All Arthroscopic Remnant-Preserving Technique to Reconstruct the Lateral Ankle Ligament Complex

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Abstract: Arthroscopic lateral ankle ligament reconstruction has been recently advocated. But this technique has not been popularized because of the technical complexity and potential iatrogenic injury. Because the talocalcaneal and calcaneofibular ligaments are extra-articular structures, how to efficiently view and address them is a difficult task. Limited dissection outside the capsule to form a working space is required, but aggressive dissection is harmful for tissue healing although it is helpful for visualization and instrumentation. Because almost the entire talar body is covered by articular cartilage, it is very difficult to safely make a bone tunnel without damaging the cartilage. The remnants of the lateral ankle ligament have proprioceptive sensors that are important for functional stability, but it is difficult to perform anatomical reconstruction arthroscopically while preserving them because of the narrow working space. Furthermore, how to properly tension the reconstructed ligaments in such a narrow working space is also a very difficult task. We have designed a technique that preserves the remnants of lateral ankle ligaments, and all of the above-mentioned problems have been successfully addressed. We have used this technique clinically, and only minor complications occurred.

Ankle lateral ligament complex reconstruction is a well-proven procedure both to restore stability and to prevent traumatic arthritis.[1-3] Open procedures have the advantages of accurate portal placement and anatomical reconstruction, but larger incision, extensive dissection and slower rehabilitation are the main disadvantages.[4-6] Arthroscopic ankle ligament reconstruction has been advocated recently.[7-9] It has the advantages of minimally invasiveness, anatomical reconstruction and one-stage intra-articular lesions treatment.[10-12] Because the anterior talofibular and calcaneofibular ligaments are both extra-articular structures, there is very little room for visualization and instrument maneuverability even though an extra-articular working space has been made.[13] We have explored this technique from 2010, and many complications, such as tunnel malposition, cartilage injury, graft loosening, and incision dehiscence, have been found. Therefore, we have revised this technique repeatedly, and the complications have been decreased. The final version of our technique is reported below.

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Surgical Technique

Step 1: Patient Position, Viewing Portal Placement

The patient is placed in the supine position. Thigh tourniquet is applied. A sandbag is placed under the lower leg to elevate the ankle to a height of 10 mm above the operation table (Fig 1A). A 30° 4-mm arthroscopy is used. The first established portal is the anterior midline portal (portal 1), which is located close to the medial border of the anterior tibial tendon and 1 cm proximal to the ankle joint line. Using this portal, routine examination of the anterior ankle is performed. The arthroscopy is then turned to the anterolateral ankle gutter; an anterolateral portal (portal 2) is created by a spinal needle pointed to the lateral gutter under arthroscopic visualization (Video 1). The landmark of the anterolateral portal is adjacent to the lower tibiofibular articulation and 1 cm proximal to the joint line (Fig 1B).

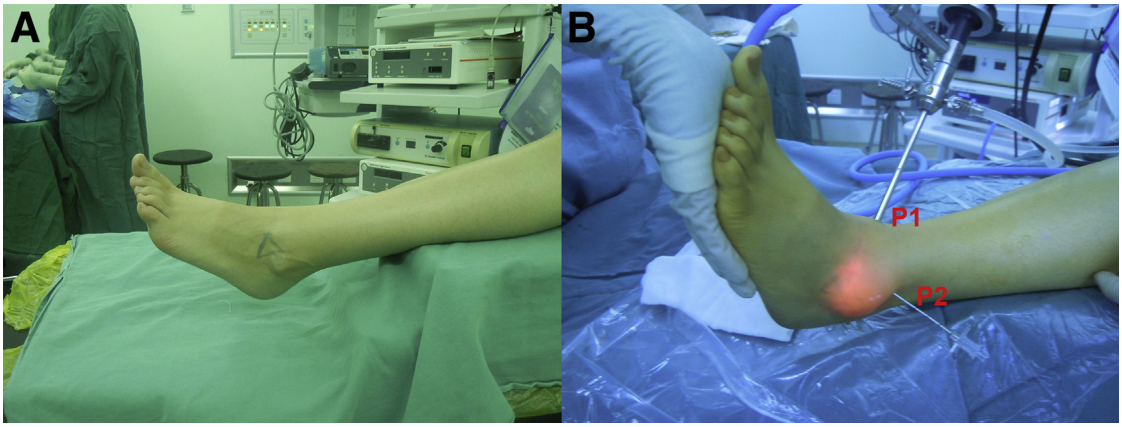

Fig 1. (A) Patient is placed supine. The left ankle is elevated to facilitate tunnel creation by a sandbag placed under the lower leg. (B) The arthroscopy is placed at portal 1; portal 2 is created by an 18-gauge spinal needle aimed at the lateral gutter under arthroscopic visualization. (P1, portal 1; P2, portal 2.)

Step 2: Limited Dissection and Working Space Creation

Portal 1 is now acting as a viewing portal, and portal 2 is a working portal (Fig 2A). The lateral gutter is cleared by use of a shaver. The remnant of the anterior talofibular ligament is preserved (Fig 2B, Video 1). The dissection is continued distally from the talar remnant of the anterior talofibular ligament until the anterior gap of the posterior subtalar joint is visualized. The dissection anterior to the talar body can be extended medially to the talar neck, with careful attention to protect the calcaneal roots of the inferior extensor retinaculum anteriorly (Fig 2C). The dissection is also extended laterally until the anterolateral corner of the

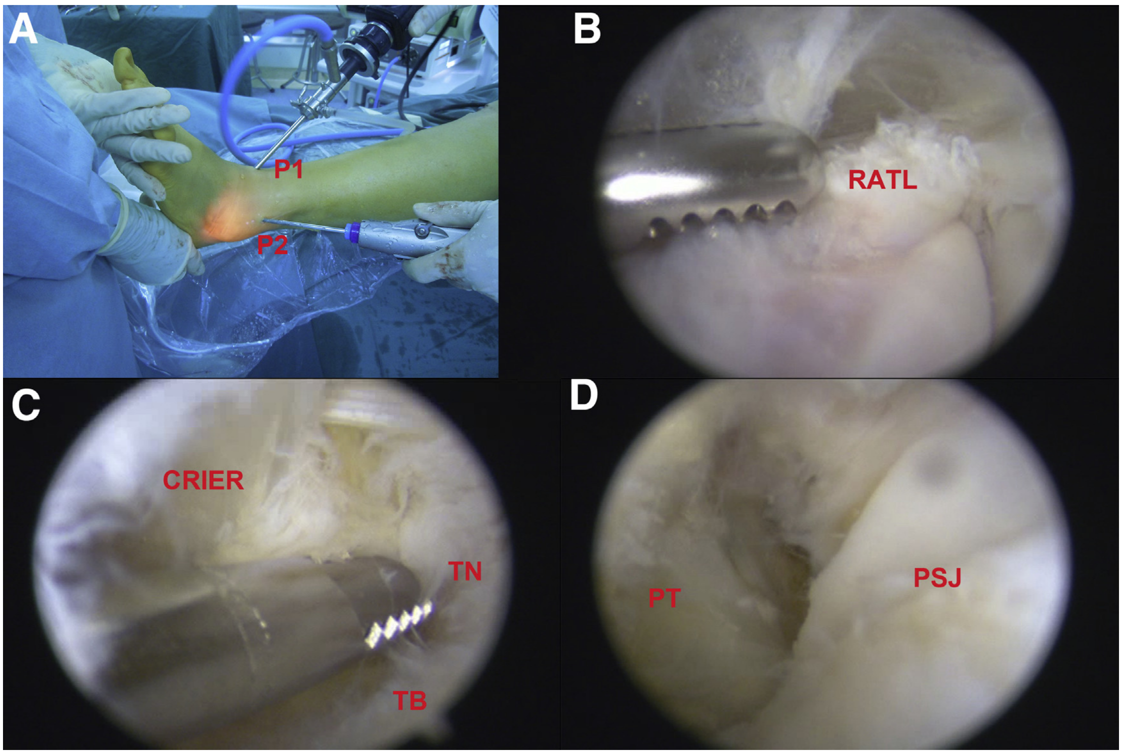

Fig 2. (A) Working space can be established by viewing at portal 1 and working at portal 2. (B) The lateral gutter is debrided. The remnant of the anterior talofibular ligament is preserved. (C) Working space can be extended medially to the talar neck, with careful attention to protect the calcaneal roots of the inferior extensor retinaculum anteriorly. (D) Working space can be extended laterally until the anterolateral corner of the posterior subtalar joint and the peroneus tendons are viewed. (CRIER, calcaneal roots of the inferior extensor retinaculum; P1, portal 1; P2, portal 2; PSJ, posterior subtalar joint; PT, peroneus tendons; RATL, remnant of the anterior talofibular ligament; TB, talar body; TN, talar neck.)

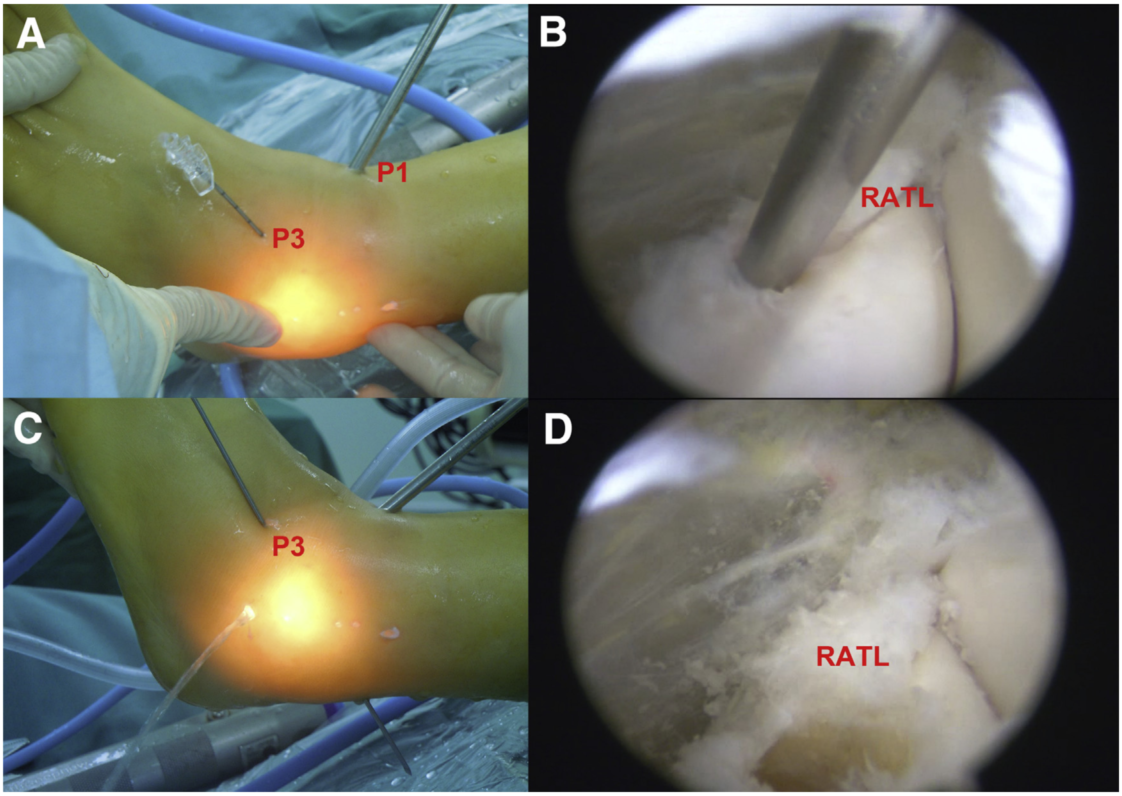

Fig 3. (A) Portal 3 is created by a spinal needle aimed at the fibular attachment site of the anterior talofibular ligament while viewing at portal 1. (B) A guidewire is introduced from portal 3 to a site adjacent to the fibular remnant of the anterior talofibular ligament. (C) The guidewire is inserted and advanced in an anteroinferior to posterosuperior direction. (D) Following the guidewire, the fibular tunnel is made adjacent to the remnant. (P1, portal 1; P3, portal 3; RATL, remnant of the anterior talofibular ligament.)

posterior subtalar joint and the peroneus tendons are well viewed (Fig 2D). Using these 2 structures as landmarks, the dissection is continued posteriorly until the calcaneal attachment site of the calcaneofibular ligament is reached.

Step 3: Fibular Bone Tunnel Creation Through Working Portal 3

Usually, portal 2 is the primary viewing portal for the following procedures. Rarely, portal 1 is better for visualization. The fibular remnant of the anterior talofibular ligament is visualized, and the third portal (portal 3) is introduced by a spinal needle pointed to the fibular remnant of the anterior talofibular ligament under arthroscopic visualization (Fig 3A). The body landmark of the third portal is close to the peroneus tertius tendon and 1.5 cm anterior to the talar body. Using this portal, a guidewire is introduced to a site adjacent to the fibular remnant of the anterior talofibular ligament (Fig 3B). The guidewire is then advanced in an anteromedial to posterolateral direction to a site 4 to 5 cm proximal to the lateral malleolus tip and exits lateral to the peroneus tendons with the foot and ankle placed at maximal inversion (Fig 3C). A small incision is made at the exit site. A bone tunnel of 1 cm depth is created in the fibular by a cannulated reamer of 6 mm diameter (Fig 3D).

Step 4: Talar and Calcaneal Bone Tunnel Creation Through Working Portal 4

The arthroscopy is turned to view the calcaneal attachment site of the calcaneofibular ligament. The fourth portal (portal 4) is also introduced by a spinal needle pointed to the calcaneal attachment site of the calcaneofibular ligament (Fig 4A). The body landmark of the fourth portal is 1 cm above the peroneus tendons and 0.5 cm anterior to the talar body (Fig 4B). A guidewire (Smith & Nephew, Memphis, TN) is inserted to the calcaneal attachment site of the calcaneofibular ligament and advanced plantarly in an anterolateral to posteromedial direction (Fig 4C). The exit point usually sits at the medial calcaneal tuberosity plantarly. A bone tunnel is created by a cannulated reamer of 6 mm diameter (Fig 4D). The arthroscopy is then turned to view the talar remnant of the anterior talofibular ligament. Following the fibers of the remnant medially, an area of the talar neck adjacent to the talar body is revealed. A guidewire is inserted to this area from

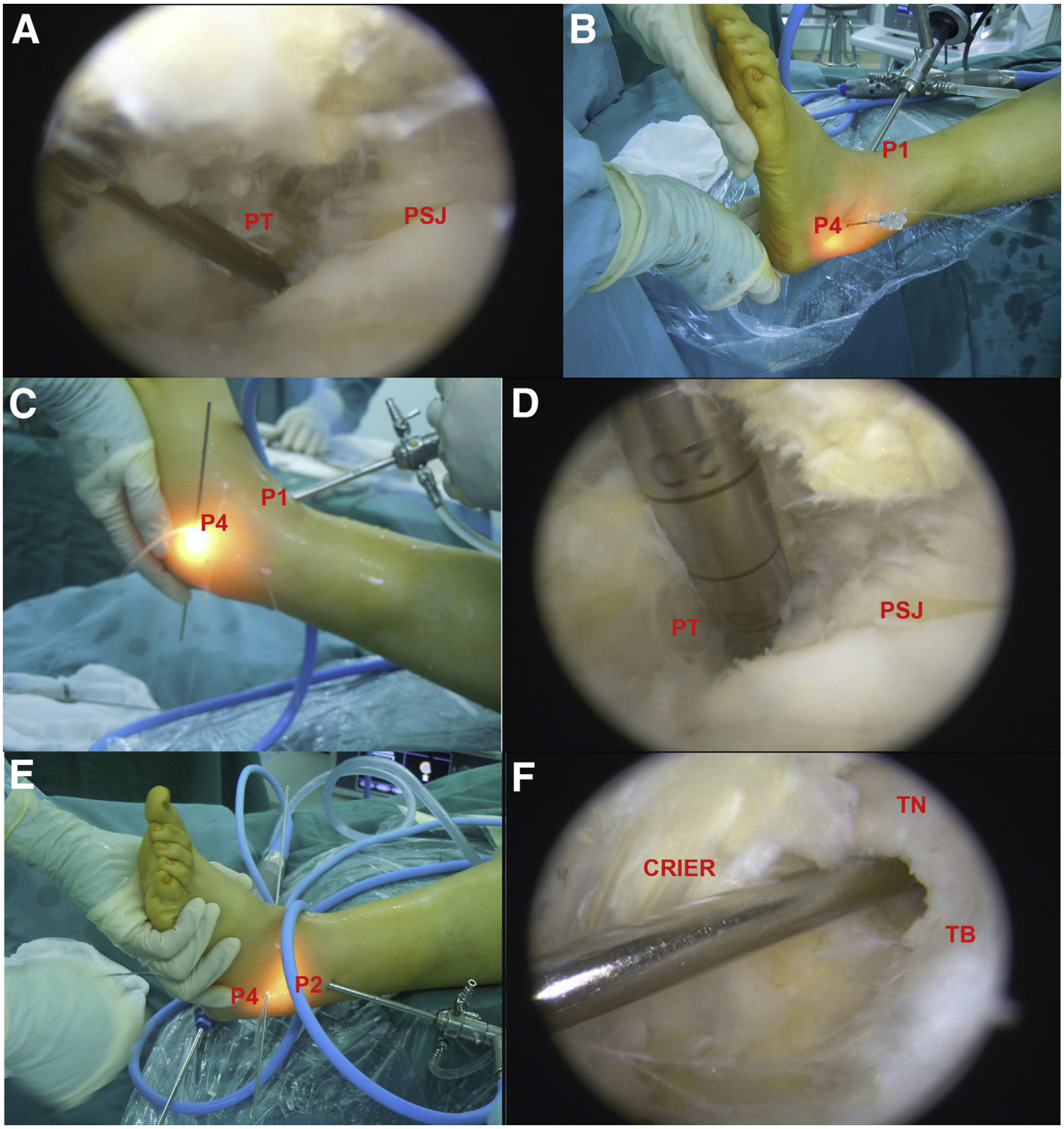

Fig 4. (A) A spinal needle is inserted at the calcaneal attachment site of the calcaneofibular ligament. (B) Portal 4 is created by the spinal needle while viewing at portal 1. (C) A guidewire is inserted from portal 4 and advanced plantarly in an anterosuperior to posteroinferior direction. (D) Following the guidewire, a calcaneal tunnel is made by a reamer. (E) A guidewire is inserted from portal 4 and advanced medially while viewing at portal 2. (F) Following the guidewire, a bone tunnel is made at an area of the talar neck adjacent to the talar body. (CRIER, calcaneal roots of the inferior extensor retinaculum; P1, portal 1; P2, portal 2; P4, portal 4; PSJ, posterior subtalar joint; PT, peroneus tendons; TB, talar body; TN, talar neck.)

portal 4 and advanced medially. The exit point usually sits anterior to the medial malleolus (Fig 4E). A bone tunnel of 1.5 cm depth is created by a cannulated reamer of 6 mm diameter (Fig 4F).

Step 5: Graft Harvest and Placement in the Bone Tunnels

An autologous semitendinosus tendon is harvested, and each end of the graft is whip-stitched. One end of the graft is pulled into the talar tunnel by use of a Beath pin from portal 4 (Fig 5A). The opposite end of the graft is pulled out of portal 3 to save room for interference screw insertion (Fig 5B); an interference screw of 6 mm diameter (Smith & Nephew) is used to fixate the graft in the talar tunnel (Fig 5C). A suture loop made by 2 No. 2 Ethibond sutures is introduced from portal 3 and delivered through the fibular tunnel by use of a Beath pin (Fig 5D). Outside portal 3, the suture loop wraps the graft to form a graft loop (Fig 5E) and leads the graft loop into the fibular tunnel posteriorly (Fig 5F). All 4 ends of the suture loop emerge from the posterior fibular incision made previously (Video 1). Lastly, the

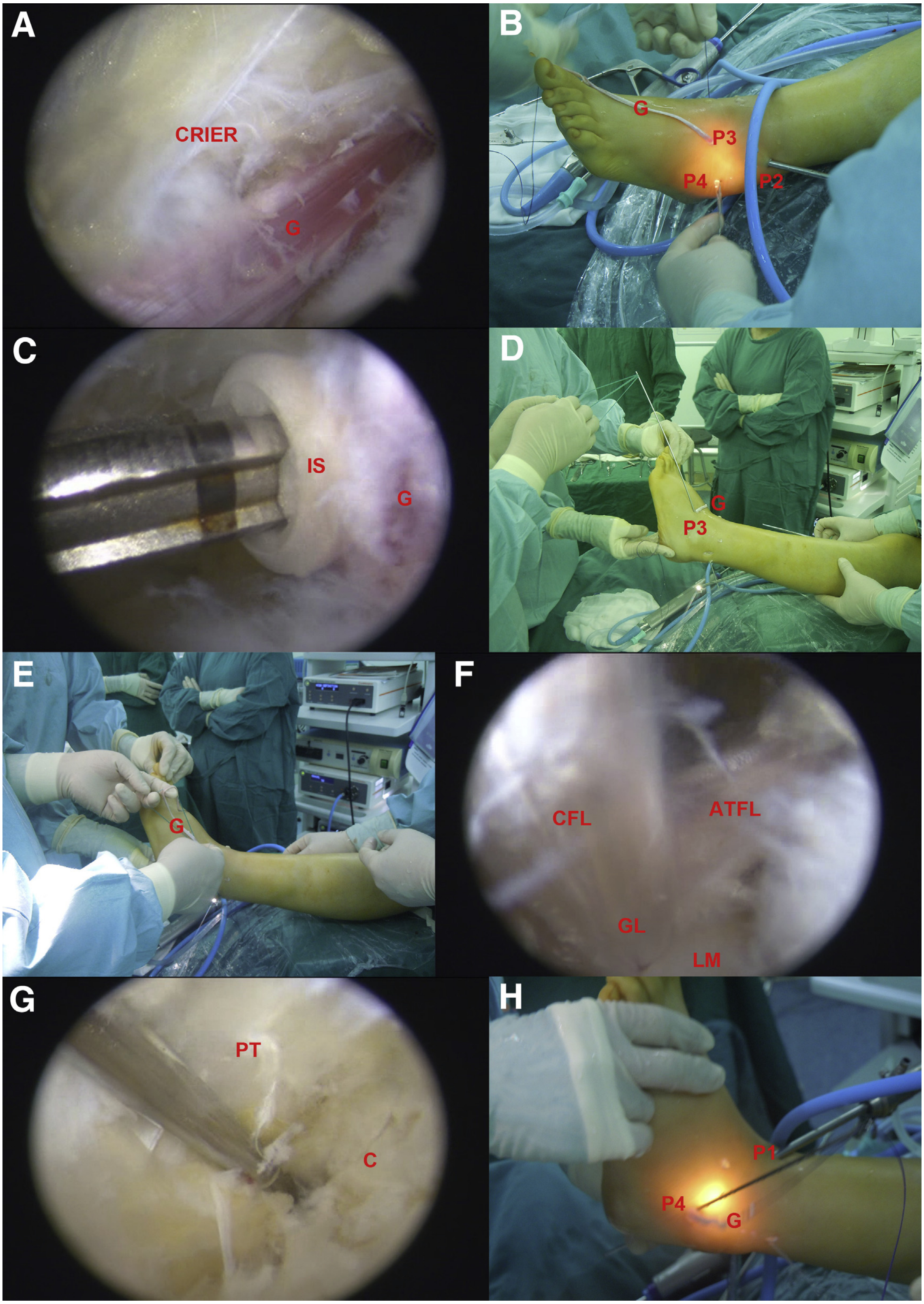

Fig 5. (A) One end of the graft is pulled into the talar tunnel from portal 4 while viewing at portal 2. (B) The opposite end of the graft is pulled out of portal 3, and a K-wire is inserted into the talar tunnel. (C) An interference screw is inserted for talar side fixation of the anterior talofibular ligament under the guidance of the K-wire. (D) Outside portal 3, a Beath pin loaded with a suture loop made by 2 No. 2 Ethibond sutures is inserted into the fibular tunnel. (E) Graft loop, with one limb as the anterior talofibular ligament and the other limb as the calcaneofibular ligament, is formed by the suture loop. (F) The graft loop is pulled into the fibular tunnel by the suture loop. (G) A Beath pin is inserted into the calcaneal tunnel while viewing at portal 1.

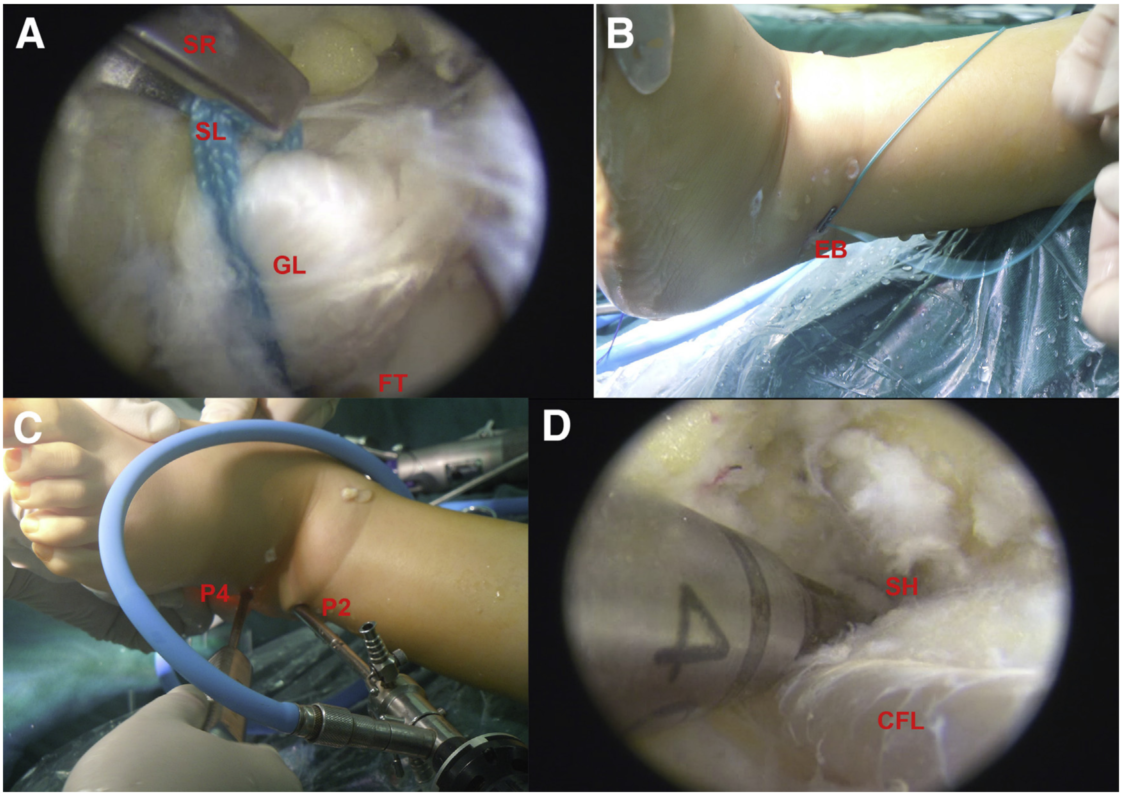

Fig 6. (A) The suture retriever grasps the suture loop together with the graft loop out of the fibular tunnel. The suture loop acts as a pulley. The graft glides on the suture loop and becomes tightened as the opposite end of the graft outside the calcaneal tunnel is manually tensioned. (B) Suspension fixation of the graft loop in the fibular bone is achieved by Endobutton when the ankle is placed at neutral position in the sagittal plane and 10° of eversion. (C) The calcaneal side fixation of the calcaneofibular ligament is achieved by an interference screw inserted from portal 4 while viewing at portal 2. (D) Care is taken to prevent screw head protrusion leading to peroneus tendon irritation. (CFL, calcaneofibular ligament; EB, Endobutton; FT, fibular tunnel; GL, graft loop; P2, portal 2; P4, portal 4; SH, screw head; SL, suture loop; SR, suture retriever.)

opposite end of the graft is pulled out of portal 4 and the arthroscopy is turned to view the opening of the calcaneal tunnel. By the assistance of the Beath pin (Fig 5G), the opposite end of the graft is pulled into the calcaneal tunnel and emerges from the medial calcaneal tuberosity (Fig 5H).

Step 6: Graft Tensioning and Fixation

With the graft well placed in the 3 tunnels, it is time to tension the graft properly. The ankle should be placed at neutral position in the sagittal plane and 10° of eversion (Video 1). A suture retriever is introduced from portal 4 to grasp the folded graft out of the fibular tunnel until the suture loop is viewed arthroscopically. The suture loop is grasped by the suture retriever and acts as a pulley (Fig 6A). Now, the opposite end of the graft outside the calcaneal tunnel is manually tensioned and held by an assistant (Video 1). Under arthroscopic surveillance, the graft glides on the suture loop and becomes taut (Video 1). The suture loop together with the graft loop is again pulled into the fibular tunnel to the desired depth. The 4 ends of the suture loop are put through the 2 central holes of the Endobutton (Smith & Nephew), and ties are made for suspension fixation of the graft in the fibular bone (Fig 6B). Finally, the arthroscopy is turned to view the opening site of the calcaneal tunnel. An interference screw of 6 mm diameter is inserted to secure the graft in the calcaneal tunnel (Fig 6C), with careful attention to prevent screw head protrusion leading to peroneus tendon irritation (Fig 6D, Video 1).

Step 7: Postoperative Rehabilitation

Magnetic resonance imaging examination is routinely performed postoperatively. The anterior talofibular and

(H) The opposite end of the graft is transferred to portal 4 and inserted into the calcaneal tunnel by the Beath pin. (ATFL, anterior talofibular ligament; C, calcaneum; CFL, calcaneofibular ligament; CRIER, calcaneal roots of the inferior extensor retinaculum; G, graft; GL, graft loop; IS, interference screw; LM, lateral malleolus; P1, portal 1; P3, portal 3; P4, portal 4; PT, peroneus tendons.)

Fig 7. Postoperative magnetic resonance imaging shows the anatomically reconstructed anterior talofibular ligament and calcaneofibular ligament. The graft loop is well placed in the fibular tunnel. (ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; GL, graft loop.)

calcaneofibular ligaments are well reconstructed in the anatomical position (Fig 7). The ankle was immobilized for 4 weeks, and passive exercise begins thereafter; partial weight-bearing is resumed at 6 weeks and full weight-bearing at 2 months.

Discussion

Anatomical reconstruction of the lateral ankle ligament complex is a well-recognized procedure to restore stability.[1-3] We modified the talar insertion of the anterior talofibular ligament a little medially to the talar neck close to the talar body because of the following concerns. First, if the bone tunnel is made in the talar body, the cartilage and posterior tibial neurovascular bundle may have higher risks to be damaged. Fluoroscopy is usually required to confirm the guidewire location. The injury to the tibialtalar and subtalar cartilage can be prevented by lateral fluoroscopy, but the lateral talofibular articular cartilage cannot be completely protected even though the anteroposterior fluoroscopy is used because the fluoroscopy image is a two-dimensional image and the posterior talus is narrower than the anterior part. Even if the guidewire is proved to be correctly placed by fluoroscopy, there is no guarantee that the larger-sized reamer would not violate the lateral talofibular articular cartilage. To avoid the damage to the lateral talofibular articular cartilage, it is natural to move the tunnel medially, which will put the posterior tibial neurovascular bundle at highest risk to be injured. A blind-ended tunnel has been proposed.[12,14,15] Although the technique of blind-ended tunnel decreases the likelihood of cartilage damage to some extent but not to zero, it creates another problem that the graft cannot always be properly tensioned and fixated in the tunnel. We put the talar tunnel at the talar neck, which can completely avoid cartilage damage and make graft fixation very easy. Second, our talar tunnel is very near to the original attachment site of the anterior talofibular ligament. In most cases, the fibers of the anterior talofibular ligament extend to the talar neck under our arthroscopic examination. Third, the technique of talar neck tunnel has been used by us and other doctors clinically in the open procedure. Good results have been reported in the literature.[16] As a summary, the talar neck tunnel is technically safe and anatomical.

One of the difficulties in performing arthroscopic ankle ligament reconstruction is the limited working space.[13] Although extensive extra-articular dissection may be helpful to enlarge the working space, it is harmful for tissue healing. Sustained fluid exudates and incision dehiscence would be highly anticipated. As a result, limited dissection is performed by us to form a working space. The anterior boundary of our working space is the calcaneal roots of the inferior extensor retinaculum, the medial boundary is the talar neck adjacent to the talar body without violation of the contents in the sinus tarsi, the lateral boundary is the peroneus tendons and the subcutaneous tissues that is better to be kept intact, and the posterior boundary is the anterior surface of the lateral talar body. Usually, the working space can be successfully created by viewing at portal 1 and debriding at portal 2. Sometimes, portals 3 and 4 may be needed. We think 4 portals are the minimum portals required for arthroscopic reconstruction because a probe can be inserted from the adjacent portal to act as a retractor if the visualization field is obscured by the subcutaneous tissues. The 4 portals, designed by us, are placed as far distally as possible to the working space, thus preventing scuffing of the arthroscopy and instruments.

Table 1. Advantages and Disadvantages

Advantages	Disadvantages
Minimally invasiveness	Higher learning curve
Less scarring	Higher cost
Faster rehabilitation	Tunnel malposition
Lower morbidity	Graft loosening
Better proprioception	Incision dehiscence

Table 2. Surgical Procedures, and Pearls and Pitfalls

Surgical Procedures	Pearls	Pitfalls
Portals	It is essential to have the portals correctly placed: always use needles.	Portal malposition could lead to poor visualization, difficult maneuverability, and tunnel malposition.
Working space creation	Limited dissection to form a working space is recommended.	If the working space is too small, visualization and instrumentation could be very difficult. If the working space is too large, tissue damage will be increased and incision dehiscence would be resulted.
Tunnel creation	Preoperative computed tomography examination and measurement will be helpful for tunnel creation. The diameter and depth of the tunnels should be tailored by computed tomography calculation.	Wrong-sized or malpositioned tunnel could result in talar neck or fibular bone fracture.
Graft fixation	The graft thickness should be at least 3 mm in diameter and have good quality. The diameter of the interference screw at the talar side is 1 mm less than that of the bone tunnel if hard bone is encountered. The diameter of the interference screw at the calcaneal side should be equal to or 1 mm thicker than that of the bone tunnel if soft bone is encountered. If the graft is more than 3 mm thick, the folded part of the graft, which is intended to be inserted into the 6-mm fibular tunnel, can be trimmed a little smaller to facilitate insertion.	Poor quality of the graft could lead to graft breakage by the interference screw. Graft breakage would be resulted by the interference screw that has the same diameter as the hard bone tunnel. Graft fixation failure at the calcaneal side in the osteoporotic patients could lead to ankle instability recurrence. The graft can be damaged or the fibular tunnel could be broken if the graft loop is larger than the fibular tunnel.
Incision healing	Postoperative drainage is helpful. Sustained compression around the ankle is required until the incision is healed.	Incision dehiscence will be resulted due to the hematoma formation in the working space.

Another difficulty in performing arthroscopic ankle ligament reconstruction is to tension the graft properly. The sequence of fixation and the position of the ankle during fixation are very important. Some authors choose to tension and fixate the graft according to the estimated lengths of the anterior talofibular and calcaneofibular ligaments.[12] In our experience, it is so rough an estimation that the graft is not always tensioned very well. We choose a suture loop to act as a pulley in the fibular side. When the graft end out of the calcaneal tunnel is manually tensioned, the graft will glide on the suture loop and become tightened, which can be checked arthroscopically. Final fixation of the graft in the calcaneal tunnel can be easily performed with the ankle placed at a little eversion. Our method does not need any calculation of the graft length and is very simple.

Working space creation would compromise the blood supply of the talus. The blood of the talus is derived primarily from an extraosseous arterial network that enters the bone through 5 well-defined, yet limited, anatomic areas. These include the tarsal canal, sinus tarsi, superior neck, medial body, and posterior tubercle.[17] These areas have not been touched during the process of creating the working space. The major arterial supply to the body of talus is the artery of the tarsal canal and its anastomotic branches. Branches of the anterior tibial artery supply the superomedial half of the talar head and neck. The inferolateral half of the talar head and neck are supplied by the tarsal sinus artery and/or the lateral tarsal artery.[18] All of these arteries are well preserved because safe distances between the working space and these arteries are kept. Therefore, avascular necrosis of the talus is impossible in theory and there is also no occurrence found in our cases in the clinical settings.

Because the ligament itself has proprioceptive sensors, it is better to preserve the remnant of the lateral ankle ligament. The benefits of remnant-preserving ligament reconstruction have been reported in the literature.[19-21] Our technique provides good visualization of the torn lateral ligaments and the bone tunnels are made adjacent to the original ligament attachment sites. But the long-term result of our technique needs to be further evaluated. The advantages and disadvantages/limitations of our technique are shown in Table 1 and pearls/pitfalls in Table 2.

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