

How to Succeed in Arthroscopic Anterior Cruciate Ligament Primary Repair? Step-by-Step Technique



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Abstract: Historically, poor results of open primary repair of anterior cruciate ligament (ACL) injuries have been reported. It has recently been recognized that favorable outcomes of primary ACL repair are possible when selectively performed in patients with proximal tears and good tissue quality. Moreover, with arthroscopic technological advances, primary repair can be a valuable treatment option for patients with proximal tears. Preserving the native ACL has several advantages, including maintenance of native proprioceptive function and biology. The procedure is also minimally invasive and reduces the inflammatory reaction often seen in ACL reconstruction. Recently, it has been suggested that additional suture augmentation of the primary repair technique may be beneficial for protecting ligament healing during early range of motion. In this Technical Note, we present the step-by-step surgical technique of arthroscopic primary repair using a femoral suspensory device with suture augmentation.

Open primary repair of the anterior cruciate ligament (ACL) rupture was a popular treatment in the 1970s and 1980s¹ but later was abandoned because of poor functional outcomes, high rates of rerupture, and comparative studies demonstrating superior results of ACL reconstruction.²⁻⁴ Feagin and Curl² reported a rate of retear of 53% at the 5-year follow-up. However, Chambat et al.⁵ reported lower failures rates in ACL repair with an additional intra-articular or anterolateral (AL) extra-articular biological augmentation. Moreover, Sherman et al.⁶ suggested

that tear location was a possible explanation for these unpredictable outcomes supporting better results with open primary repair of proximal tears.

Since 2008, a resurgence of interest has been noted in ACL preservation with an emphasis on the biological process of healing and arthroscopic ACL repair techniques, as compared with an open approach.^{3,7,8} DiFelice and van der List³ have reported promising clinical results in 10 patients with a 5-year minimum follow-up after arthroscopic primary ACL repair, and Achtnich et al.⁸ performed arthroscopic primary repair and have noted that the outcomes and findings from stability examinations were equivalent when compared with ACL reconstruction. Clinical outcomes might be further improved by the use of 2 emerging concepts: (1) biological adjunct of a collagen-based scaffold placed into the notch to improve the healing potential of the ACL repair and (2) positioning of an internal brace, which is reported to biomechanically protect the ligament during the healing phase.^{4,9-12}

In this Technical Note, we describe an arthroscopic primary ACL repair technique with an intraligamentary suture augmentation using a suspensory device as femoral fixation and a biocomposite anchor for tibial fixation.

Surgical Technique

Patient Selection

Appropriate patient selection is crucial for successful use of this technique (Tables 1 and 2, Video 1). Isolated

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Table 1. Indications and Contraindications for Arthroscopic Primary ACL Repair With Suture Augmentation

Indications	Contraindications
No age limit to date	Midsubstance and intraligament ACL tears (Sherman III or IV)
Proximal (femoral) avulsion tears (Sherman I or II)	Retracted proximal tear or partial tear ¹³ (however, concomitant partial ACL repair with graft augmentation is still possible)
Partial ACL tear	Poor tissue quality
Sufficient length and tissue quality	ACL revision surgery
Acute rupture	
Chronic proximal avulsion tears of the ACL reattached to the PCL	
Isolated ACL injuries	
PCL, posterior cruciate ligament.	

arthroscopic primary repair is only suitable for patients with proximal ACL avulsion (Sherman type I or eventually type II tears^{6,14}) (Fig 1) and adequate tissue of good quality allowing an effective reattachment of the remaining ligament to the femoral wall. This is mainly seen in the subacute phase (i.e., between 2 weeks and 3 months^{7,8,12}) when the surgery is carried out but is also seen in chronic ACL ruptures if the ACL is scarred to the posterior cruciate ligament.¹⁴

General Preparation

The patient is placed in the supine position, and the operative leg is prepped and draped as for standard knee arthroscopy. After standard AL and anteromedial (AM) portals have been established, the feasibility of repair is determined by confirming the proximal ACL

avulsion, tissue quality, and reducibility of the remnant (Fig 2).

Tibial ACL Tunnel and ACL Remnant Suture

Debridement and bleeding of the notch wall is then induced using a 4.2-mm shaver, and microperforations are made with an awl (ChondroPick, Arthrex, Naples, FL) in the anatomic femoral footprint to enhance healing of the ACL repair (Fig 3). Considering that the more anterior fibers of the ACL have a curvilinear path, a slightly posterior placement of the K-wire in relation to the anatomic footprint is recommended when the ACL tibial guide (Arthrex) is used (Fig 4). Afterward, the 4-mm tibial tunnel is drilled in a remnant-sparing manner¹⁵ (Fig 5A). After the handpiece reamer and the K-wire have been removed, the 4-mm reamer is left

Table 2. Steps, Pearls, and Pitfalls of Arthroscopic Primary ACL Repair With Suture Augmentation

Surgical Steps	Tips and Pearls	Pitfalls
Notch debridement	4.2-mm shaver for notch debridement to avoid damaging the ACL remnant. - Visualize the femoral ACL footprint correctly by placing the arthroscope in the AM portal.	Inappropriate tunnel placement may occur owing to poor visualization from the AL portal because of the ACL remnant.
ACL tibial tunnel	- Cautious drilling of the 4-mm tunnel until the 2nd cortical. - K-wire positioned as posterior as possible to ease the suture of the ACL remnant. - Ensure alignment with the ACL path by repositioning the K-wire after tunnel drilling with the knee close to extension.	Overdrilling can cause iatrogenic injury to the remnant.
ACL suture	- Importance of keeping the plastic tube of the TigerStick (Arthrex) as posterior as possible. - Lasso-loop knot.	
ACL femoral tunnel and button deployment	- Correct entry point for the femoral tunnel localization with the arthroscope visualizing the lateral gutter and with the guidance of a spinal needle. - Soft tissue debridement of the lateral gutter using a 4.2-mm shaver. - Visualize the femoral ACL footprint from the AM portal (target: AM bundle insertion). - If necessary, perform an open approach for direct vision of button deployment in the lateral gutter.	- If the cortical button is not directly visualized, there is a risk that the sutures placed in the remnant will not be secured over it. - Other complications include not visualizing the button in the lateral gutter (e.g., soft tissue interposition, button migration).
Sutures and graft fixation	The FiberTape (Arthrex) is fixed with the knee in full extension. ACL sutures are fixed with the knee flexed at 90° (eventually using a cannula).	There is a risk of overconstraining the “internal brace” if the FiberTape (Arthrex) is fixed at 20° of flexion.

ACL, anterior cruciate ligament; AM, anteromedial.

Fig 1. Preoperative magnetic resonance image obtained from a 36-year-old woman who sustained an injury after twisting her right knee. Sagittal (A) and coronal (B) proton density weighted images show a proximal ACL avulsion (type I ACL tear with good tissue quality) (white arrow). The distal ACL has homogeneous low signal intensity, often indicating good tissue quality. (ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.)

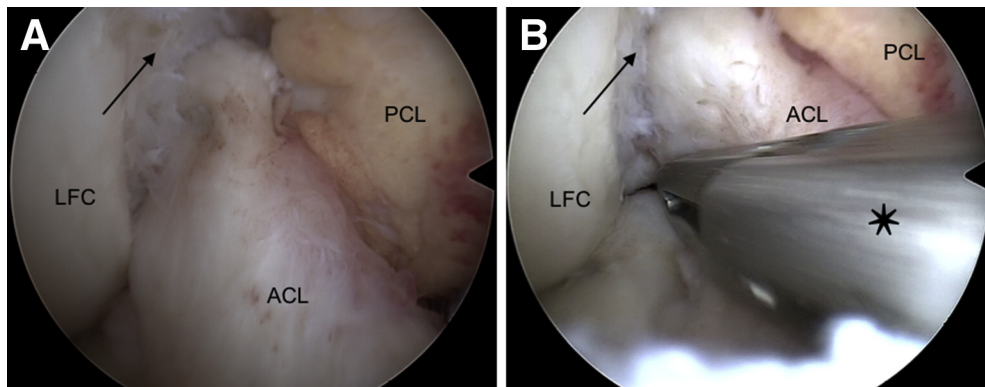
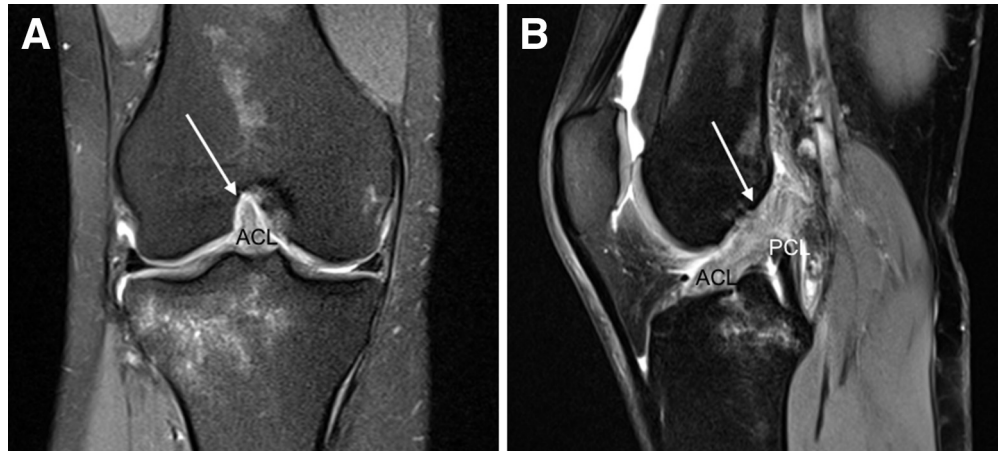


Fig 2. Arthroscopic image of a right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. (A) Arthroscopic diagnosis of a proximal avulsion (Sherman I) of the ACL (black arrow). (B) A KingFisher Retriever/Grasper (Arthrex) (black asterisk) is used to probe the tissue quality of the ACL remnant in a proximal rupture (black arrow). (ACL, anterior cruciate ligament; LFC, lateral femoral condyle; PCL, posterior cruciate ligament.)

in place, emerging into the bone so that a path is created. A TigerStick (Arthrex) (Fig 5B) is inserted in place of the K-wire. The plastic tube is left in position to protect the No. 2 TigerWire while the ACL remnant suture is performed. The reamer is withdrawn using the Switching Stick Insertor (Arthrex).

Use of the AM and AL portals is important because correct visualization of anteromedial and posterolateral bundles is necessary for ACL remnant suturing. With the 30° arthroscope positioned in the AM portal, a No. 0 FiberLink is passed through the ACL remnant using the Knee Scorpion Suture Passer (Arthrex) through the AL portal about 5 to 7 mm distal to the proximal aspect of the remnant to create a lasso-loop knot¹⁶ (Fig 6A). Afterward, with visualization from the AL portal, the procedure is repeated using a No. 0 TigerLink and the Knee Scorpion Suture Passer through the AM portal and about 5 to 7 mm distal to the previous suture (Fig 6B). After the remnant has been sutured (Fig 6C), to avoid tissue interposition, the articular ends of the No. 2 TigerWire, the No. 0 FiberLink, and the No. 0

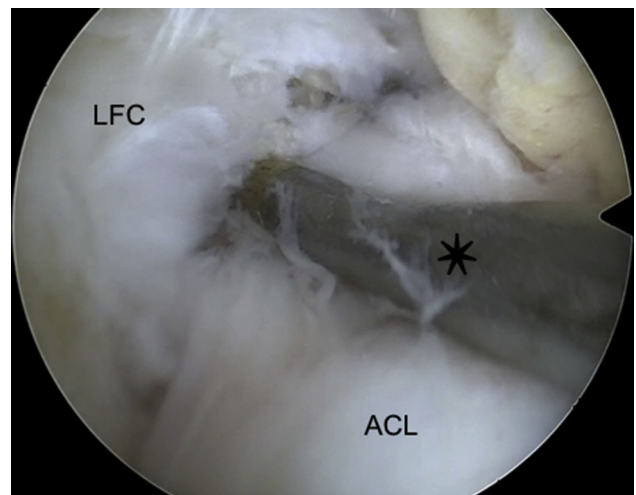


Fig 3. Arthroscopic image of a right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. Microfractures created with a ChondroPick (black asterisk) adjacent to the ACL femoral footprint enhance the healing response by recruitment of marrow elements at the repair site. (ACL, anterior cruciate ligament; LFC, lateral femoral condyle.)

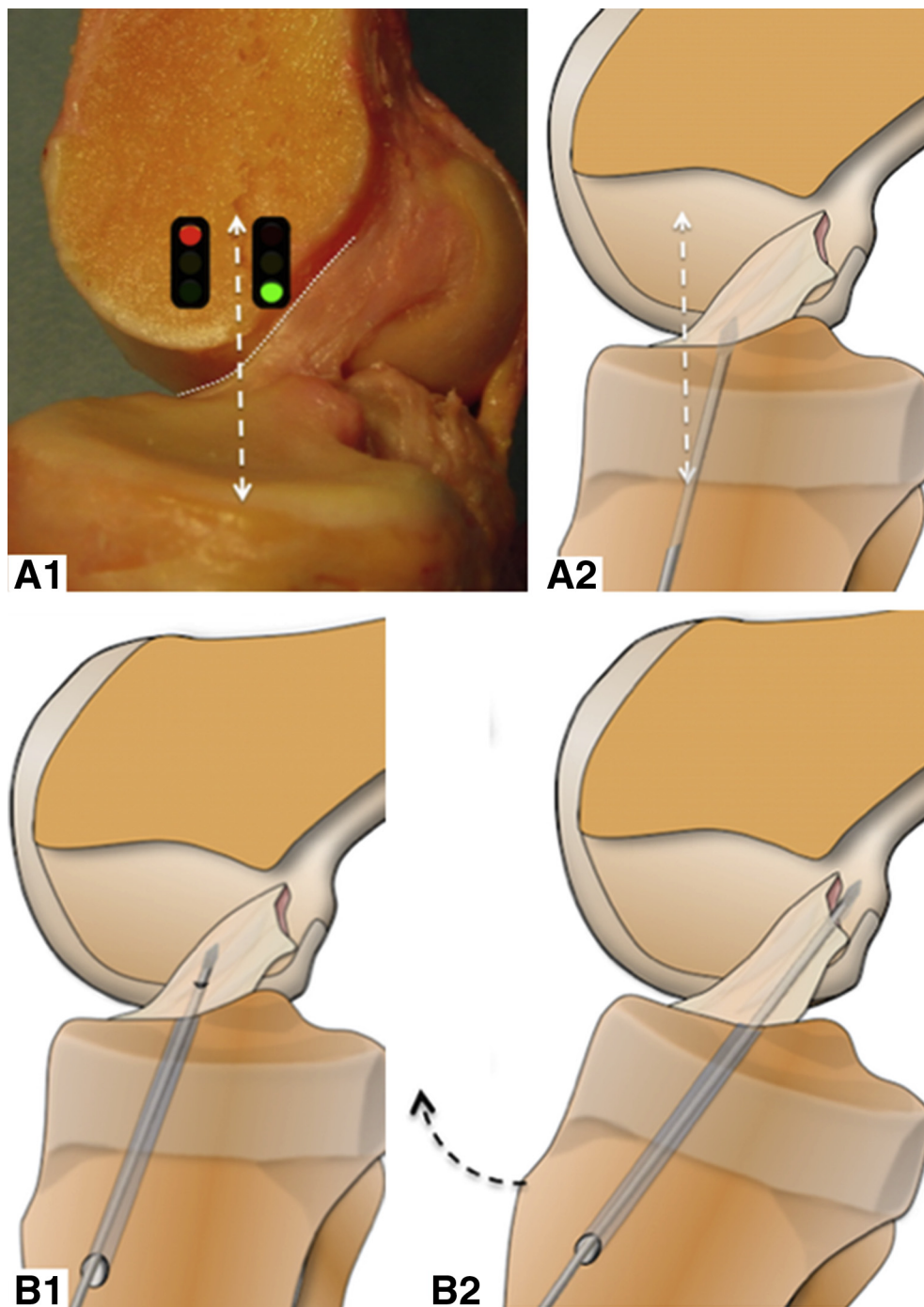


Fig 4. Using the ACL tibial remnant as a placement landmark. (A1) Sagittal cadaveric cut of a right knee. The anterior fibers of the ACL demonstrate a curvilinear path at the more anterior tibial insertion (white dotted line). Guide pin placement in this anterior area will compromise further repositioning after tunnel drilling of the guide pin through the entire length of the ACL remnant. (A2) Scheme of a right knee in 90° of flexion. An efficient placement should be posterior to these anterior fibers (white dotted line). (B) Scheme of a right knee. After tibial tunnel drilling (4 mm in diameter), the guide pin is repositioned with the hand through the entire ACL remnant length. (B1) Repositioning the guide pin at 90° of knee flexion is challenging. (B2) Placing the knee at 30° of flexion will align the tibial tunnel with the ACL remnant and will facilitate guide pin repositioning through the entire ACL remnant. (ACL, anterior cruciate ligament.)

TigerLink are retrieved together through the AM portal to unravel them using the KingFisher Grasper (Arthrex) (Fig 7).

Femoral ACL Tunnel

With the arthroscope in the AL portal, visualizing the lateral gutter, the optimal femoral tunnel is located under guidance of a spinal needle before the skin is incised (Fig 8). The arthroscope is now positioned in the

AM portal for better visualization of the femoral footprint, and the ACL Femoral Guide Out-In (Arthrex) is introduced through the AL portal. The target of the K-wire is the anatomic location of the AM bundle of the native ACL. A 4-mm tunnel is created with the reamer once the correct location has been validated (Fig 9). After the handpiece reamer and the K-wire have been removed, a FiberStick previously loaded with an additional No. 2 TigerWire is inserted in place of the K-wire

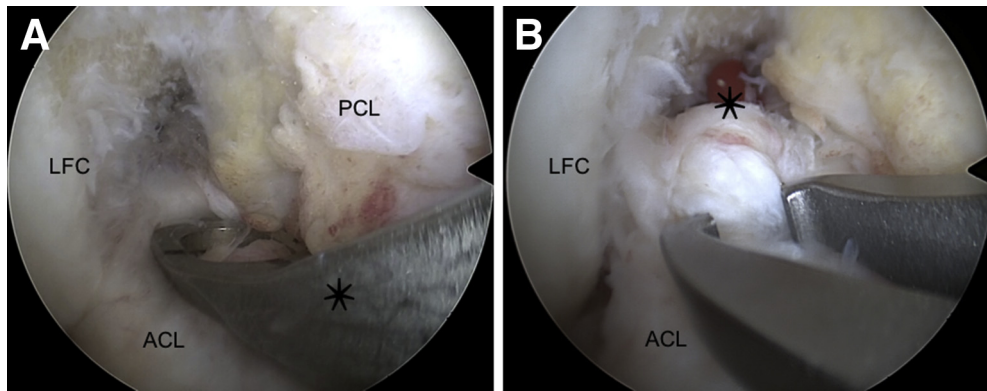


Fig 5. Arthroscopic image of a right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. (A) A tibial guide (black asterisk) is positioned at the center of the intact ACL fibers in the tibial footprint. (B) After a 4-mm tunnel has been drilled without moving the ream, a No. 2 TigerStick (black asterisk) is passed through the tibial tunnel and left in place. (ACL, anterior cruciate ligament; LFC, lateral femoral condyle; PCL, posterior cruciate ligament.)

to have 2 “shuttling sutures” in the plastic tube. The arthroscope is brought back to the AL portal, and both sutures are retrieved through the AM portal using a KingFisher Grasper (Fig 10). The reamer is then removed using the Switching Stick Insertor.

“Internal Brace” and “Button Deployment”

Articular ends of both No. 2 TigerWires are retrieved together to unravel them and avoid soft tissue interposition through the AM portal. The femoral No. 2 TigerWire is used as a shuttling suture for the tibial No. 2 TigerWire, resulting in a single TigerWire suture, which will later shuttle the “internal brace.” A FiberTape (length = 137.2 cm and width = 2 mm; Arthrex) is loaded on an ACL TightRope RT after the adjustable loop (TightRope, Button, Oblong 3.4 × 13 mm; Arthrex) has been removed (Fig 11A). The button is pulled out through the tibial and femoral tunnel using the No. 2 TigerWire (Fig 11B). Under arthroscopic visualization in the lateral gutter, the ACL TightRope RT button is flipped onto the lateral femoral cortex¹⁷ (Fig 12). An additional PassPort Button Cannula

(Arthrex) can be used for better visualization in the lateral gutter and to facilitate suture management later on.

Pulling Out ACL Remnant Sutures

The 2 lasso-loops (No. 0 FiberLink and No. 0 TigerLink) are retrieved together through the AM portal with the articular end of the No. 2 FiberWire to unravel them (Fig 13). This last one will be used as a shuttling suture. After the No. 0 FiberLink and the No. 0 TigerLink have been pulled out and the lateral gutter has been visualized from the AL portal, a knot pusher is used to locate each suture (No. 0 FiberLink and No. 0 TigerLink) on each side of the button suspensory device (Fig 14).

Tibial Fixation and ACL Remnant Repair

The knee is placed in full extension. Then the free ends of the FiberTape are threaded through a 4.75-mm Bio-Composite SwiveLock anchor (Arthrex) and fixed in the tibia distally to the 4-mm tunnel (Fig 15). Afterward, with the knee at 90° of flexion and the arthroscope in the

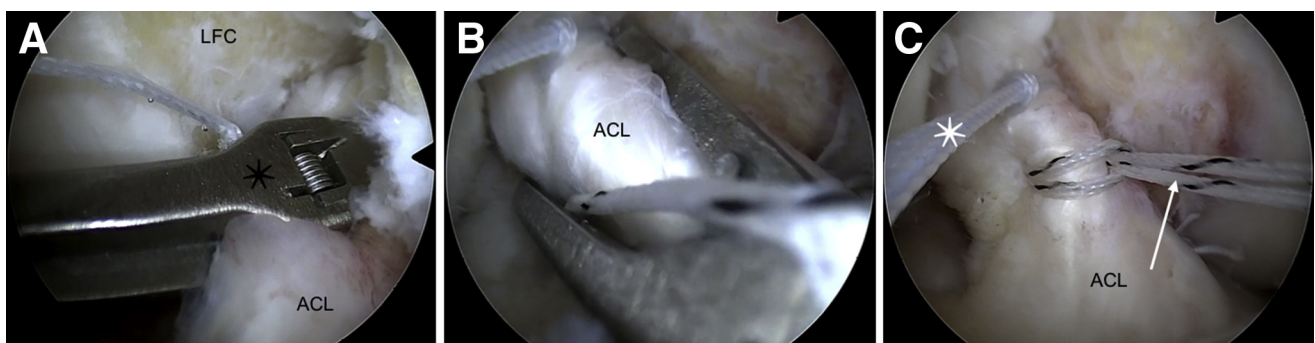


Fig 6. Arthroscopic image of a right knee with the patient supine and the knee in 90° of flexion. (A) From an anteromedial view, a No. 0 FiberLink is passed through the ACL remnant in a lasso-loop knot-tying configuration using the Knee Scorpion Suture Passer (black asterisk) through the AL portal. (B) From an AL view, the procedure is repeated with a No. 0 TigerLink through the anteromedial portal. (C) From an AL view, the ACL remnant is already sutured with the No. 0 FiberLink (white asterisk) and No. 0 TigerLink (white arrow). (ACL, anterior cruciate ligament; AL, anterolateral; LFC, lateral femoral condyle.)

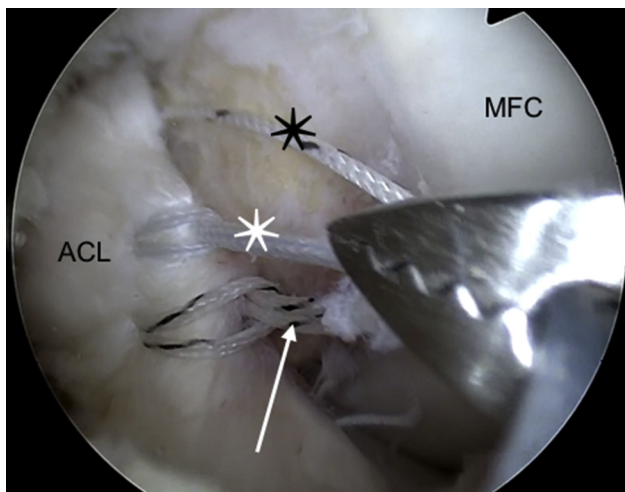


Fig 7. Arthroscopic image of a right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. The No. 2 TigerWire (black asterisk) and the free ends of the No. 0 FiberLink (white asterisk) and No. 0 TigerLink (white arrow) are retrieved together through the anteromedial portal. (ACL, anterior cruciate ligament; MFC, medial femoral condyle.)

lateral gutter, the No. 0 FiberLink and the No. 0 TigerLink are tensioned, tied, and secured over the ACL TightRope RT button under direct visualization using 6 static half hitches (Fig 16) while arthroscopic assessment of the ACL tension is subsequently verified (Fig 17).

Postoperative Course

Immediate full weight bearing without a brace is allowed, but the repair is protected by the use of crutches during the first 3 weeks to avoid unexpected falls as a result of arthrogenic muscle inhibition.

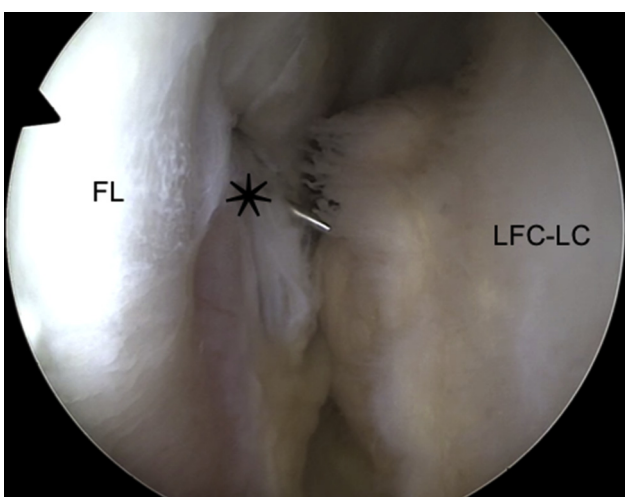


Fig 8. Arthroscopic image of a right knee in 90° of flexion and with the arthroscope located and visualizing the lateral gutter. Using a spinal needle (G 21, 0.8 × 40 mm, green) (black asterisk), the correct location of the femoral tunnel is assessed before the skin is incised. (FL, fascia lata; LFC-LC, lateral femoral condyle–lateral cortex.)

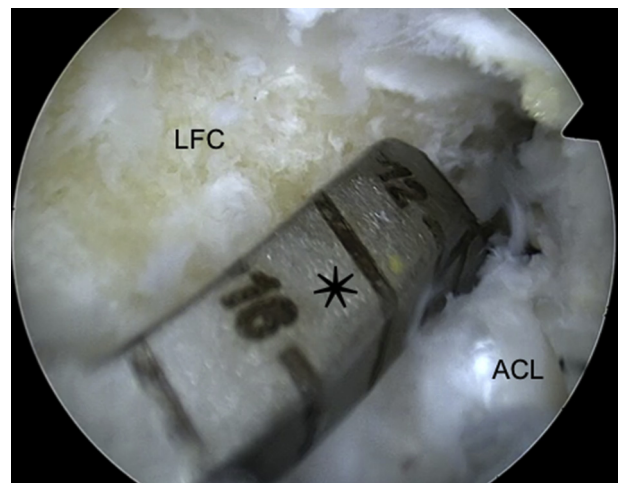


Fig 9. Arthroscopic image of a right knee viewed from the anteromedial portal with the patient supine and the knee in 90° of flexion. ACL Femoral Guide Out-In (Arthrex) (black asterisk) is used for femoral tunnel drilling. (ACL, anterior cruciate ligament; LFC, lateral femoral condyle.)

Physiotherapy for analgesia, patella mobilization, progressive full range-of-motion exercises, and isometric quadriceps contraction exercises are allowed with the expectation of normal walking, full extension, and 110° of flexion at 1 month after surgery. Cycling and swimming are allowed at 3 months, and running is allowed at 4 months. A return to pivot sports is possible around 6 months.

Discussion

In the recent literature, primary ACL repair to treat acute proximal tears has gained attention.^{4,7,8} Multiple

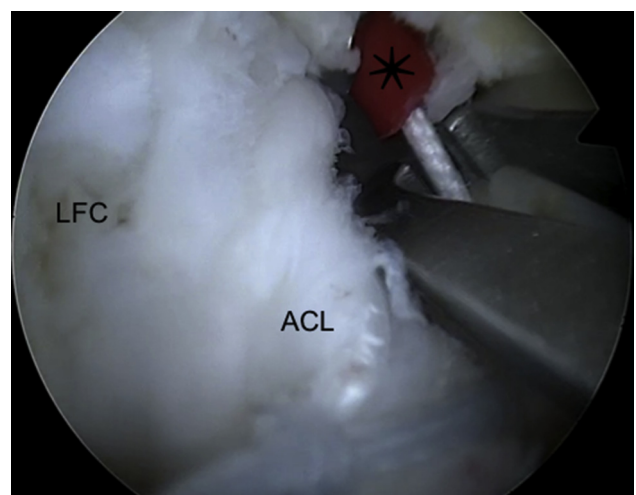


Fig 10. Arthroscopic image of a right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. The plastic tube (black asterisk) is inserted through the 4-mm femoral tunnel with a No. 2 TigerWire and a No. 2 FiberWire. Both are retrieved through the anteromedial portal by using the KingFisher Retriever/Grasper. (ACL, anterior cruciate ligament; LFC, lateral femoral condyle.)

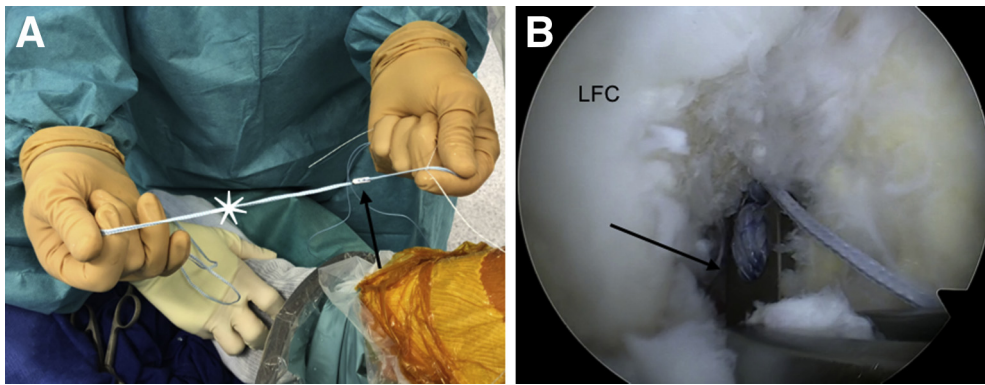


Fig 11. (A) External view. After retrieval of both TigerWires and use of the femoral TigerWire to shuttle the tibial No. 2 TigerWire, the ACL TightRope RT button (black arrow) with the FiberTape (white asterisk) is passed through its loop with the free ends inferiorly attached to the No. 2 TigerWire. (B) Arthroscopic image of a right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. The TigerWire is being pulled, and the ACL Tightrope RT button (black arrow) is pulled up through the femoral tunnel. (LFC, lateral femoral condyle.)

arthroscopic techniques^{12,18-20} have been described in the past few years, explained by (1) advances in diagnostic imaging and the possibility of recognizing the different types of ACL tears,⁶ (2) emergence of arthroscopy that enables intraoperative diagnosis of the ACL tear for correct decision making (repair vs reconstruction) and minimally invasive surgery (Table 3), and (3) choice among multiple fixation methods (anchors, button suspensory devices, screws). Sherman et al.⁶ highlighted the importance of patient selection for success of isolated ACL repair. The main purpose of this Technical Note is to describe all of the pearls in the step-by-step process of successfully reattaching the ACL

to the femoral wall in patients with Sherman type I or II tears. These tears occur in approximately 16% of the ACL ruptures in adults according to findings from a recent magnetic resonance imaging study.²¹ Furthermore, the ACL remnant must be of good quality and sufficient length to ensure the possibility of suturing the ACL remnant to the femoral wall without a gap (Table 1).

The main reasons to consider ACL repair are the potential advantages of reduced morbidity because of the absence of graft harvesting, drilling of smaller

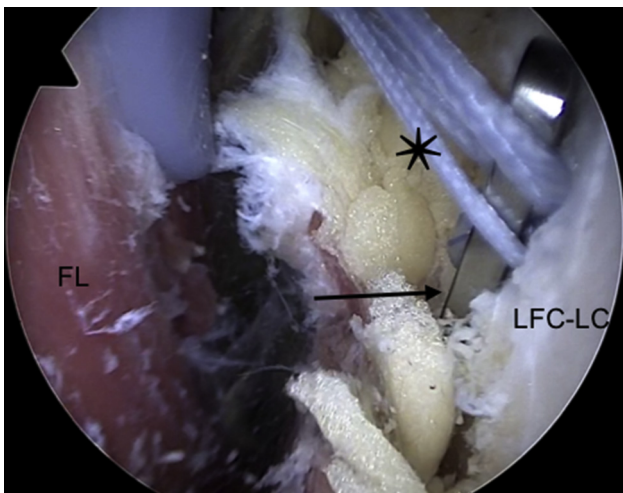


Fig 12. Arthroscopic image of a right knee with the arthroscope located and viewing the lateral gutter, with the patient supine and the knee in 90° of flexion. The ACL Tightrope RT button (black arrow) is deployed over the lateral femoral cortex and No. 2 FiberWire (black asterisk) that will be used as shuttling suture. (FL, fascia lata; LFC-LC, lateral femoral condyle–lateral cortex.)

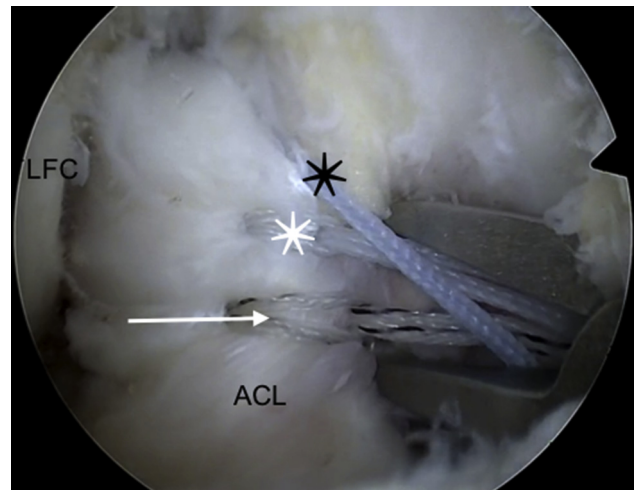


Fig 13. Arthroscopic image of a right knee viewed from the anterolateral portal with the patient supine and the knee at 90° of flexion. No. 0 FiberLink (white asterisk) and No. 0 TigerLink (white arrow) are retrieved together with the articular end of the No. 2 FiberWire (black asterisk) through the anteromedial portal. This last suture (No. 2 FiberWire) is going to be used for shuttling the first 2 (No. 0 FiberLink and No. 0 TigerLink). (ACL, anterior cruciate ligament; LFC, lateral femoral condyle.)

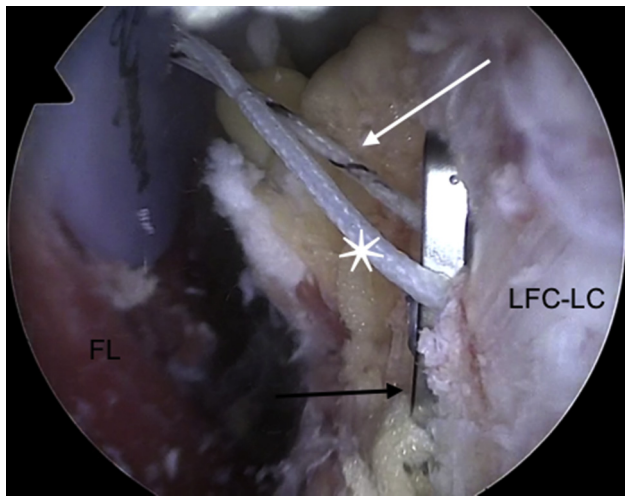


Fig 14. Arthroscopic image of a right knee with the arthroscope located and viewing the lateral gutter, with the patient supine and the knee in 90° of flexion. The ACL TightRope RT button (black arrow) is deployed, and each suture (No. 0 FiberLink [white asterisk] and No. 0 TigerLink [white arrow]) is passed, 1 at each side of the button, using the Knot Pusher. (FL, fascia lata; LFC-LC, lateral femoral condyle–lateral cortex.)

tunnels, and reduced debridement. In addition to preserved biological and proprioceptive properties from the native ligament, the faster healing process as a result of the absence of ligamentization observed in reconstructions²² allows for early recovery.^{6,9} The procedure could be an attractive alternative to conservative treatment with external brace over ACL reconstruction with any graft choice in eligible patients (i.e., those with proximal tears and sufficient tissue of good quality). Moreover, a primary repair does not burn any bridges for the future of the patient in case of failure (Table 3).²³ The



Fig 15. External view of a right knee in full extension. After the 2 free ends of the FiberTape (white asterisk) have been tensioned, the internal brace is fixed in the tibia using a 4.75-mm BioComposite SwiveLock anchor (white arrow).

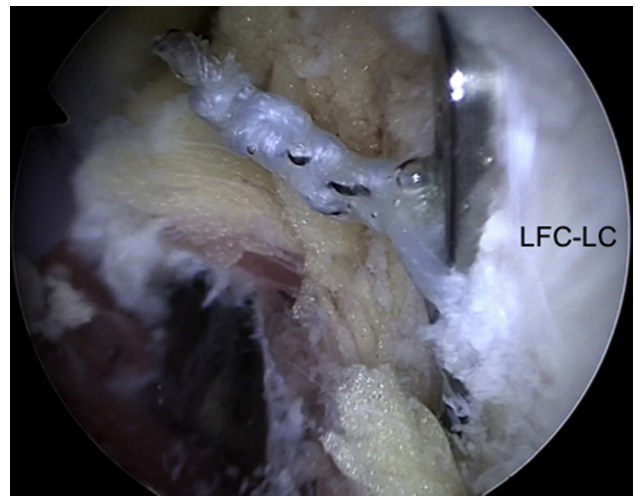


Fig 16. Arthroscopic image of a right knee with the arthroscope located and viewing the lateral gutter, with the patient supine and the knee in 90° of flexion. The No. 0 FiberLink and No. 0 TigerLink are secured and tied over the ACL Tightrope RT button. (LFC-LC, lateral femoral condyle–lateral cortex.)

improvement in healing response²⁴⁻²⁷ with the presence of platelet-derived stem cells can be achieved by microfracturing the femoral footprint before the repair.

We consider that using a suspensory button device for the femoral fixation instead of knotless suture anchors¹⁴ may have the following advantages: (1) avoidance of any physical or biomechanical reaction at the bone–ACL fiber interface because of absence of fixation devices at the aperture, and (2) in the case of revision surgery, easy removal of the hardware from both the tibial and femoral sides with a minimally invasive approach.

Short-term outcomes of arthroscopic primary repair of proximal tears have been reported with satisfactory results.^{7,8} In a small series (11 patients) with a longer follow-up of 5 years, DiFelice⁷ reported only 1 anatomic and clinical failure (10%), which seems promising. However, the risk of failure as a result of isolated precarious suture of the ACL remains a concern. The systematic use of an internal brace suture augmentation concept may provide a valuable reinforcement of the construct during the healing phase. Recently, Mackay et al.²⁸ have described the benefit of a suture augmentation technique with the rationale of protecting the ligament during early rehabilitation. A reduction of revision surgery could therefore be possible.

Further studies are necessary to determine the best criteria for patient selection (i.e., age, level of sport activity, delay between injury and surgery). Another important point that needs further clarification is the possible effect of stress shielding caused by the internal brace.

Fig 17. Arthroscopic image of a right knee viewed from the anterolateral portal with the patient supine and the knee in 90° of flexion. (A) Primary repair of the ACL in the anatomic femoral footprint can be seen. (B) A probe through the anteromedial portal is used to assess the correct tension of the ACL. (ACL, anterior cruciate ligament; LFC, lateral femoral condyle; PCL, posterior cruciate ligament.)

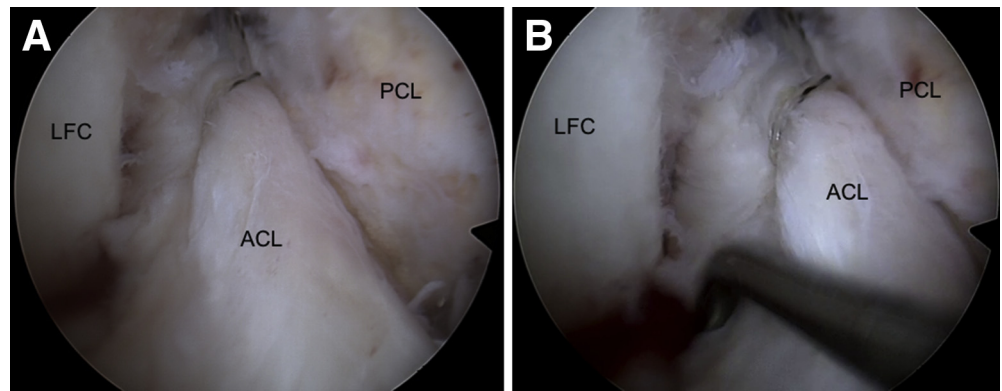


Table 3. Advantages and Disadvantages of Arthroscopic Primary ACL Repair With Suture Augmentation

Advantages	Disadvantages
Relatively short procedure (30-45 min)	Only suitable for proximal avulsions (intraoperative decision after arthroscopic evaluation of the reducibility of the remnant in a figure-of-4 position)
Avoids graft donor site morbidity	Technical skills needed for knot tying in the lateral gutter
Preservation of biological properties of the ACL (proprioception and vascularization)	Cost of disposable additional devices
Less invasive (4-mm tunnels)	Very few clinical results published
Lower inflammatory reaction with reduced effusion, pain, stiffness, and arthrogenic muscle inhibition	
Faster recovery than ACL reconstruction (however, further studies are necessary to prove it)	
ACL healing protected by suture augmentation	
Physseal sparing option in pediatric patients	
No biochemical reaction owing to the absence of intra-articular fixation devices	
Ease of ACL revision if needed	

ACL, Anterior cruciate ligament.

In conclusion, historical results of primary repair are mixed, and this could be attributed in part to inappropriate patient selection, relatively invasive surgery, and postoperative immobilization.^{2,6} Currently, however, better results of primary ACL repair are being reported because of improved patient selection enabled by magnetic resonance imaging, less invasive surgical techniques (i.e., arthroscopy), and rehabilitation focusing on early range of motion.

References

1. van der List JP, DiFelice GS. Primary repair of the anterior cruciate ligament: A paradigm shift. *Surgeon* 2017;15:161-168.
2. Feagin JA, Curl WW. Isolated tear of the anterior cruciate ligament: 5-year follow-up study. *Am J Sports Med* 1976;4:95-100.
3. DiFelice GS, van der List JP. Clinical outcomes of arthroscopic primary repair of proximal anterior cruciate ligament tears are maintained at mid-term follow-up. *Arthroscopy* 2018;34:1085-1093.
4. Taylor SA, Khair MM, Roberts TR, DiFelice GS. Primary repair of the anterior cruciate ligament: A systematic review. *Arthroscopy* 2015;31:2233-2247.
5. Chambat P, Walch G, Deschamps G, Dejour H. [Acute lesions of the anterior cruciate ligament of the knee. Apropos of 71 follow-up cases]. *Rev Chir Orthop* 1984;70:152-155 [in French] (Suppl 2).
6. Sherman MF, Lieber L, Bonamo JR, Podesta L, Reiter I. The long-term followup of primary anterior cruciate ligament repair: Defining a rationale for augmentation. *Am J Sports Med* 1991;19:243-255.
7. DiFelice GS, Villegas C, Taylor S. Anterior cruciate ligament preservation: Early results of a novel arthroscopic technique for suture anchor primary anterior cruciate ligament repair. *Arthroscopy* 2015;31:2162-2171.
8. Achtnich A, Herbst E, Forkel P, et al. Acute proximal anterior cruciate ligament tears: Outcomes after arthroscopic suture anchor repair versus anatomic single-bundle reconstruction. *Arthroscopy* 2016;32(12):2562-2569.
9. Proffen BL, Sieker JT, Murray MM. Bio-enhanced repair of the anterior cruciate ligament. *Arthroscopy* 2015;31:990-997.
10. van Eck CF, Limpisvasti O, ElAttrache NS. Is there a role for internal bracing and repair of the anterior cruciate

- ligament? A systematic literature review. *Am J Sports Med* 2018;46:2291-2298.
11. Murray MM, Flutie BM, Kalish LA, et al. The bridge-enhanced anterior cruciate ligament repair (BEAR) procedure: An early feasibility cohort study. *Orthop J Sports Med* 2016;4: 232596711667217.
12. van der List JP, DiFelice GS. Arthroscopic primary anterior cruciate ligament repair with suture augmentation. *Arthrosc Tech* 2017;6:e1529-e1534.
13. Sonnery-Cottet B, Barth J, Graveleau N, Fournier Y, Hager J-P, Chambat P. Arthroscopic identification of isolated tear of the posterolateral bundle of the anterior cruciate ligament. *Arthroscopy* 2009;25:728-732.
14. van der List JP, DiFelice GS. Successful arthroscopic primary repair of a chronic anterior cruciate ligament tear 11 years following injury. *HSS J* 2017;13:90-95.
15. Sonnery-Cottet B, Freychet B, Murphy CG, Pupim BHB, Thaumat M. Anterior cruciate ligament reconstruction and preservation: The single-antromedial bundle biological augmentation (SAMBBA) technique. *Arthrosc Tech* 2014;3:e689-e693.
16. Boutsiadis A, Karampalis C, Tzavelas A, Vraggalas V, Christodoulou P, Bisbinas I. Anterior cruciate ligament remnant-preserving reconstruction using a "lasso-loop" knot configuration. *Arthrosc Techn* 2015;4:e741-e746.
17. Sonnery-Cottet B, Rezende FC, Martins Neto A, Fayard JM, Thaumat M, Kader DF. Arthroscopically confirmed femoral button deployment. *Arthrosc Tech* 2014;3:e309-e312.
18. Weninger P, Wepner F, Kissler F, Enenkel M, Wurnig C. Anatomic double-bundle reinsertion after acute proximal anterior cruciate ligament injury using knotless PushLock anchors. *Arthrosc Tech* 2015;4:e1-e6.
19. Smith PA, Bley JA. Anterior cruciate ligament primary repair with independent tensioning of the anteromedial and posterolateral bundles. *Arthrosc Tech* 2017;6:e2123-e2128.
20. DiFelice GS, van der List JP. Arthroscopic primary repair of proximal anterior cruciate ligament tears. *Arthrosc Tech* 2016;5:e1057-e1061.
21. 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: 232596711770996.
22. Claes S, Verdonk P, Forsyth R, Bellemans J. The "ligamentization" process in anterior cruciate ligament reconstruction: What happens to the human graft? A systematic review of the literature. *Am J Sports Med* 2011;39:2476-2483.
23. van der List JP, DiFelice GS. Range of motion and complications following primary repair versus reconstruction of the anterior cruciate ligament. *Knee* 2017;24:798-807.
24. Gobbi A, Bathan L, Boldrini L. Primary repair combined with bone marrow stimulation in acute anterior cruciate ligament lesions: Results in a group of athletes. *Am J Sports Med* 2009;37:571-578.
25. Eggli S, Kohlhof H, Zumstein M, et al. Dynamic intra-ligamentary stabilization: Novel technique for preserving the ruptured ACL. *Knee Surg Sports Traumatol Arthrosc* 2015;23:1215-1221.
26. Murray MM. Current status and potential of primary ACL repair. *Clin Sports Med* 2009;28:51-61.
27. Rowan FE, Haddad FS. The future of ACL reconstruction is more than tunnels and grafts. *Bone Joint J* 2018;100-B: 269-270.
28. Mackay GM, Blyth MJ, Anthony I, Hopper GP, Ribbans WJ. A review of ligament augmentation with the InternalBrace: The surgical principle is described for the lateral ankle ligament and ACL repair in particular, and a comprehensive review of other surgical applications and techniques is presented. *Surg Technol Int* 2015;26:239-255.