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Percutaneous Ankle Reconstruction of Lateral Ligaments (Perc-Anti RoLL)

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Chronic ankle instability following ankle sprains causes pain and functional problems such as recurrent giving way. If non-operative treatments fail, then operative ankle stabilization may be required to improve pain and function.[13,15] Operative options include both anatomic repair and reconstruction techniques.[12] Anatomic repair techniques utilize pre-existing ligament remnants that are either reattached or tightened to improve stability of the ankle.[3] If pre-existing ligament structures have been damaged beyond repair or are insufficient to allow repair, then it is appropriate to choose an anatomic reconstructive technique.[12,18] These procedures have traditionally been performed using open techniques and have been successful in restoring function and decreasing pain.[12,27]

In 2005, an open anatomic reconstruction technique using a gracilis Y-graft and Inside-out technique was reported with good results.[27] In the current paper we describe a Percutaneous Ankle Reconstruction of the Lateral Ligaments (Perc-Anti RoLL), which is a new minimally invasive surgical technique for anatomic reconstruction of the lateral ligaments of the ankle that utilizes the anatomic Y-graft and Inside-out technique.[27] The Perc-Anti RoLL technique can be performed percutaneously using fluoroscopic guidance.

Operative Technique

General Preoperative Technique Considerations

We recommend that standard ankle arthroscopy be performed prior to the percutaneous stabilization procedure if there is any associated ankle pathology. However, the Perc-Anti RoLL technique does not require arthroscopy to reconstruct the lateral ligaments of the ankle and may be performed in isolation if there is no associated ankle pathology present.

Landmark Drawing and Patient Positioning

The patient is positioned lateral with a support under the leg to allow access to the medial side of the ankle on an operating table that will allow perfect anterior posterior and lateral fluoroscopic examinations throughout the procedure to enable accurate anatomic landmark identification. Anatomic landmarks should be drawn on the patient's skin before starting surgery. The Perc-Anti RoLL anatomic landmarks include the distal edge of the tibial plafond, the lateral and medial malleoli, the extensor digitorum tendon, and the peroneus tendon. The bony landmarks for the origin and insertion sites of the anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL) should be drawn under fluoroscopic view. The landmark for the fibular origin of the ATFL and CFL when using an anatomic Y-graft should be between the ATFL and CFL origin sites on the fibula.

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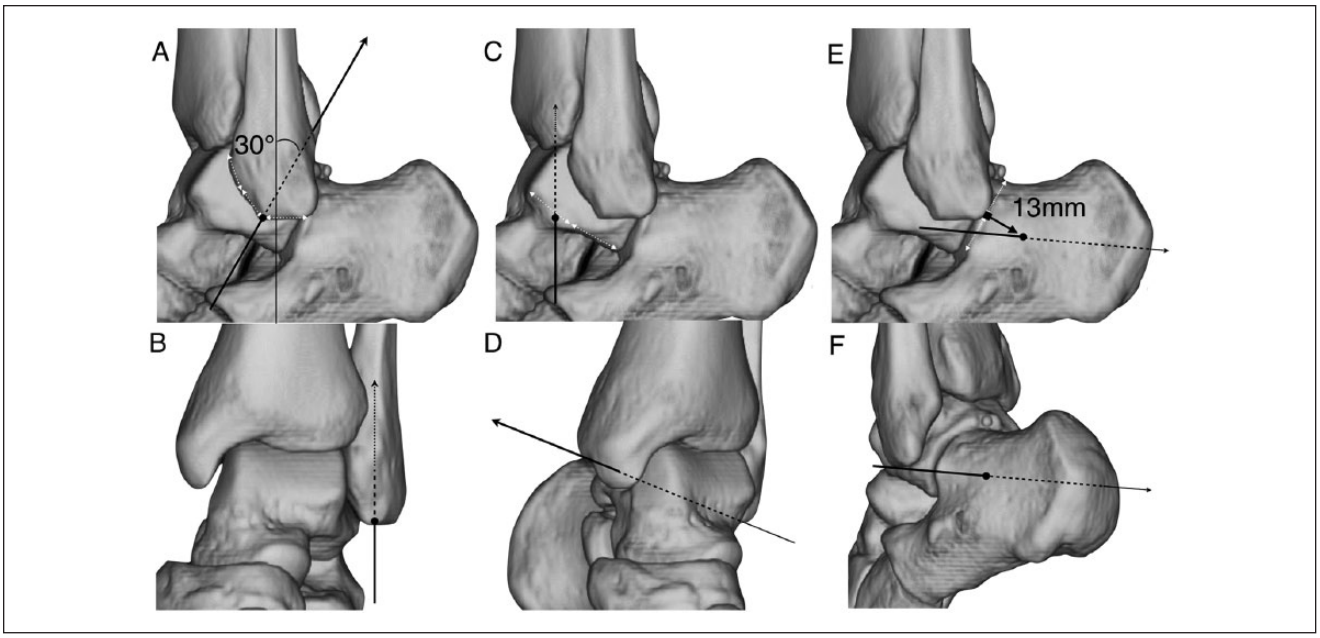

Figure 1. Landmark (black dot) and direction (arrow lines and broken lines) of the each guide pin (A) For fibular bone tunnel, lateral view. White arrows show the alternative landmark. (B) For fibular bone tunnel, anterior posterior view. (C) For talar bone tunnel, lateral view. White arrows show the alternative landmark. (D) For talar bone tunnel, anteromedial oblique view. (E) For calcaneal bone tunnel, lateral view. Black arrow with black box shows the alternative landmark. (F) For calcaneal bone tunnel, posterolateral oblique view.

This ATFL and CFL origin site can be localized at the fibular obscure tubercle (FOT) on the anterior-inferior border of the fibula (Figure 1A).[5] In case the FOT is not detectable with fluoroscopic view or palpation, the inferior one-third point between the inferior tip and anterior tubercle of the fibula on its anterior border would be the alternative (Figure 1A).[28] The landmark for the talar insertion of the ATFL should be the talar obscure tubercle (TOT) on the anterolateral border of the talar body (Figure 1C).[14] If the TOT is not detectable with fluoroscopy or palpation, the point just proximal to the midpoint between the superior corner and inferior corner of the talar body would be the alternative (Figure 1C).[6,28] The landmark for the calcaneal insertion of the CFL should be the tuberculum ligamenti calcaneofibularis (TLC) on the lateral wall of the calcaneus (Figure 1E).[14] If the TLC is not detectable with fluoroscopy or palpation, the point at 13 mm distal and on the vertical line down from the center of the subtalar joint would be the alternative (Figure 1E).[4,5,24]

Constructing the Anatomic Y-Graft for Anti-RoLL

The surgeon and patient may choose an autograft (eg, gracilis tendon) harvested from the ipsilateral knee using a tendon harvester, or an allograft of sufficient size (at least 135 mm length, 15-mm × 9 components, and approximately 3 to 5 mm diameter) and strength for the reconstruction of the ATFL and CFL. The graft is prepared in the anatomic "Y" configuration with 3 (fibular, talar, and calcaneal) looped stems by doubling the graft to a length of 15 mm at all 3 ends of the "Y" configuration to facilitate attachment of a "tensioning thread" for graft delivery and tensioning (Figure 2). The looped stems will be anchored in a bone tunnel and single 15- and 30-mm parts between the stems to the ATFL and CFL respectively.

Construction of the Bone Tunnels and Insertion of Passing Threads

Construction of the 3 bone tunnels (fibula, talus, and calcaneus) and insertion of a passing thread in each bone tunnel is required to accept the Y-graft insertion and interference screw fixation. Three 1-cm incisions are made using a "nick and spread" technique (cut the skin only and then bluntly spread the subcutaneous tissue). The first incision is used to construct the common ATFL and CFL origin site and designated the Y graft delivery site (Figure 5B). A guide pin is introduced at the common ATFL and CFL origin site using the anatomic and fluoroscopic landmarks on the fibula described above and passed through the far cortex of the bone and the skin (Figure 3A) using fluoroscopic guidance. Guide pin direction is described in next section. Next the second and third incisions are made sequentially to allow construction of the talar and calcaneal insertion bone tunnels.

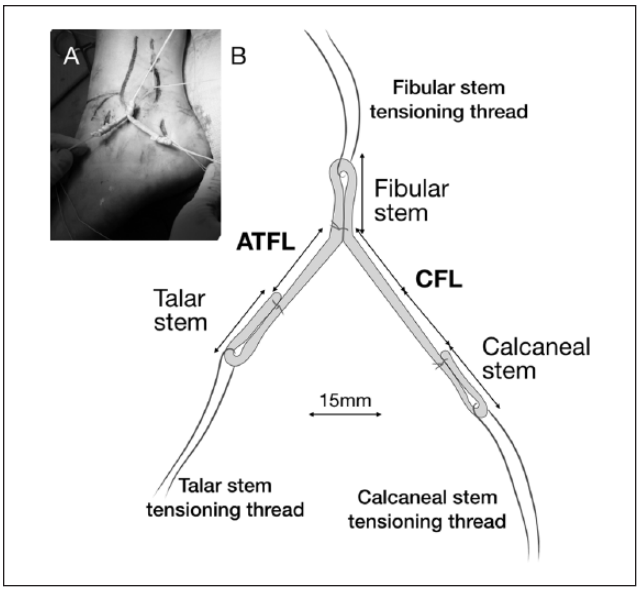

Figure 2. Construction of the anatomic Y-graft. (A) Intraoperative photograph shows the configuration of the Y-graft and skin incisions. (B) Schematic diagram of the Y-graft showing its 15-mm × 9 components and construction of each looped stem, the ligaments part (anterior talofibular ligament [ATFL] and calcaneofibular ligament [CFL]) and each tensioning thread (gray line).

A cannulated drill is then used to overdrill the guide pins, constructing a bone tunnel diameter of 6 mm and a depth of 20 mm in the fibula and talus and 30 mm in the calcaneus (Figure 3B). A passing thread is attached to the hole at the end of the guide pin (Figure 3C) and introduced through the bone tunnel by antegrade pulling of the guide pin (Figure 3D). Leave one end (closed loop) of the passing thread exiting from the pin entry site incision (Figure 3E) and the other end (the second limb of the thread) exiting from the skin at the guide pin exit site. These 2 ends are clamped (Figure 3E, 4C).

It is essential that local neurovascular structures and tendons be protected when using these techniques to avoid complications using "nick and spread" technique and a drill guide and targeting guide system to allow more precision when passing the guide pin and drill through the bone to protect the surrounding soft tissues.

Guide Pin Direction

The fibular guide pin is inserted from the FOT or the alternative landmark mentioned above on the lateral ankle fluoroscopic view (Figure 1A). The guide pin is directed to the posterior cortex of the fibula approximately 30 degrees to the long axis of the fibula on the lateral view (Figure 1A, 3A). Fluoroscopic anterior-posterior views are taken to ensure that the guide pin is passed through the central portion of the fibula to prevent fracture when it is overdrilled (Figures 1B and 3B).

The talar guide pin is inserted from the TOT or the alternative landmark mentioned above on the anterolateral border of the talar body using the lateral ankle fluoroscopic view (Figure 1C). The guide pin should be directed slightly proximal and posterior toward a point just proximal of the medial malleolus (Figures 1D and 4A). This pin direction allows the guide pin to run through the talar body to place the interference screw in dense cancellous bone and prevents talar neck fracture, misdirection through the talus or sinus tarsi, and damage to the posterior tibial neurovascular bundle.

The calcaneal guide pin is inserted from the TLC or the alternative landmark on the lateral wall of the calcaneus (Figure 1E). The guide pin should be directed toward the inferior, medial, and posterior area of the calcaneus without damaging the medial calcaneal branch of the tibial nerve (Figure 1F, 4B).

Delivery and Fixation of Each Looped Stem of the Y-Graft to the Corresponding Bone Tunnels With Inside-out Technique

All 3 looped stems of the Y-graft are delivered through the Y-graft delivery site using an inside-out technique by pulling each passing thread (Figure 5B). First, a tensioning thread is passed through the fibular looped stem of the Y-graft into the fibula passing suture loop that exits the fibular site skin incision (Figure 5A). Then the other end of the passing thread that comes out from the posterior aspect of the fibula is pulled through. This series of inside-out technique allows the fibular stem of the Y graft to be delivered into the fibular bone tunnel with the tensioning thread exiting the posterior aspect of the fibula (Figure 5B).

Next, the talar and calcaneal stems are introduced into each bone tunnel using the same inside-out technique. To deliver the talar stem, a mosquito forceps is passed through the Y graft delivery incision site and along the lateral wall of the talus exiting at the talus bone tunnel incision (Figure 5B) to retrieve the trailing end of the talar stem passing thread, which is then passed out the Y-graft delivery incision site. This trailing end of the talar passing thread is attached to the talar stem thread to allow delivery of the talar stem through the Y-graft delivery site incision and into the talar bone tunnel. Finally, the calcaneal stem of the Y-graft is delivered to the calcaneal tunnel in a similar manner through the calcaneal incision site (Figure 5B) by passing a mosquito forceps through the Y-graft delivery incision site and passed along the lateral wall of the calcaneus being certain to pass under the peroneal tendons and sural nerve to exit at the calcaneal incision to retrieve the trailing end of the calcaneal stem passing suture. This will allow the CFL portion of the Y-graft

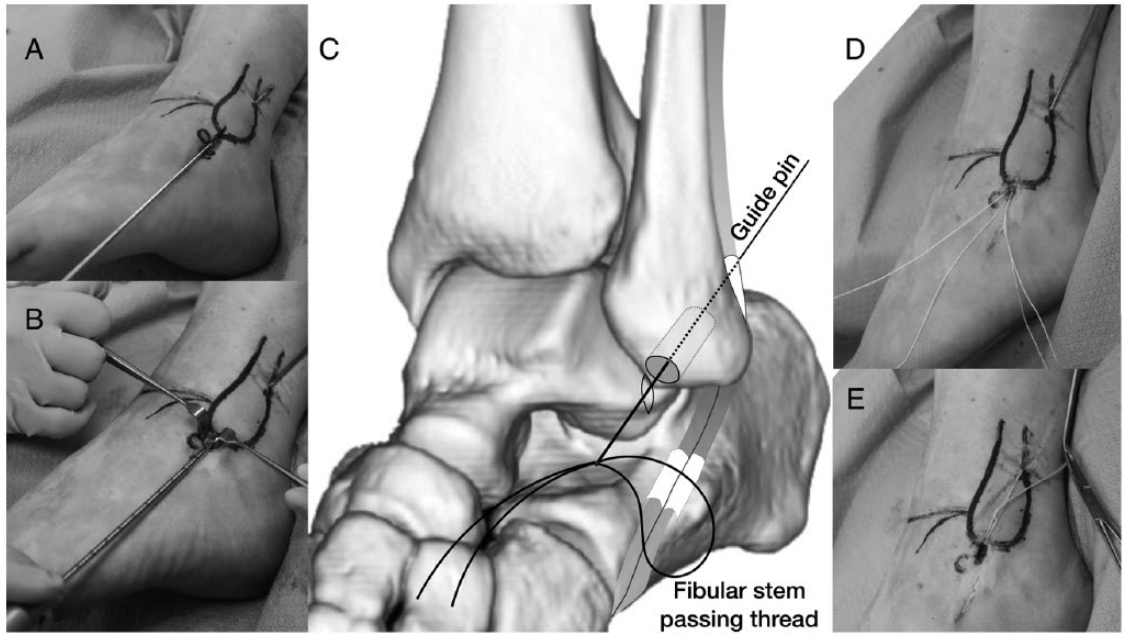

Figure 3. Construction of the fibular bone tunnel. (A) Inserting a guide pin under fluoroscopy. (B) Overdrilling with cannulated drill. (C) Schematic diagram of changing the guide pin to the fibular passing thread. (D) Introducing the passing thread by pulling the guide pin. (E) Holding the passing thread with a clamp.

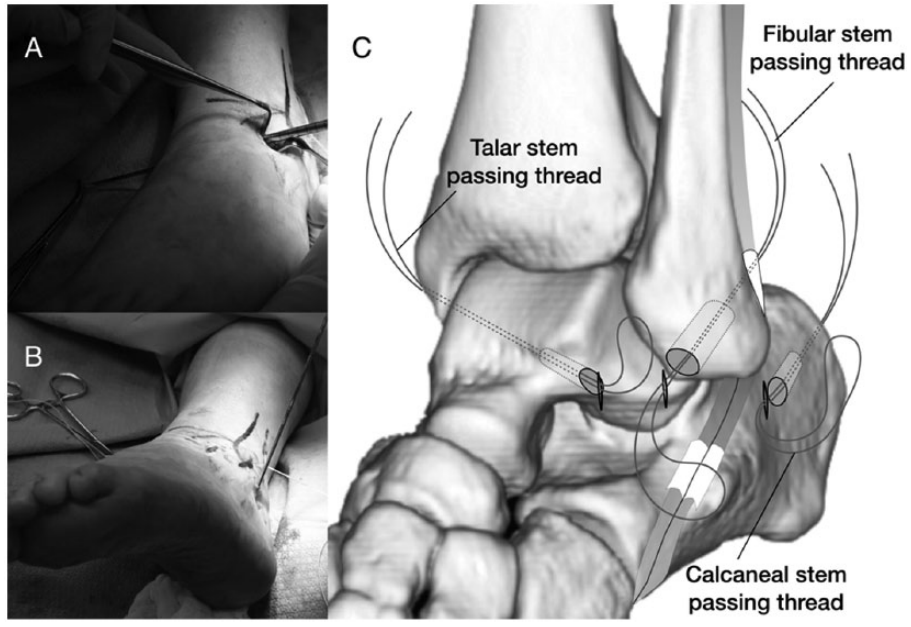

Figure 4. Construction of the talar and calcaneal bone tunnel. (A) Drilling the talar bone tunnel. (B) Inserting the guide pin for the calcaneal bone tunnel. (C) Schematic diagram of 3 bone tunnels and passing thread out from each skin incision.

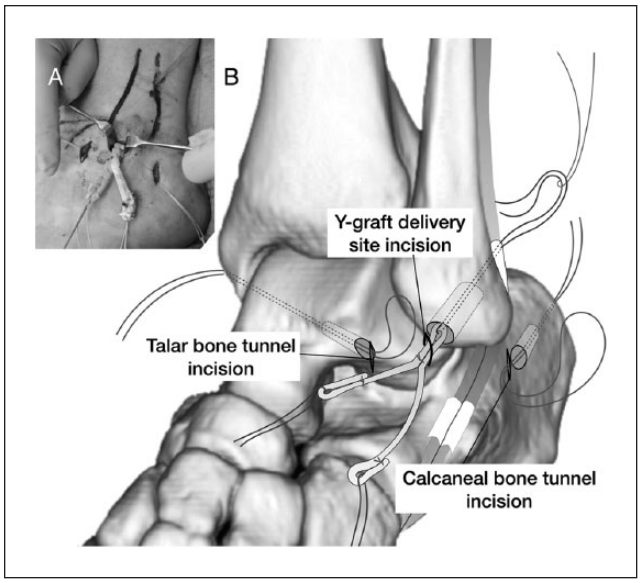

Figure 5. Inside-out passage of the anatomical Y-graft stem into the fibular bone tunnel. (A) Intraoperative photograph of inserting the Y-graft into fibular bone tunnel. (B) Schematic diagram of inserting the Y-graft into fibular bone tunnel.

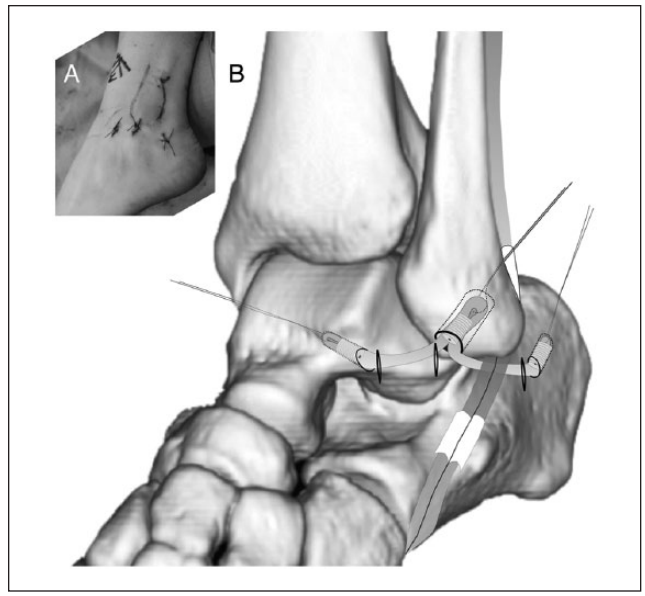

Figure 6. Final image of the surgery. (A) The placement of the skin incisions. (B) Schematic diagram of the placement and the fixation of the Y-graft with tensioning the tension threads.

to pass along the lateral wall of the talus and calcaneus on a path nearly anatomic to the native CFL.

Fixation of Anatomic Y-Graft to the Bone Tunnel

With the ankle in neutral dorsiflexion, the Y-graft is balanced and tensioned by pulling the tension threads. Once the graft placement and tension is appropriate, a blunt-tipped interference screw guide pin is inserted into the each bone tunnel, and each looped stem of the Y-graft in the bone tunnel is fixed using a 6 × 15 mm interference screw (Figure 6B). Tension should be maintained on the sutures during screw insertion to prevent graft extrusion. Once all 3 stems of the anatomic Y-graft are fixed, the tensioning threads are removed and the incision sites are closed using nylon sutures (Figure 6A). The lower extremity is dressed and immobilized with a below-knee cast.

Postoperative Care

The patient's operative limb is immobilized in a below-knee cast for a total of 6 weeks with weight bearing as tolerated. Wound inspection and suture removal occurs between 1 and 2 weeks postoperatively.

Discussion

Recently, there have been advances in the field of arthroscopic[*] and minimally invasive[9,17,23,30,33] ankle stabilization techniques that may allow faster recovery compared to open techniques.[21] The arthroscopic procedure allows one to assess and treat intra-articular pathology of the ankle concurrently with stabilization[11,19,25] but may be more technically demanding.[10] In contrast, the advantage of the percutaneous technique is a simple concept that does not require the skill of an experienced arthroscopist.[10] In addition, the use of fluoroscopic guidance allows more reliable and anatomic positioning of the graft to the ATFL and CFL insertion sites.

The current percutaneous technique has advantages compared to the previous reported percutaneous reconstruction techniques. Previous studies adopted 2 oblique triangular fibular bone tunnels[22] for anatomic percutaneous reconstruction or one anterior to posterior transverse fibular bone tunnel,[9,17,33] but it was thought to be nonanatomic.[17] Perc-Anti RoLL technique allows anatomic reconstruction of both the ATFL and CFL with only one fibular bone tunnel. We have performed this technique for 4 patients so far and have had good early clinical results without any major complications.

In conclusion, Perc-Anti RoLL technique is a feasible, minimally invasive anatomic reconstruction technique for chronic instability of the ankle. Further prospective studies on efficacy and safety with a large number of patients followed over the long term is necessary to clarify the effectiveness as well as to verify the advantages it offers over previously reported operative techniques.

[*]References 1, 2, 7, 8, 10, 11, 16, 19, 20, 22, 25, 26, 29, 31, 32.

Declaration of Conflicting Interests

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