



Anatomical Arthroscopic Anterior Talofibular Ligament and Calcaneofibular Ligament Reconstruction Using an Autogenic Hamstring Tendon: Safe Creation of Anatomical Fibular Tunnel

Reiji Higashiyama, M.D., Ph.D., Jun Aikawa, M.D., Ph.D., Dai Iwase, M.D.,
Yasuyuki Takamori, M.D., Ph.D., Eiichiro Watanabe, M.D., Ph.D., and
Masashi Takaso, M.D., Ph.D.

Abstract: Ankle sprains are the most common lower extremity injuries associated with sports activity. Although ligament repair techniques are popular, reconstruction methods using free tendons are considered when the ligament remnant is insufficiently strong, when high-demand athletes sustain repeat ankle sprains, or in revision cases after repair. Recently, some arthroscopic reconstruction techniques have been reported. The distal fibular end is thin; therefore, surgeons must be careful while drilling the fibular tunnel. This report indicates the safe creation method of an anatomical fibular tunnel during anatomical arthroscopic reconstruction of the anterior talofibular ligament and calcaneofibular ligament. This also provides a stronger reconstruction using a 2-strand tendon graft for the anterior talofibular ligament substitute, which is thought to have less risk for postoperative graft failure.

Ankle sprains are the most common lower extremity injuries associated with sports activity.¹ The Brostrom technique is the most popular procedure for repairing the ruptured anterior talofibular ligament (ATFL)²; however, postoperative results may be poor when a long time has passed after an ankle sprain, the ATFL remnant is insufficiently strong, and/or a high-demand athlete sustains a repeat ankle sprain. A ligament reconstruction method using a free tendon is believed to provide a better prognosis in such cases.³

From the Department of Orthopaedic Surgery, Kitasato University School of Medicine, Minami (R.H., J.A., D.I., M.T.), Sagami-hara, Kanagawa, and the Department of Orthopaedic Surgery, Fuji Orthopaedic Surgery Hospital (Y.T., E.W.), Fuji, Shizuoka, Japan.

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Address correspondence to Reiji Higashiyama, M.D., Ph.D., Department of Orthopaedic Surgery, Kitasato University School of Medicine, 1-15-1 Kitasato, Minami, Sagami-hara, Kanagawa 252-0374, Japan. E-mail: higashiyama_reiji@yahoo.co.jp

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There are a few technical reports⁴⁻⁸ and short-term clinical results⁹⁻¹² of the arthroscopic lateral ankle ligament reconstruction. The distal fibular end is thin; hence, surgeons should pay attention to avoid intraoperative fracture of the distal fibula during the tunnel drilling during the arthroscopic ATFL and calcaneofibular ligament (CFL) reconstruction. Moreover, previous technical reports of ATFL and CFL reconstruction use a tendon graft composed of 1-strand ATFL and CFL.⁴⁻⁶

Here, we describe the technique of an anatomical arthroscopic ATFL and CFL reconstruction using a hamstring tendon graft composed of a 2-strand ATFL and a 1-strand CFL using safe methods of creating a fibular tunnel. A summary of key steps is provided in [Table 1](#); a summary of the technique is provided in [Video 1](#).

Surgical Technique

Step 1: Patient Positioning

This surgery is performed under general anesthesia with the patient in the supine position. A tourniquet is placed on the proximal thigh. The foot is suspended from the distal edge of the bed. The contralateral leg is slightly lowered to provide a wide working space ([Fig 1A](#)).

Table 1. Key Surgical Steps, Pearls, and Pitfalls

Key Surgical Steps	Pearls	Pitfalls
Patient position	The foot is suspended from the distal edge of the bed. The contralateral leg is slightly lowered to provide a wide working space.	If the foot is not suspended from the distal edge of the bed, it will be difficult to dorsiflex the ankle using the surgeon's belly.
Harvest a hamstring tendon	The gracilis tendon is usually enough to create the graft. A semitendinosus tendon is harvested if the gracilis is too thin or too short. The harvested tendon usually needs to be longer than 160 mm. The length is determined by preoperative magnetic resonance imaging.	An extremely short tendon will be difficult to prepare the 2-strand ATFL graft.
Creation of the AM portal	The ankle is positioned neutrally. The AM portal is created medial to the anterior tibial tendon, which is slightly displaced laterally by pushing with the thumb.	If the AM portal is created too medially, visualization of the ATFL remnant will be difficult.
Creation of the AAL portal	The ankle is dorsiflexed to view the ATFL remnant. Before the AAL portal is created, a needle is inserted into the portal site to confirm accessibility to the ATFL talar footprint.	If the AAL portal is created without confirmation by the needle, the AAL portal position will not be suitable for the talar tunnel creation.
Creation of the talar tunnel	A microfracture awl is used to mark the center of the ATFL talar footprint, and a guidewire is inserted through the AAL portal to drill the talus towards the distal end of the medial malleolus.	A guidewire may slip at the ATFL talar footprint without marking. If a guidewire is directed too posteriorly, the neurovascular bundle is at risk for damage. If the tunnel is deeper than 20 mm, the risk for talar penetration may be higher.
Creation of the ST portal	The ST portal is created just below the distal end of fibula after confirming accessibility to the fibular footprint by a needle.	If the ST portal is created too anteriorly, the fibular tunnel is directed distally and the risk of tunnel fracture will be higher.
Creation of the fibular tunnel	Intraoperative fluoroscopy is used to confirm the guidewire position.	If the fibular tunnel is created without fluoroscopic assistance, the risk for tunnel fracture and tunnel malposition may be higher.
Dissection of the CFL remnant	The shaver opening can be safely directed toward the calcaneus during the CFL remnant dissection.	If the shaver opening is directed laterally or distally, the peroneal tendon might be damaged.
Creation of the calcaneal tunnel	A 25- to 30-mm-deep calcaneal tunnel is overdrilled through the ST portal. The drill should pass gently near the peroneal tendon.	If the tunnel is drilled through the AAL portal, the drill angle to the calcaneal surface will be too sharp and tunnel wall fracture might occur.
Passing pin to the fibular tunnel	A pin is inserted anteriorly from the anterior edge of the tunnel inlet to the posterior and proximal edge to penetrate the posterior cortical wall of the fibula and the skin.	If a pin is inserted parallel to the tunnel, it may not penetrate the skin on the posterior aspect, and a longer passing pin will be necessary.
Graft fixation	The ATFL graft should be fixed first.	If the CFL graft is fixed with extremely strong tension before the ATFL graft fixation, anterior drawer stress of the talus may occur and anterior stability will decrease.

AAL, accessory anterolateral; AM, anteromedial; ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; ST, subtalar.

Step 2: Graft Preparation

The gracilis tendon is harvested, and a reversed Y-shaped graft is prepared. The semitendinosus tendon is used if the gracilis is too thin or too short. The harvested tendon usually needs to be longer than 160 mm. It contains 2 strands of an approximately 20-mm-long bundle for ATFL and 1 strand of 25- to 30-mm-long bundle for CFL. The length is determined by a preoperative magnetic resonance imaging. The 3 ends form a 15-mm long loop to facilitate the attachment of the thread for graft delivery (Fig 1B and C). If the graft length is longer than 190 mm, the CFL graft can also be prepared as a 2-strand bundle. The recommended graft diameter is 4.5 to 6.0 mm.

Step 3: Portal Placement of Ankle Arthroscopy

Three portals are created step by step: a conventional anteromedial (AM) portal, an accessory anterolateral (AAL) portal, and a subtalar (ST) portal. The ankle is positioned neutrally. The AM portal is created medial to the anterior tibial tendon, which is slightly displaced laterally by pushing with the thumb (Fig 2A). A 30° 2.7-mm- or 4.0-mm-diameter arthroscope is introduced through the AM portal. The ankle is dorsiflexed to view the ATFL remnant. Before the AAL portal is created, a needle is inserted into the portal site to confirm accessibility to the ATFL talar footprint. The portal is usually created at approximately 20 mm anterior to the antero-inferior tip of the distal fibula, which is called the *fibular*

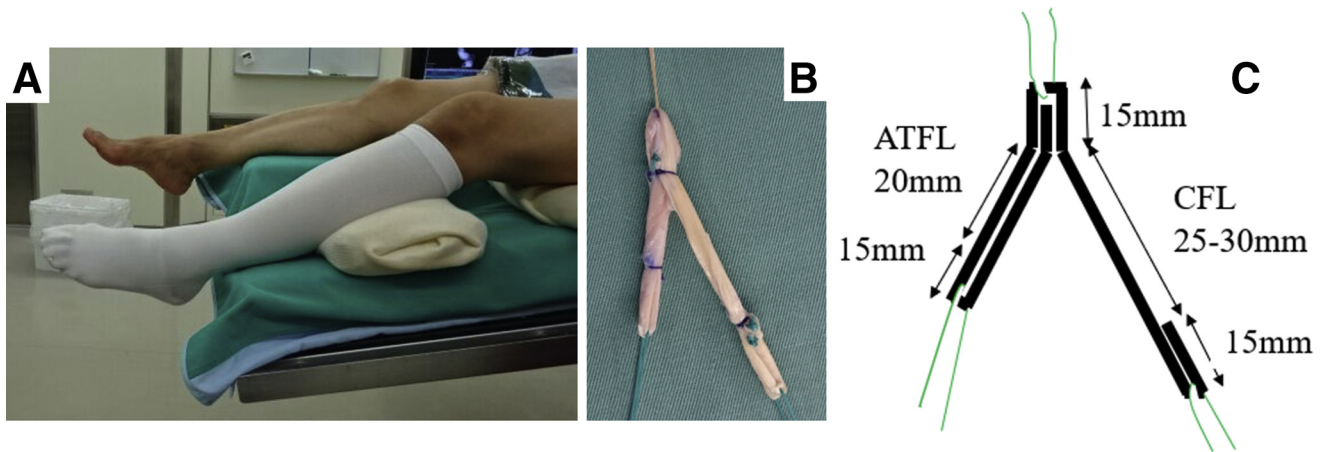


Fig 1. Patient position and graft preparation. (A) The right ankle is the operative side. Surgery is performed under general anesthesia with the patient in the supine position. A tourniquet is placed on the proximal thigh and the foot is suspended from the distal edge of the bed. The contralateral leg (left) is slightly lowered to provide a wide working space. (B, C) A gracilis tendon graft is harvested and a reversed Y-shaped graft is prepared. The semitendinosus tendon is used if the gracilis is too thin or too short. It contains 2 strands of an approximately 20-mm-long bundle for the ATFL and 1 strand of 25- to 30-mm-long bundle for the CFL. The length is determined by preoperative magnetic resonance imaging. The 3 ends form a 15-mm-long loop to facilitate attachment of a thread for graft delivery. Parts (A) and (B) are from patients different from the patient in the video case because of photo quality. (ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament.)

obscure tip (FOT) (Fig 2B).¹³ The intra-articular lesions are assessed through these 2 portals.

Step 4: Tunnel Creation

The ATFL remnant is dissected. A microfracture awl is used to mark the center of the ATFL talar footprint and a 2.4-mm guidewire is inserted through the AAL portal to drill the talus from the ATFL footprint toward the distal end of the medial malleolus.¹⁴ The guidewire is

then overdrilled, using a drill having the same diameter as the graft end, to create a 20-mm-deep talar tunnel (Fig 2C).

When the ATFL fibular footprint is not adequately viewed through the AM portal, surgeons can try to dorsiflex the ankle, change to the 70° arthroscope, or place the scope through the AAL portal. The ST portal is created just below the distal end of the fibula after confirming accessibility to the fibular footprint by a

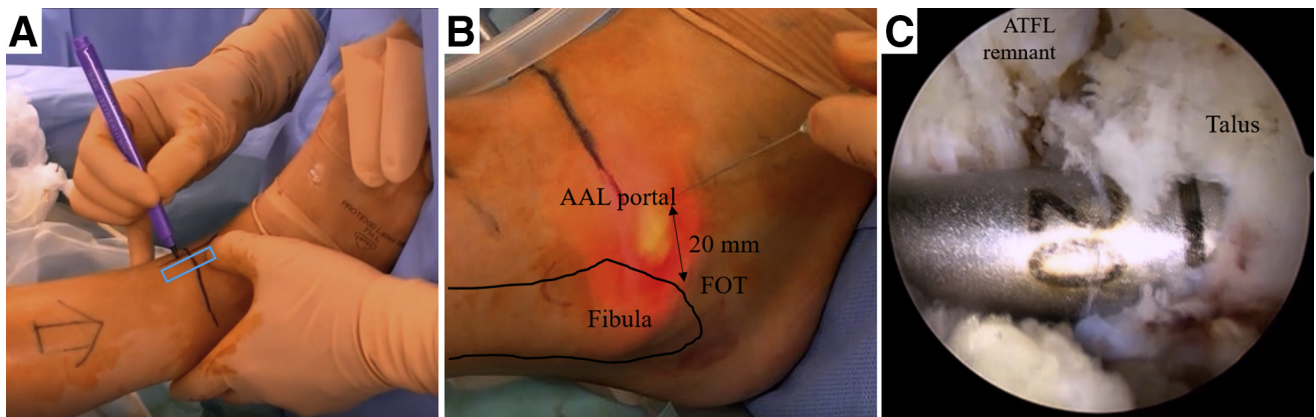


Fig 2. Creation of the AM portal, ALL portal, and talar tunnel (right ankle). (A) The right ankle is positioned neutrally. The AM portal is created medial to the anterior tibial tendon (blue box), which is slightly displaced laterally by pushing with the thumb. An arthroscope is introduced through the AM portal. The ankle is dorsiflexed to view the ATFL remnant. (B) Before the AAL portal is created, a needle is inserted into the portal site to confirm accessibility to the ATFL talar footprint. It is usually created at a point approximately 20-mm anterior to the FOT. (C) The ATFL remnant is dissected. A microfracture awl is used to mark the center of the ATFL talar footprint, and a 2.4-mm guidewire is inserted through the AAL portal to drill the talus, from the ATFL footprint toward the distal end of the medial malleolus. The guidewire is then overdrilled, using a drill having the same diameter as the graft end, to create a 20-mm-deep talar tunnel. (AM, anteromedial; AAL, accessory anterolateral; ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; FOT, fibular obscure tip; ST, subtalar.)

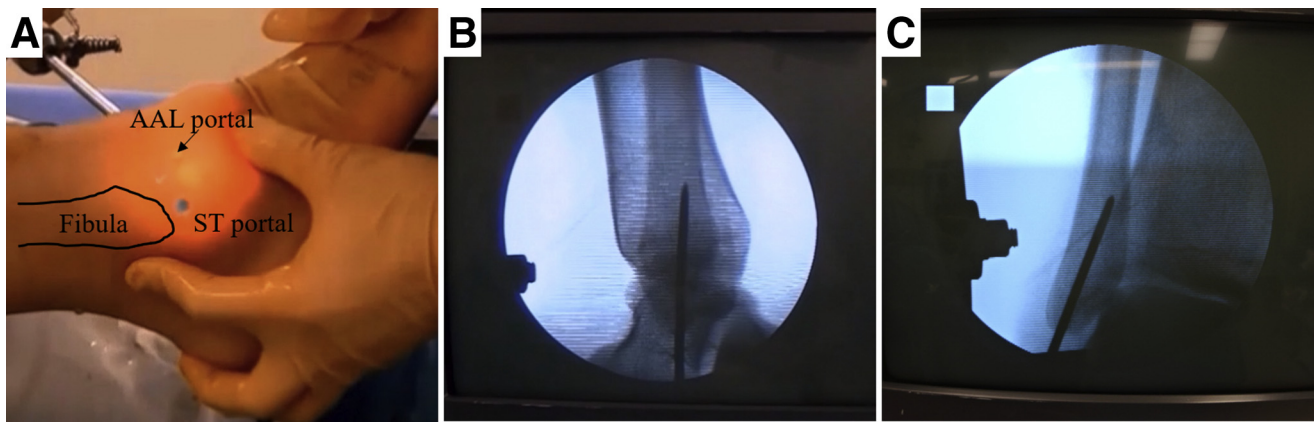


Fig 3. Creation of the ST portal and the fibular tunnel (the right ankle). (A) The ST portal is created just below the distal end of the fibula after confirming accessibility to the fibular footprint by a needle. A guidewire is inserted through the ST portal. (B) Intraoperative fluoroscopy is used to confirm the guidewire position. Insertion point should be below the FOT. The guidewire is directed nearly along the long axis of the fibula on the lateral view. (C) The guidewire is directed almost on the angle bisector of the fibular end on the anteroposterior view. Viewed from the AAL portal, the guidewire is then overdrilled to create a 20-mm-deep fibular tunnel. (AAL, accessory anterolateral; FOT, fibular obscure tip; ST, subtalar.)

needle (Fig 3A). A guidewire is inserted through the ST portal. Intraoperative fluoroscopy is used to confirm the guidewire position. The insertion point should be below both of articular tip and the FOT.¹³ The guidewire is directed nearly along the long axis of the fibula on the lateral view (Fig 3B) and almost on the angle bisector of the fibular end on the anteroposterior view (Fig 3C). Viewed from the AAL portal, the guidewire is then overdrilled to create a 20-mm-deep fibular tunnel. The CFL remnant is debrided by a shaver through the ST portal. The surgeon must pay attention to the peroneal tendons because they run just superficial to the CFL.

The shaver opening can be safely directed toward the calcaneus, with the debridement continuing to the lateral wall of the calcaneus. The CFL footprint can be observed. A 25- to 30-mm-deep calcaneal tunnel is overdrilled after the guidewire insertion through the ST portal (Fig 4A and B).

Step 5: Tendon Graft Introduction and Fixation

A 1.6-mm passing pin (Meira, Nagoya, Japan) is inserted into each tunnel. These pins penetrate the bone and skin on the opposite side. When piercing the fibular tunnel, a pin is inserted anteriorly from the

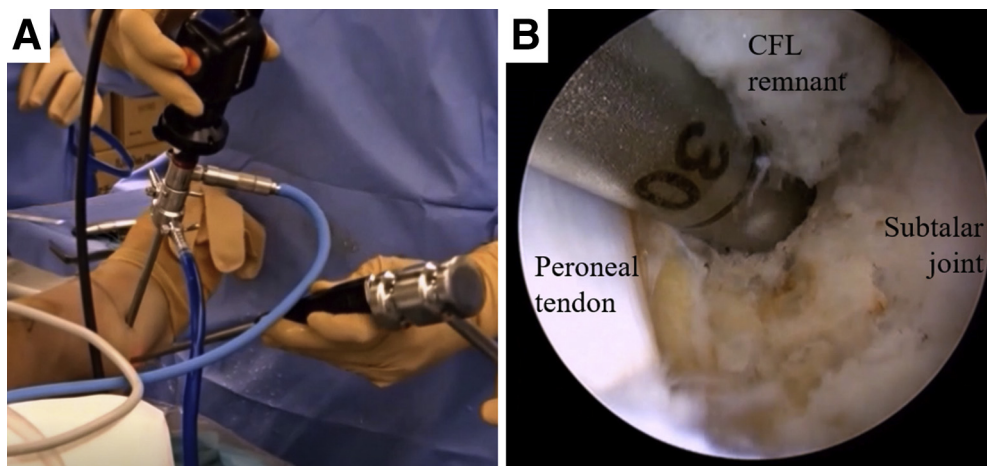


Fig 4. Creation of the calcaneal tunnel (the right ankle). (A) Viewed from the AAL portal, the CFL remnant is debrided by the shaver through the ST portal. The surgeon must pay attention to the peroneal tendons because they run just superficial to the CFL. The shaver opening can be safely directed toward the calcaneus, with debridement continuing to the lateral wall of the calcaneus. The CFL footprint can be observed. A microfracture awl is used to mark the center of the CFL talar footprint. (B) A 25- to 30-mm-deep calcaneal tunnel for the CFL graft is overdrilled after the guidewire insertion through the ST portal. The ST joint is to the right side of the picture. Peroneal tendon is observed on the left side of the drill. (AAL, accessory anterolateral; CFL, calcaneofibular ligament; ST, subtalar.)

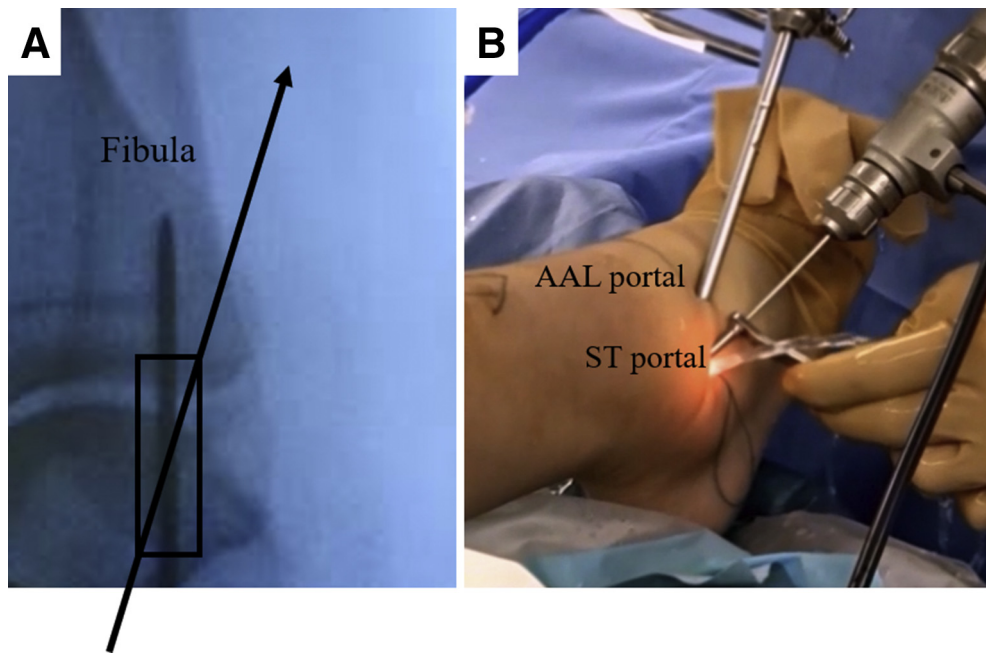


Fig 5. Passing pin direction in the fibular tunnel (the right ankle). (A) A 1.6-mm passing pin is inserted into each tunnel. These pins penetrate the bone and the skin on the opposite side. When piercing the fibular tunnel, a pin is inserted anteriorly from the anterior edge of the tunnel inlet to the posterior and proximal edge to penetrate the posterior cortex wall of the fibula and the skin. A passing pin is passed along the diagonal line (arrow →) of the fibular bone tunnel (box) for graft delivery. (B) Viewed from the AAL portal, a passing pin is inserted to the fibular tunnel through the ST portal using a guide sleeve to protect the skin damage. Part (A) shows a different patient from that of the video case because of photo quality. (AAL, accessory anterolateral; ST, subtalar).

anterior edge of the tunnel inlet to the posterior and proximal end to penetrate the posterior cortical wall of the fibula and the skin (Fig 5 A and B). A looped thread is passed through the eye of each passing pin. The passing pins are completely pulled. The looped thread penetrating the talar tunnel needs to be led from the

AAL portal to the ST portal. All 3 looped threads are then connected with each graft end; then, the tendon graft is introduced from the ST portal to each tunnel by pulling the looped threads.

Manual tension is applied on the graft, and each tunneled end of the tendon graft is fixed with a

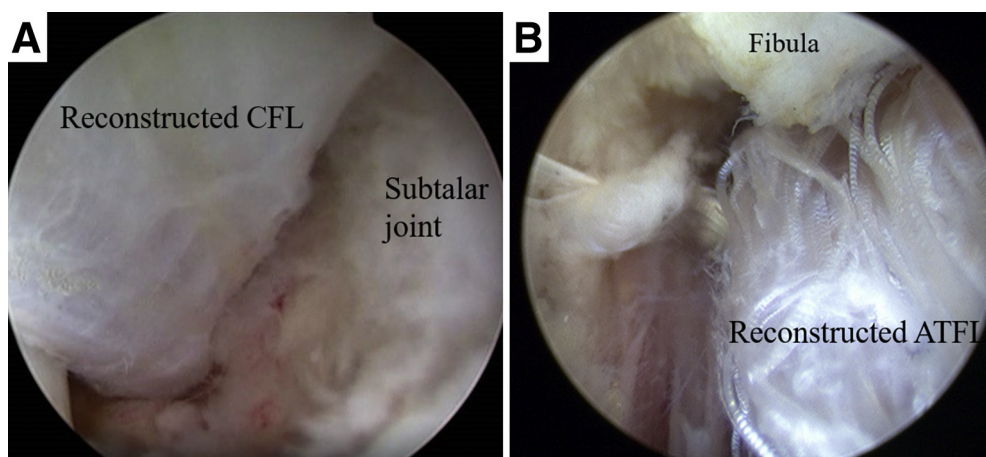


Fig 6. Graft introduction and fixation (the right ankle). A looped thread is passed to the eye of each passing pin. Passing pins are completely pulled. The looped thread penetrating the talar tunnel needs to be led from the AAL portal to the ST portal. All 3 looped threads are then connected with each graft end; then, the tendon graft is introduced from the ST portal to each tunnel by pulling the looped threads. Each tunneled end of the tendon graft is fixed with a 5- to 6-mm-diameter 15-mm-long bioabsorbable interference screw, with the ankle in the neutral position. (A) Reconstructed CFL and ST joint. (B) Reconstructed ATFL and distal fibula. (AAL, accessory anterolateral; ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; ST, subtalar).

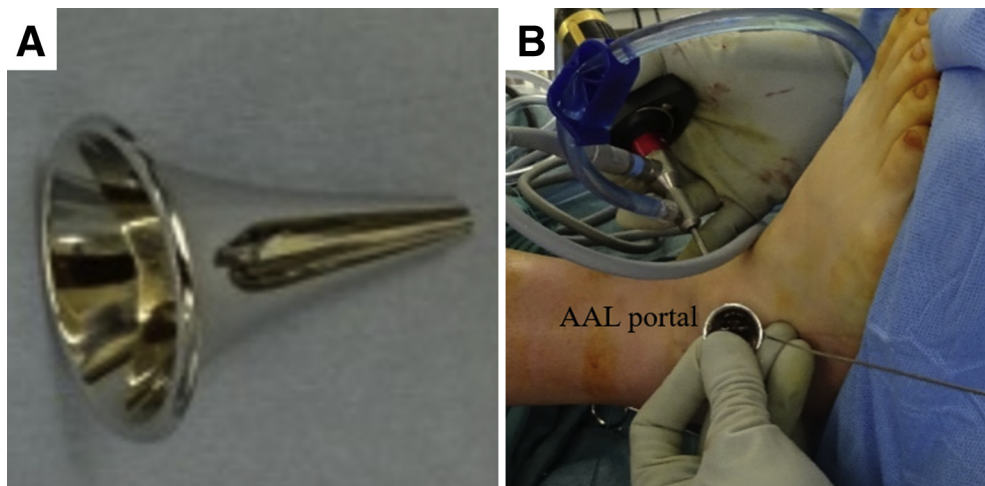


Fig 7. Optional technique of cancellous bone tip transplantation (right ankle). (A) Funnel-shaped device. (B) If the screw is not firmly fixed, a bigger size screw or cancellous bone tips are grafted to the space between the tunnel and tendon graft using a funnel-shaped device and a flat-ended 3-mm Kirschner wire for pushing bone tips. The cancellous bone can be harvested from the knee or from the allograft. This indicates the transplantation of the bone tips into the talar tunnel through the AAL portal using a funnel-shaped device and a Kirshner wire. Parts (A) and (B) are from different patients than that of the video case because of the optional technique. (AAL, accessory anterolateral.)

5- to 6-mm-diameter, 15-mm-long bioabsorbable interference screw, with the ankle in the neutral position (Fig 6). If the CFL graft is fixed with extremely strong tension before the ATFL graft fixation, anterior drawer stress of the talus may occur; therefore, the ATFL graft should be fixed first.

Optional Technique When the Screw Is Not Firmly Fixed

If the screw is not firmly fixed, the screw size is changed to a bigger size or the cancellous bone tips are

grafted to the space between the tunnel and tendon graft, using a funnel-shaped device (Fig 7A) and a flat-ended 3-mm Kirschner wire for pushing the bone tips (Fig 7B). The cancellous bone can be harvested from the knee or be prepared from the allograft.

Optional Technique for the Graft Fixation in the Fibular Tunnel

When the bone quality is weak, a JuggerKnot Soft Anchor-2.9 mm (Zimmer-Biomet, Warsaw, IN) is placed at the bottom of the fibular tunnel (Fig 8A). One

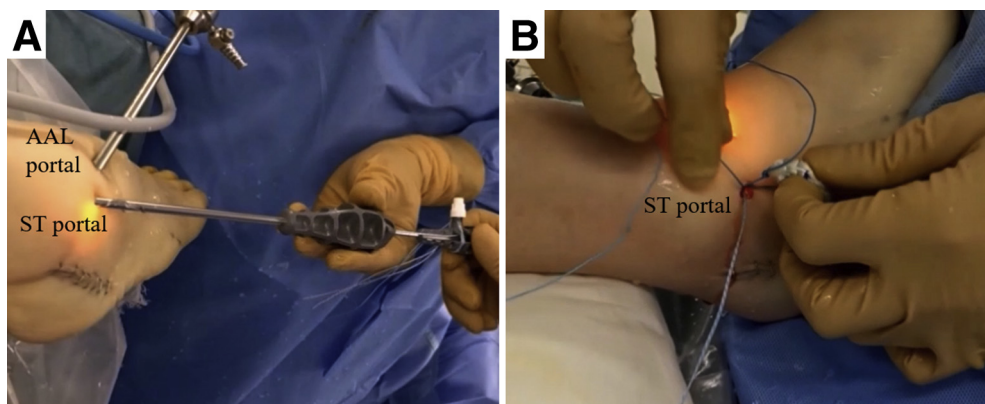


Fig 8. Optional technique for the graft fixation in the fibular tunnel (right ankle). (A) When the bone quality is weak, the JuggerKnot Soft Anchor-2.9 mm is placed at the bottom of the fibular tunnel through the ST portal. (B) One strand is sutured to the fibular end of the tendon graft; the other strand is pulled; then, the strands are tied. If the patient is an athlete and wants to start rehabilitation as early as possible, both suture anchor and interference screw fixation are used for stronger initial fixation. There is another operative scar on the lateral skin of the calcaneus, and the tendon graft is a straight shape for ATFL reconstruction, because the patient in these figures underwent calcaneal osteotomy combined with arthroscopic ATFL reconstruction. (ATFL, anterior talofibular ligament; ST, subtalar.)

Table 2. Advantages and Disadvantages

Advantages	
Safe and reproducible tunnel creation	
Stronger graft and less risk of ligament rupture recurrence	
Anatomical reconstruction and less postoperative risk of range of motion restriction	
Only 2 looking portals and shorter learning curve	
Smaller operative scar formation	
Less risk of superficial peroneal nerve damage	
Optional technique for the graft fixation in the fibular tunnel in patient with lower bone quality	
Optional technique when the screw is not firmly fixed	
Disadvantages	
Possible longer operative time than open technique	
Possible risk of tunnel fracture	
Necessary for the basic arthroscopy skill	
Usage of intraoperative fluoroscopy	

strand is sutured to the fibular end of the graft and the other strand is pulled (Fig 8B); then, the strands are tied. If the patient is an athlete and wants to start rehabilitation as early as possible, both suture anchor and interference screw fixation are used for stronger initial fixation.

Discussion

About 20% to 40% of patients have persistent pain and experience recurrent sprains because of chronic lateral instability of the ankle,¹⁵ which eventually requires surgery. The Brostrom technique is the most popular procedure for repairing the ruptured ATFL,² and recent reports have described arthroscopic repair methods.^{3,16-19} Arthroscopic ligament reconstruction techniques using a graft tendon have also been reported⁴⁻⁶; these are believed to be stronger than repair techniques but need tunnel creation at the distal fibular end. Surgeons should create a fibular tunnel carefully to avoid intraoperative fracture because the fibular end is thin. To date, however, no technical reports have focused on the safe creation method of the fibular tunnel during arthroscopic ATFL and CFL reconstruction. Because of the connection between the ATFL and CFL,^{20,21} 1 fibular tunnel is more reasonable and safer than the creation of 2 fibular tunnels.⁴ When the anatomical fibular tunnel is drilled through the AAL portal, the drill will pass anteroinferiorly to posterosuperiorly; therefore, the risk of the intraoperative fracture of the tunnel wall is greater. The drill should be introduced from the ST portal to direct it along the long axis of the fibula. To create a safer fibular tunnel, we strongly recommend using intraoperative fluoroscopy to confirm guidewire direction before overdrilling.

Intraoperative fluoroscopy is also necessary to confirm the guidewire insertion position for a correct fibular tunnel position because the intersection of the ATFL and CFL is located 2.4 mm (range, 0-6.3 mm) distal to the FOT, which is 1.3 mm (range, 0-5.3 mm)

distal from the articular tip of the fibula, which can be observed by an arthroscope.¹³

In other techniques, the calcaneal tunnel is drilled through the sinus tarsi tunnel⁵ or the AAL portal;⁶ however, drilling through the ST portal is less risky for lateral wall fracture of the calcaneum because the ST portal is closer to the CFL footprint. In other words, the drilling direction becomes near perpendicular to the lateral wall of the calcaneum.

The present procedure is also easier for surgeons to get used to because there are only 2 looking portals: the AM portal and the ALL portal. One report needs 4 looking portals,⁵ which needs a longer learning curve. However, there are only 3 necessary portals in the present technique: the AM, AAL, and ST portals. The risk of superficial peroneal nerve damage near the AL portal can be diminished.

Some articles have described a similar Y-shaped tendon graft that contains single-strand ATFL and single-strand CFL.^{5,6,22} Grafts with larger diameters could cause fewer graft failures²³; moreover, the tendon is folded into a 2-strand ATFL graft in the present technique.

We also provided an optional technique of the graft introduction and fixation in the fibular tunnel. Some older patients have weak bone quality and have a relatively high risk of intraoperative fibular fracture during interference screw fixation. Postoperative rehabilitation program should be slower when using only a suture anchor because of its weaker initial fixation strength than that of an interference screw fixation.^{24,25} A summary of advantages and disadvantages is provided in Table 2.

Precise anatomical ligament reconstruction with a stronger tendon graft and safe tunnel creation method should be preferred to restore the normal kinematics of the ankle joint and ST joint, and long-term results will be promising.

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