2017;6:e1633-e1638.
10. Buranapuntaruk T, Kongrukgreatiyos K, Itthipanichpong T. All-inside arthroscopic anterior cruciate ligament reconstruction and internal brace with recycling suture. *Arthrosc Tech* 2021;10:e2429-e2434.
11. Hopper GP, El Helou A, Philippe C, Campos JP, Vieira TD, Sonnery-Cottet B. How to avoid knee tunnel convergence when performing a modified Lemaire extra-articular tenodesis. *Arthrosc Tech* 2022;11:e1111-e1115.
12. Haidar IM, Billières J, Saithna A, et al. Outside-in drilling allows avoidance of two-stage surgery in revision anterior cruciate ligament reconstruction. *Arthrosc Tech* 2021;10:e691-e696.
13. Muller B, Bowman KF, Bedi A. ACL graft healing and biologics. *Clin Sports Med* 2013;32:93-109.

14. Pioger C, Saithna A, Rayes J, et al. Influence of preoperative tunnel widening on the outcomes of a single stage—only approach to every revision anterior cruciate ligament reconstruction: An analysis of 409 consecutive patients from the SANTI study group. *Am J Sports Med* 2021;49:1431-1440.
15. van der List JP, DiFelice GS. Arthroscopic primary anterior cruciate ligament repair with suture augmentation. *Arthrosc Tech* 2017;6:e1529-e1534.
16. Shin SS, van Eck CF, Uquillas C. Suture tape augmentation of the thumb ulnar collateral ligament repair: A biomechanical study. *J Hand Surg* 2018;43:868.e1-868.e6.
17. Yoo JS, Yang EA. Clinical results of an arthroscopic modified Brostrom operation with and without an internal brace. *J Orthop Traumatol* 2016;17:353-360.
18. Scheffler SU, Schmidt T, Gangéy I, Dustmann M, Unterhauser F, Weiler A. Fresh-frozen free-tendon allografts versus autografts in anterior cruciate ligament reconstruction: Delayed remodeling and inferior mechanical function during long-term healing in sheep. *Arthroscopy* 2008;24:448-458.
19. Nordin JS, Olsson O, Lunsjö K. The gracilis tendon autograft is a safe choice for orthopedic reconstructive procedures: A consecutive case series studying the effects of tendon harvesting. *BMC Musculoskelet Dis* 2019;20:138.