# Chronic Lateral Ankle Instability Treated With Tendon Allografting

## A Preliminary Comparison of Arthroscopic and Open Anatomic Ligament Reconstruction

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**Background:** Roughly 30% of patients with chronic lateral ankle instability (CLAI) have long-lasting painful instability requiring surgical intervention. Ligament reconstruction with the traditional open method and using tendon allografts can provide sufficient mechanical stability for severe CLAI. Arthroscopic ligament reconstruction with tendon allograft has recently been introduced to treat CLAI.

**Purpose:** In this study, we describe an arthroscopic ligament reconstruction procedure involving the use of the tendon allograft for patients with CLAI, and we compare the efficacy of this procedure with open ligament reconstruction with tendon allograft.

**Study Design:** Cohort study; Level of evidence, 3.

**Methods:** We enrolled 10 patients (4 men and 6 women) with CLAI (mean age, 37.3 years; range, 16-57 years) who underwent arthroscopic ligament reconstruction with tendon allografting between November 2017 and June 2019. The control group consisted of 10 patients who received open tendon allograft reconstruction. Preoperative and 2-year postoperative functional outcomes were evaluated using the American Orthopaedic Foot & Ankle Society ankle-hindfoot scale (AOFAS), Karlsson Ankle Functional Score (KAFS), pain visual analog scale (VAS), 12-Item Short Form Health Survey (SF-12), and Tegner activity score (TAS).

**Results:** The mean operative time was 118 and 110 minutes in the arthroscopic and open groups, respectively. At 2-year follow-up, scores on the AOFAS improved significantly compared with preoperatively, from 71.3 to 96.4 ($P = .006$) in the arthroscopic group, and from 68.6 to 96.7 ($P = .005$) in the open group. The postoperative AOFAS, VAS, KAFS, and SF-12 scores did not differ significantly between the 2 groups; however, the TAS score was significantly higher in the arthroscopic reconstruction group compared with in the open group (7 vs 6.1, respectively; $P = .01$).

**Conclusion:** Arthroscopic ligament reconstruction with tendon allografting resulted in sufficient ankle stability and no donor-site morbidity. This procedure can yield similar functional outcomes to open reconstruction technique and may be an option for the management of CLAI.

**Keywords:** arthroscopic ligament reconstruction; chronic lateral ankle instability; tendon allograft; ultrasound

Lateral ankle instability is an often-seen result of sports-related injury that occurs not only in elite athletes but also in individuals participating in recreational sports activities. The incidence rate of ankle sprains is 2 to 7 per 1000 person-years in the general population, and lateral ankle ligament injury accounts for up to 80% of the ankle sprains.[16,29,37] Acute injury can be treated using conservative treatment modalities such as ankle bracing, ice packing, and subsequent physical therapy. Approximately 30% of patients who do not respond to nonoperative management can develop chronic lateral ankle instability (CLAI).[14] Surgical intervention is an optimal option in case of the failure of nonoperative treatment. Currently, an open Broström repair with or without Gould modification is the gold standard surgical treatment for CLAI.[14] For elite athletes with the excessive attenuation of the lateral ligament, a failed Broström procedure, and hypermobility disorder, ligament reconstruction can be an appropriate choice for improving mechanical strength.[26] Open ligament reconstruction surgery for severe CLAI provides the advantages of requiring less technical expertise and maintaining easily adjustable suture tension

The Orthopaedic Journal of Sports Medicine,10(10), 23259671221126693
DOI: 10.1177/23259671221126693

during surgery. Tendon allografting has been demonstrated to provide optimal functional outcome and mechanical strength.[3,38] However, wound complications are still a major concern in this procedure.[28]

Recent studies have reported that arthroscopic surgery for lateral ankle ligament reconstruction resulted in favorable outcomes including fewer wound complications, shorter rehabilitation time, and faster recovery to previous daily activities.[13,30] Tendon allograft has been proposed as an alternative option of tissue source without donor-site morbidity.[11,34,38]

In this study, we describe an arthroscopic ligament reconstruction procedure involving the use of the tendon allograft for patients with CLAI. We evaluated the surgical results of this procedure in comparison with the open ligament reconstruction using tendon allograft.

## METHODS

The protocol for this study was approved by an institutional review board and all participants provided informed consent. Between November 2017 and June 2019, we enrolled 10 patients diagnosed as having severe CLAI through physical examination, ankle stress radiographs, ultrasound, and magnetic resonance imaging (MRI). Arthroscopic ligament reconstruction by using a tendon allograft was performed for all the patients after detailed assessment. For the control group, we chose patients from a previous open surgical group who underwent tendon allograft reconstruction for severe CLAI between July 2006 and September 2017 (n = 35 patients). All patients who were included in the study had at least 2 years of follow-up. The exclusion criteria for this study consisted of patients with midfoot or hindfoot varus deformity, tarsal coalition, poor skin condition, local cellulitis, or impeded lower-limb circulation.

To perform a more efficient comparison between the groups with less variability, an independent statistics professor (I.S.T.) matched the case and control groups by sex and age at a ratio of 1:1 (Table 1). Both groups consisted of 4 men and 6 women, and the mean age was 37.3 years (range, 16-57 years) for the arthroscopic and 35.4 years (range, 18-51 years) for the open groups. In addition, we attempted to prevent potential bias caused by anthropometric characteristics. In the arthroscopic and open groups, the respective mean heights were 164.6 and 164.7 cm, the mean weights were 65.8 and 65.6 kg, and mean body mass index values were 23.91 and 23.88.

All patients reported having a repetitive ankle sprain history when exercising or walking. Physical examination revealed an obvious laxity of the lateral ankle ligament compared with the contralateral ankle during the ankle anterior drawer test and talar tilt test. Stress view radiographs were performed to evaluate the severity of ankle laxity (Figure 1). MRI was conducted to evaluate the severity of lateral ligament injury including the extent of ligament injury for the anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL), and posterior talofibular ligament; the texture of the residual ligament; and the existence of the avulsed bony fragment concomitant with the osteochondral lesions of the talus (Figure 2). Ultrasound examination was performed to examine the severity of ligament injury.[7]

Under dynamic ultrasound evaluation, we observed the gap approximation between the ruptured ATFL and its fibular origin site (Figure 3). The gap approximation between the ruptured ends of the fibula and ligament was examined carefully in the neutral and plantarflexion-inversion positions of the ankle joint, respectively. In the plantarflexion-inversion position of the ankle, a gap smaller than 0.5 cm was considered to be easily reparable and thus suitable for arthroscopic repair. A ruptured ligament gap of between 0.5 and 1.5 cm was considered a reparable lesion but one that may require ligament reconstruction. In this scenario, operative intervention was decided in correspondence with the texture and tension of the residual stump. Overtightening of a ruptured ligament end to ensure contact of the stump onto the insertional site of the fibular bone can increase the risk of poor tissue healing or rerupture. A gap larger than 1.5 cm or no visualization of the residual ligament was considered irreparable, thus requiring ligament reconstruction. In addition, the following patients were suitable for ligament reconstruction: elite or professional athletes, those with os subfibulare or an avulsed bony fragment larger than 1 cm, those with a failed previous Broström procedure, and those with hypermobility disorder.[29,32]

### Surgical Technique

#### *Arthroscopic Reconstruction With Tendon Allograft*

For the arthroscopic technique, the patient was placed in the supine position with an air tourniquet applied over the thigh. We created the following arthroscopic portals: the anteromedial portal (AM portal), accessory anterolateral portal (AAL portal), and subtalar portal (ST portal). A 4.0-mm, 70° scope was inserted through the AM portal as a viewing portal. The

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Final revision submitted May 26, 2022; accepted July 12, 2022.
The authors declared that there are no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
This study was approved by the institutional review board of the Taipei Tzu Chi Hospital (No. 10-XD-086)

TABLE 1
Demographic Characteristics Within the Arthroscopic and Open Reconstruction Groups[a]

| Patient | Age, y | Sex | Causative Mechanism | BMI | Injured Limb | Reason for Ligament Reconstruction |
|---|---|---|---|---|---|---|
| Arthroscopic Reconstruction (n = 10) | | | | | | |
| 1 | 27 | F | Basketball | 23.8 | R | Elite athlete |
| 2 | 37 | M | Basketball | 24.9 | R | Competitive athlete, high demand, small fibular avulsed fragment |
| 3 | 52 | F | Basketball | 23.1 | R | >1-cm fibular avulsed fragment |
| 4 | 57 | F | Repeated sprain | 23.7 | R | Revision surgery (Broström repair 20 y ago) |
| 5 | 16 | F | Basketball | 22.5 | L | Hypermobility joint, recreational athlete, high demand |
| 6 | 47 | F | Injury during Chinese traditional chiropractic treatment | 20.9 | R | Revision surgery (Broström repair 4 y ago) |
| 7 | 34 | M | Rugby | 31.6 | R | Competitive athlete, high demand, 5-mm os subfibulare |
| 8 | 25 | M | Basketball | 21.7 | R | >1-cm os subfibulare |
| 9 | 52 | M | Fall from stairs | 21.2 | R | >1-cm old fibular avulsed fragment |
| 10 | 26 | F | Gymnastic vault | 25.6 | R | Competitive athlete, high demand |
| Mean | 37.3 | | | 23.9 | | |
| Open Reconstruction (Control; n = 10) | | | | | | |
| 1 | 37 | F | Sprain | 22.6 | L | Competitive athlete, high demand |
| 2 | 30 | M | Basketball | 23.6 | L | Competitive athlete, high demand |
| 3 | 49 | F | Basketball | 22.5 | R | Recreational athlete, high demand |
| 4 | 51 | F | Sprain | 27.2 | L | Hypermobility joint, recreational athlete |
| 5 | 19 | F | Basketball | 20.0 | R | >1-cm old fibular avulsed fragment |
| 6 | 43 | F | Fall with a sprain injury | 21.8 | R | >1-cm old fibular avulsed fragment |
| 7 | 31 | M | Basketball | 33.9 | L | Competitive athlete, high demand |
| 8 | 18 | M | Basketball | 23.0 | R | >1-cm old fibular avulsed fragment |
| 9 | 44 | M | Fall from stairs | 21.2 | R | Recreational athlete, high demand |
| 10 | 32 | F | Sprain | 26.2 | L | Recreational athlete, high demand |
| Mean | 35.4 | | | 23.9 | | |

[a]BMI, body mass index; F, female, M, male; L, left; R, right.

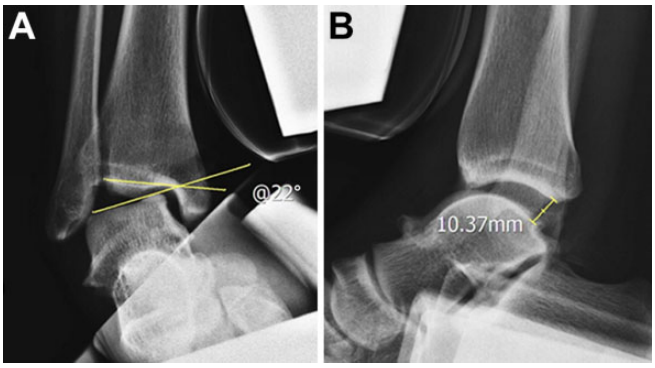


**Figure 1.** Stress radiographs for the assessment of the severity of ankle instability. (A) Anteroposterior view revealed a 22° varus tilt. (B) Anterior drawer of the ankle joint showed a 10.37-mm anterior displacement of the talus relative to the tibial plafond.

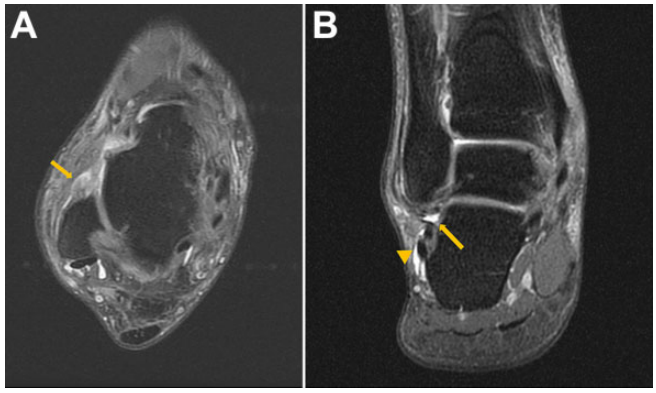


**Figure 2.** (A) T2-weighted magnetic resonance imaging scan showing an absent anterior talofibular ligament (arrow) in the axial view. (B) Fluid accumulation without calcaneofibular ligament visualization (arrow) in the coronal view. The peroneal longus and brevis tendon are intact (arrowhead).

AAL portal was set as a working portal, and meticulous debridement of the residual ruptured stump and fibrotic tissue over the lateral ankle ligament territory was performed. Any bony fragment or os subfibulare appearing over the lateral gutter or sinus tarsi area was removed. Subsequently, the viewing portal was changed to the ST portal, and the residual CFL stump was debrided using a 3.5-mm arthroscopic shaver (Stryker) through the AAL portal. After

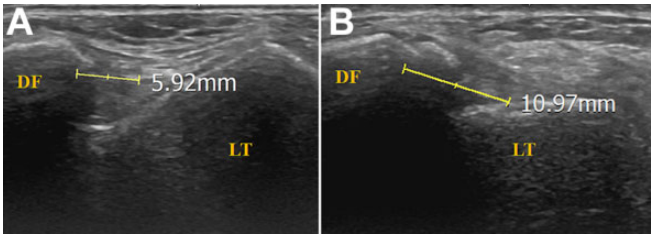


**Figure 3.** Dynamic ultrasound examination in patient 2 of the arthroscopic group. (A) In the ankle neutral position, the ultrasound revealed a 5.92-mm hypoechoic gap with a residual distal ATFL stump connected to the lateral talus (LT). (B) In the ankle plantarflexion-inversion position, a movable bony fragment was observed that was pulled distally by the residual inferior bundle of the ATFL stump. The gap between the fibular tip and distal ATFL stump including the avulsed bony fragment and hypoechoic ligament tear part was 10.97 mm, indicating that the repair of lesions is difficult owing to the presence of insufficient residual ligament tissue. ATFL, anterior talofibular ligament; DF, distal fibula.

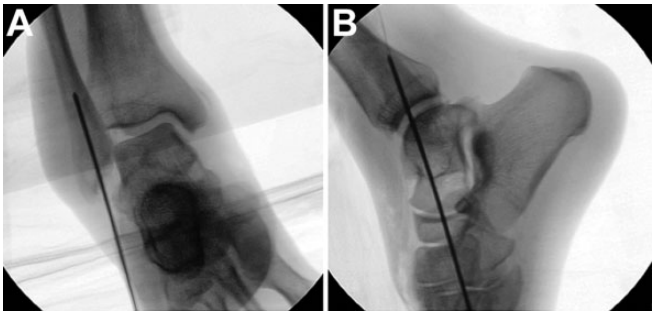


**Figure 4.** Adequate guide pin insertion under intraoperative fluoroscopic guidance. (A) The guide pin direction should be in line with the central axis of the distal fibula in the anteroposterior view. (B) The angle between the guide pin and the long axis of the fibular end in the lateral view was 20°.

performing adequate debridement and identifying the ligament insertional site, we created the bone tunnel.

*Bone Tunnel Preparation.* To create the fibular bone tunnel, we used the AM and AAL portals as the viewing and working portals, respectively. Initially, a 2.0-mm Kirschner wire was introduced into the ATFL insertional site under the guidance of C-arm roentgenography. The ideal trajectory was over the bisection of the distal fibula in the anteroposterior view, and the angle was 20° between the guide pin and the long axis of the fibular end in the lateral view (Figure 4). Subsequently, a 5.5-mm cannulated reamer was used to prepare a 2 cm–deep bone tunnel (Figure 5A). To create the talar bone tunnel, a 2.0-mm Kirschner wire was inserted into the ATFL insertional site over the talus and toward the tip of the medial malleolus through the AAL portal. A 5-mm cannulated reamer was used to prepare a 2 cm–deep bone tunnel (Figure 5B). To create the calcaneal bone tunnel, the ST and AAL portals were used as the viewing and working portals, respectively. With a hook holding the peroneal tendon, we could easily identify the CFL insertional site over the calcaneus. A 2.0-mm Kirschner wire was introduced into the posteromedial corner of the calcaneus. Subsequently, a 5 mm–diameter and 2 cm–deep bone tunnel was established (Figure 5C). All the bony edges of the tunnel were trimmed to prevent damage to the transplanted tendon allograft.

*Graft Passage and Fixation.* Tendon allografts were frozen-stored by the Taiwan Association of Tissue Bank in accordance with the guidelines of the American Association of Tissue Bank.[25] The tendon allografts were retrieved within 24 hours of donors' death and stored at −80°C. The flexor hallucis longus or flexor digitorum longus is the tendon used most commonly because of its desired tendon diameter and length. We prepared a Y-shaped tendon allograft that was folded at the fibular anchor part as a tendon loop with a length of 15 mm (Figure 6A). Subsequently, we constructed 15-mm calcaneal and 15-mm talar tendon anchor parts and sutured them with 2-0 Ethibond suture (Ethicon) for facilitating graft delivery. The desired talar limb size for the ATFL was 20 mm, and the desired calcaneal limb size for the CFL was 25 mm (Figure 6B).

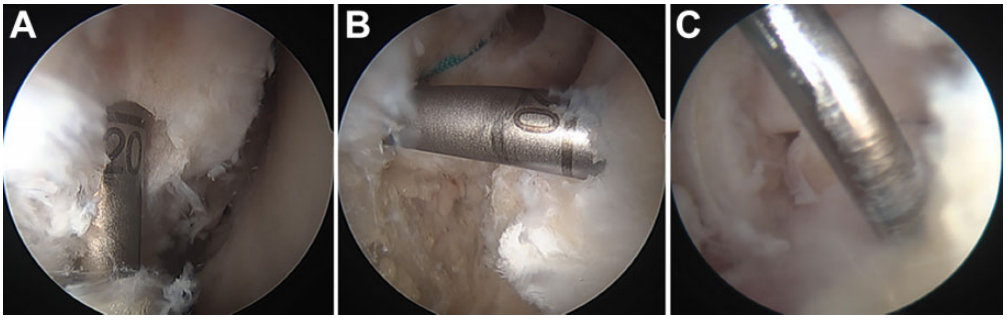


**Figure 5.** (A) Fibular bone tunnel created by a 5.5-mm cannulated reamer. The depth of the bone tunnel was 20 mm. (B) Talar bone tunnel created through the accessory anterolateral portal. (C) Calcaneal bone tunnel prepared through the accessory anterolateral portal with the peroneal tendon retracted to the lateral side. The diameter of the reamer used for the talar and calcaneal bone tunnel was 5 mm, and the depth was 20 mm.

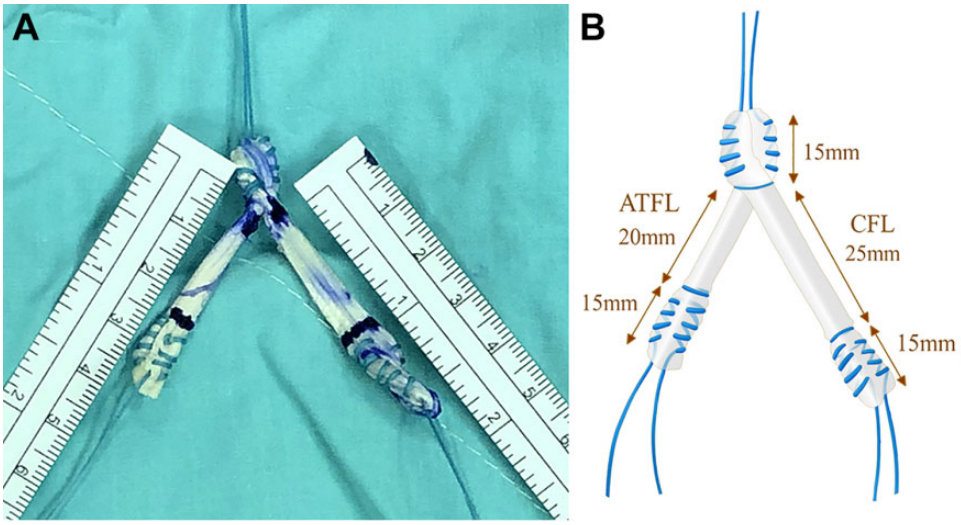


**Figure 6.** (A) Y-shaped tendon allograft. (B) Desired talar limb length was 20 mm for ATFL, and desired calcaneal limb length was 25 mm for CFL. The folded tendon allograft at the fibular anchor part as a tendon loop was prepared with a length of 15 mm. Calcaneal and talar tendon anchor parts were 15 mm in length, respectively, and sutured with 2-0 Ethibond sutures for facilitating graft delivery. ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament.

A 2.4-mm guide pin with a suture eyelet (AR-1297LS; Arthrex) was introduced into the fibular tunnel. The direction of the guide pin was oblique from the anteromedial to the posterolateral plane, and the pin penetrated out of the third quadrant of the fibula and the skin in the coronal plane (if the surgical limb was on the left side, then the quadrant was the fourth). The looped 2-0 Ethibond strand was passed through the eyelet, and a shuttle suture was placed after pulling out the guide pin. A similar procedure was used over the talar and calcaneal bone tunnels for creating another 2 shuttle sutures.

The fibular site was the first part for the passage of the tendon allograft. The upper and lower ends of the tendon allograft as the ATFL part were marked using a marking pen. The free 2-0 Ethibond strands that tagged on the fibular tendon loop were passed through the loop of the fibular shuttle suture. Subsequently, the fibular limb of the tendon allograft was pulled into the fibular bone tunnel and fixed with a 4.75-mm bioabsorbable screw (BioComposite SwiveLock suture anchor; Arthrex). The second fixed part was the talar limb of the ATFL. With the ankle placed in the neutral position, the talar tendon anchor part was introduced into the talar bone tunnel by pulling the shuttle suture. The tendon allograft was tightened by holding the 2-0 Ethibond strand sutured on the talar tendon anchor part and subsequently fixed with a 4.75-mm BioComposite SwiveLock. For the calcaneal limb in ATFL fixation, the viewing and working portals were changed to the ST and AAL portals, respectively. The adjacent peroneal tendon was pulled using a small retractor to clearly visualize the calcaneal bone tunnel and prevent the impingement of the tendon allograft by the peroneal tendon during tendon passage. The calcaneal tendon anchor part was advanced into the bone tunnel by using the suture relay technique and fixed with a 4.75-mm BioComposite SwiveLock in the neutral position of the ankle. A probe was subsequently introduced to examine the tension of the tendon allograft. Finally, the tendon allograft was able to be visualized as divergent 2 limb extended into the talar and calcaneal bone tunnel, respectively (Figure 7B). Then, 4-0 nylon stitches were used for skin closure.

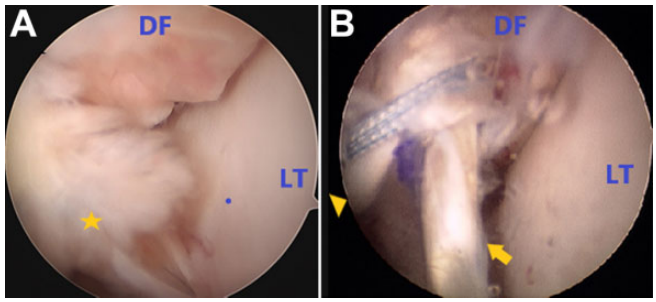


**Figure 7.** (A) Bald lateral malleolus with some poor texture, residual remnant of the anterior talofibular ligament (ATFL) (asterisk). (B) ATFL (arrow) and calcaneofibular ligament (arrowhead) were reconstructed with tendon allograft under arthroscopy. DF, distal fibula; LT, lateral talus.

*Rehabilitation Protocol.* A short walking boot without the limitation of plantarflexion or dorsiflexion was applied. On postoperative day 1, partial weightbearing with crutch assistance was allowed. The suture stitches on the skin were removed at postoperative 2 weeks, and the establishment of the range of motion of the ankle was started 2 weeks postoperatively. The patients could walk freely at postoperative week 4 by wearing high-ankle shoes for protection. Previous sports activities were allowed 4 months postoperatively after patients underwent an adequate rehabilitation program.

### Open Reconstruction With Tendon Allograft

Open anatomic ligament reconstruction was performed with the method used by Colville and Grondel[9] with a tendon allograft for CLAI. An 8-cm skin incision was made from posterior border of fibular tip toward the fourth toe. The anterolateral joint capsule was dissected, and 5-mm bone tunnels were subsequently created in the ligament insertional site of the fibula, talus, and calcaneus. The free tendon allograft was then advanced through the bone tunnels and fixed with 4.75-mm BioComposite SwiveLock screws.

## Clinical Evaluation

Clinical assessments were performed in all patients who completed the training program. Patients completed outcome measures preoperatively and at 2-year follow-up. Functional outcomes were evaluated using the American Orthopaedic Foot & Ankle Society ankle-hindfoot scale (AOFAS; 0-100 points) total score and pain, function, and alignment subscale scores; Karlsson Ankle Functional Score (0-100 points); Tegner activity score (TAS: 0-10 points)[21,23,31]; 10-point visual analog scale for pain; and the 12-Item Short Form Health Survey physical and mental component scores.[36]

## Statistical Analysis

Continuous variables are presented as means and standard deviations and as ranges, and discrete variables are expressed as the number and percentage. All outcome scores were compared between the preoperative and 2-year postoperative assessments using the Wilcoxon signed rank (paired) test, and scores were compared between the arthroscopic and open groups using the Student $t$ test. All statistical analyses were conducted using SPSS, Version 24.0 (SPSS Inc). Statistical significance was set at $P < .05$.

A power analysis was calculated from current results. The propensity score is the probability of treatment assignment conditional on observed baseline characteristics. We used the variable "AOFAS" for demonstration.[23] There are 10 matched pairs for the case group. Given the case group mean of paired difference of −25.1, the standard deviation of paired difference of 9.44, an effect size of −2.66 (ie, −25.1/9.44), and a significance level set as .05, then the post hoc power was over 90% (ie, type 2 errors <10%). Similar results were also seen with the other related variables. We used open-source software G*Power Version 3.1.9.7 (Erdfelder, Faul, & Buchner) to implement power analysis in this study.

# RESULTS

In the arthroscopic reconstruction group, the average length of hospital stay was 3.4 days (range, 3-4 days) and the average operation time was 118 minutes (range, 98-140 minutes). The intraoperative blood loss was 8 mL. All the patients reported favorable ankle stability after surgery and were satisfied with operative outcomes during the 2-month follow-up period. No local neuropathy, wound dehiscence, fistula, or pain over the lateral ankle wound area at postoperative 2 weeks was noted. In the open reconstruction group, the average length of hospital stay was 4.6 days (range, 4-5 days), and the average operation time was 110 minutes (range, 89-135 minutes). The intraoperative blood loss was 35 mL. Eight patients mentioned painful discomfort around the lateral ankle wound area lasting for 2 weeks. The patients could freely ambulate with acceptable regional pain or soreness 3 months postoperatively. The average follow-up period of all the patients was 29 months (range, 24-42 months).

## Outcomes

Table 2 lists the clinical outcome scores from preoperatively to 2 years postoperatively for both study groups. Patients in both groups showed significant improvement on all outcome scores between pre- and postoperatively. Table 3 lists the results of comparing the 2-year postoperative outcome scores between the arthroscopic and open groups. There were no significant differences between groups on any score, with the exception of the TAS. The postoperative TAS score was more significantly improved in the arthroscopic reconstruction group compared with the open group ($P = .01$) (Table 3).

## Postoperative Complications

In the arthroscopic reconstruction group, 1 patient developed a superficial wound infection a month later after the patient placed her ankle into a water tank during the hydrotherapy program. The patient's infection improved after local debridement in the outpatient clinic and treatment with oral antibiotics for 7 days. In the open reconstruction group, 1 patient felt numbness at the lateral foot over the sural nerve territory that resolved gradually 6 months postoperatively. Another patient complained of ankle stiffness sensation, especially the limitation of ankle inversion. The subtalar joint motion improved after a 4-month aggressive rehabilitation program; however, a 10° limitation of ankle inversion was still noted. In addition, 1 patient developed a stitch abscess and the infection was under control after the removal of stitches (Table 4).

# DISCUSSION

To the best of our knowledge, this is the first case series to report the comparison of the outcomes of arthroscopic tendon allografting reconstruction for CLAI with those of open allografting. The most important finding was the postoperative 2-year activity-specific TAS score was significantly higher in the arthroscopic reconstruction group than the open group ($P = .01$) and less wound complication was noted in the arthroscopic group. Our results revealed that the arthroscopic reconstruction group had more favorable activity-related outcomes compared with the open reconstruction group.

TABLE 2
Comparison of Outcome Scores Between Preoperatively and 2 Years Postoperatively in the Arthroscopic and Open Groups[a]

| Outcome Measure | Preoperative | Postoperative | *P* |
|---|---|---|---|
| Arthroscopic | | | |
| AOFAS total | 71.3 ± 13.27 (35-80) | 96.4 ± 1.42 (95-100) | **.006** |
| AOFAS–pain | 25 ± 9.71 (0-30) | 40 ± 0 (40-40) | **.004** |
| AOFAS–function | 35.1 ± 2.43 (25-40) | 46.4 ± 1.59 (45-50) | **.005** |
| AOFAS–alignment | 10 ± 0 (10-10) | 10 ± 0 (10-10) | – |
| KAFS | 51.30 ± 14.58 (15-67) | 96.8 ± 1.93 (95-100) | **.005** |
| TAS | 2.6 ± 0.70 (1-3) | 7.0 ± 0.82 (6-9) | **.001** |
| VAS pain | 5.1 ± 1.28 (4-5) | 0.8 ± 0.63 (0-2) | **.005** |
| SF-12 | 90.42 ± 8.37 (68.99-98.42) | 111.2 ± 2.37 (108.30-115.78) | **.002** |
| Physical score | 35.66 ± 6.82 (17.27-41.21) | 52.94 ± 3.07 (42.32-56.99) | **.001** |
| Mental score | 54.75 ± 4.03 (50.66-61.39) | 58.26 ± 3.51 (52.73-64.72) | **.048** |
| Open | | | |
| AOFAS total | 68.6 ± 10.96 (42-77) | 96.7 ± 4.78 (84-100) | **.005** |
| AOFAS–pain | 25 ± 7.07 (10-30) | 39 ± 3.16 (30-40) | **.004** |
| AOFAS–function | 33.6 ± 6.25 (22-44) | 47.7 ± 2.16 (44-50) | **.005** |
| AOFAS–alignment | 10 ± 0 (10-10) | 10 ± 0 (10-10) | – |
| KAFS | 53.3 ± 13.25 (20-67) | 94.9 ± 4.50 (85-100) | **.005** |
| TAS | 2.7 ± 0.48 (2-3) | 6.1 ± 0.57 (5-7) | **.001** |
| VAS pain | 5.2 ± 1.03 (4-7) | 0.6 ± 0.69 (0-2) | **.005** |
| SF-12 | 89.3 ± 6.16 (79.64-100.76) | 111.47 ± 3.06 (107.18-117.33) | **.001** |
| Physical score | 37.7 ± 6.21 (25.52-48.24) | 51.92 ± 2.64 (48.83-56.58) | **.001** |
| Mental score | 51.5 ± 2.86 (45.49-55.06) | 55.45 ± 1.91 (55.45-61.60) | **.001** |

[a]Data are reported as mean ± SD (range). Boldface *P* values indicate statistically significant difference between pre- and postoperative values ($P < .05$). Dashes indicate variables that could not be compared (SD = 0 for both groups). AOFAS, American Orthopaedic Foot & Ankle Society; KAFS, Karlsson Ankle Functional Score; SF-12; 12-Item Short Form Health Survey; TAS, Tegner activity scale; VAS, visual analog scale.

TABLE 3
Comparison of 2-Year Postoperative Outcome Scores Between the Arthroscopic and Open Groups[a]

| Outcome Measure | Arthroscopic | Open | *P* |
|---|---|---|---|
| AOFAS total | 96.4 ± 1.42 (95-100) | 96.7 ± 4.78 (84-100) | .107 |
| AOFAS–pain | 40 ± 0 (40-40) | 39 ± 3.16 (30-40) | .368 |
| AOFAS–function | 46.4 ± 1.59 (45-50) | 47.7 ± 2.16 (44-50) | .107 |
| AOFAS–alignment | 10 ± 0 (10-10) | 10 ± 0 (10-10) | - |
| KAFS | 96.8 ± 1.93 (95-100) | 94.9 ± 4.50 (85-100) | .360 |
| TAS | 7.0 ± 0.82 (6-9) | 6.1 ± 0.57 (5-7) | **.01** |
| VAS pain | 0.8 ± 0.63 (0-2) | 0.6 ± 0.69 (0-2) | .475 |
| SF-12 | 111.2 ± 2.37 (108.30-115.78) | 111.47 ± 3.06 (107.18-117.33) | .909 |
| Physical score | 52.94 ± 3.07 (42.32-56.99) | 51.92 ± 2.64 (48.83-56.58) | .272 |
| Mental score | 58.26 ± 3.51 (52.73-64.72) | 55.45 ± 1.91 (55.45-61.60) | .241 |

[a]Data are reported as mean ± SD (range). Boldface *P* value indicates statistically significant difference between groups ($P < .05$). Dash indicates variables that could not be compared (SD = 0 for both groups). AOFAS, American Orthopaedic Foot & Ankle Society; KAFS, Karlsson Ankle Functional Score; SF-12, 12-Item Short Form Health Survey; TAS, Tegner activity score; VAS, visual analog scale.

The choice of the tendon autograft or allograft remains under debate in knee cruciate ligament reconstruction surgery. A study including a minimum follow-up duration of 10 years reported that the failure rate of patients receiving a tendon allograft was 3 times higher than that of those receiving an autograft.[2] However, a meta-analysis study evaluated the clinical outcomes of using hamstring grafts for anterior cruciate ligament reconstruction and found no significant difference between autografts and allografts.[10] The reported advantages of allografts include the absence of donor-site morbidity, availability of desired allograft size and length, and short duration of operation. However, immune reaction, high costs, and disease transmission risk are the major concerns of this technique.

Few studies have compared the benefits of autografts with those of allografts for ankle ligament reconstruction. In 1 retrospective study, Xu et al[38] compared the efficacy of the semitendinosus autograft with that of the allograft for

TABLE 4
Postoperative Complications[a]

| Complication | Arthroscopic | Open |
|---|---|---|
| Recurrent pain | 0 | 0 |
| Deep infection | 0 | 0 |
| Superficial infection | 1 | 1 |
| Deep infection | 0 | 0 |
| Large hematoma | 0 | 0 |
| Stiffness of the ankle | 0 | 1 |
| Paresis of the sural nerve or superficial peroneal nerve | 0 | 1 |
| Deep vein thrombosis | 0 | 0 |
| Recurrent ankle instability | 0 | 0 |
| Total, n/N (%) | 1/10 (10) | 3/10 (30) |

[a]Data are reported as No. of patients unless otherwise indicated.

lateral ankle ligament reconstruction. They concluded that both grafts exhibited comparable efficacy except that tendon healing was significantly faster in the autograft group. Recently, a systematic review of 12 studies including 357 patients who underwent lateral ankle ligament reconstruction reported no differences in patient satisfaction, graft survivorship, and clinical outcomes between the allograft and autograft groups.[3] Among 151 patients who underwent allograft reconstruction, no adverse events and immunological responses correlating with the tendon allograft were noted. In our series, we compared surgical outcomes between the arthroscopic reconstruction and open surgery groups. All the tendon grafts used were allogeneic, and no graft rejection or resorption related to immune reaction was observed. With regard to the risk of disease transmission, no acute or delayed bacterial or viral infection was noted during follow-up. These favorable findings can be attributable to the use of fresh-frozen allograft with decreased antigenicity; the allograft was submerged in the antibiotic solution before graft implantation to prevent the growth of pathogens.[19] Furthermore, graft rupture was not observed in both groups. In addition, revision surgery was not required in both groups during the 2-year follow-up. All 20 ankles had a 100% allograft survival rate in our study. In terms of postoperative functional outcomes, the improvement in the total AOFAS and Karlsson Ankle Functional Score scores was comparable without statistical significance between the arthroscopic reconstruction and open surgical groups. Only the TAS score was significantly higher in the arthroscopic reconstruction group. This finding may be attributable to the potential of faster recovery, shorter rehabilitation, less wound complication, and ankle stiffness of the minimally invasive surgery. However, this assumption is limited because of the inclusion of a small sample size in this study. A large prospective study should be conducted to obtain better evidence.

Studies have described the all-inside arthroscopic ligament reconstruction technique for CLAI.[13,15] The outcomes of the all-inside arthroscopic ligament reconstruction were comparable with those of traditional open lateral ankle ligament reconstruction. The learning curve and the use of intraoperative fluoroscopy were the disadvantages of this technique.[17,30] In addition, the risk of bone tunnel iatrogenic fracture existed during surgery especially while creating the fibular tunnel. Appropriate guide pin insertion under intraoperative fluoroscopic guidance is paramount for preventing complications. The guide pin direction should be in line with the central axis of the distal fibula in the anteroposterior view, and the angle between the guide pin and the long axis of the fibular end in the lateral view should be 20°.[17,18,30] By using this method, the fibular bone tunnel can be located in the central area of the cross section of the fibular end. In our series, no fibular iatrogenic fracture was noted while applying this technique. Furthermore, the difficulty in the visualization of the CFL insertion site underneath the peroneal tendon was an obstacle during the creation of the calcaneal tunnel. To solve this problem, Iwashita et al[20] reported a concept called "A+P roll," which involved the use of arthroscopy for ATFL reconstruction and the percutaneous method for CFL reconstruction. They reported that this technique can serve as an alternative option since the CFL insertion site is found to be difficult visualizing during the arthroscopic procedure. To facilitate the direct visualization of the CFL insertion site and prevent the injury of the peroneal tendon during the introduction of the instrument, we used a hook device to hold the peroneal tendon steadily throughout the procedure. All the patients underwent this technique smoothly and did not require shifting to the open or percutaneous method for performing CFL ligament reconstruction.

For reparable lesions, Broström suggested repairing only the ATFL because the incidence rate of CFL rupture is only 23%; thus, the reattachment of the CFL is of minor importance.[4,5] However, the frequency of CFL involvement is considerably higher, and it varies from 50% to 75%.[12] A recent study reported that the inferior bundle of the ATFL was connected with the CFL at the fibular insertion site. An arthroscopic grade 2 or 3 ATFL injury often has an intact or a partial-thickness tear of the inferior bundle, and the repair of the residual remnant of the ATFL can simultaneously exert tension on the CFL.[33,35] Thus, CFL repair might not be necessary during most of the lateral ankle ligament repair procedures. However, for irreparable CLAI, the scenario is different for the aforementioned grade 2 or 3 lesion. The ATFL and CFL are completely detached from the fibular insertion site. Although ATFL reconstruction alone might result in satisfactory functional outcomes, singular ligament reconstruction would not provide adequate mechanical strength for ankle inversion, especially in the dorsiflexion position.[18] Thus, we advocate simultaneous ATFL and CFL reconstruction if the repair procedure is not optimal for providing lateral ankle stability. Another alternative option may be the use of anti-inversion force if the residual CFL stump is reattached onto the reconstructed ATFL ligament, mimicking the connection in between; however, the efficacy of this procedure should be evaluated in future studies. In our series, all the patients received ATFL and CFL reconstruction with a Y-shaped tendon allograft. Although the preparation of the calcaneal bone tunnel may be time-consuming, with adequate ST portal creation and proper visualization of the

CFL insertion site underneath the peroneal tendon, the additional surgical time would not exceed 30 minutes. Satisfactory ankle stability was remarkable, and the patients could resume previous exercise activity at postoperative 4 months. The follow-up stress radiographs showed no ankle varus tilt instability or laxity during the anterior drawer of the ankle at 6 months and 2 years postoperatively.

Ultrasound is useful in the diagnosis of soft tissue injury because of its feasibility and real-time image depiction. For CLAI, the diagnostic accuracy of ultrasound is similar to that of MRI in the assessment of ATFL rupture and is even higher in the evaluation of CFL injuries.[8,27] Nevertheless, the utility of ultrasound for CLAI has been confined to disease diagnosis. Previously, we reported ultrasound-guided minimally invasive techniques for Achilles sleeve avulsion rupture and indicated that reparable lesions or injury requires reconstruction under dynamic ultrasound guidance.[24] The favorable image depiction of the tendon gap and the texture of the stump end can provide objective guidance for choosing appropriate treatment.

In this study, we used dynamic ultrasound preoperatively to more efficiently assess and grade the severity of the lateral ankle ligament injury.[1,6,22] Patients with severe lateral ankle instability have mostly type 4 or 5 lesions according to the Kemmochi ultrasonographic classification, indicating the absence of ligament attachment at the fibular insertion site.[22] However, this classification addresses only ATFL injury and does not provide information regarding injury status of the CFL, which is a crucial lateral ankle static stabilizer. Cho et al[7] reported the effect of stress ultrasound for the evaluation of diagnosis of chronic lateral ankle instability; 22 of 28 patients were classified as having clinical grade 3 instability and 6 patients as having grade 2. The ligament length in the ankle stress position and resting condition was 2.8 ± 0.3 cm and 2.1 ± 0.2 cm, respectively. The definition of their ligament length is just according to the bony landmark without depiction of the ruptured ligament gap. The mean ATFL length of the contralateral ankle under ATFL-stress and under ATFL-resting was 2.3 ± 0.2 cm and 2.1 ± 0.1 cm, respectively. The difference in ATFL-stress between injured and uninjured ankle was 0.5 ± 0.2 cm, which inferred that the gap between ATFL fibular insertional site and ATFL ruptured stump end might be 0.5 cm. All the patients in their group were treated with the modified Broström procedure, and ligament injuries were all verified arthroscopically as grade 3 lesions.

We routinely used dynamic ultrasound preoperatively to assess the ATFL and CFL injury. A gap of less than 5 mm in the ATFL ligament tear in the ankle plantarflexion-inversion position often indicates ligament approximation in the fibular insertion site or nearby during the motion of the ankle back to the neutral position, demonstrating the presence of easily reparable lesions. Patients with a gap larger than 1.5 cm or no visualization of the ligament would be suitable candidates for ligament reconstruction. A gap of 0.5 to 1.5 cm is controversial. This type of ligament stump should be assessed carefully, and the thickness of the residual stump should be measured by setting the ultrasound at the orthogonal position of the long axis of the ligament. In our experience, a ligament stump with a thickness of more than 2 mm exhibits a better tissue texture for mounting suture strings and possesses less likelihood of experiencing a suture cut through during string tightening. Another concern for a relatively larger ligament gap is that overtightening may lead to rerupture or dislodge the suture anchor. In addition, if the gap between the CFL stump and fibular insertion site as well as between the ATFL stump and fibular bone is 1.0 to 1.5 cm, respectively, in the ankle plantarflexion-inversion position, then ligament reconstruction should be considered if repair is difficult during surgery.

Thus far, although no patient has been shifted to the ligament reconstruction procedure in our daily practice, 2 patients receiving arthroscopic Broström repair complained of limited ankle inversion and required longer rehabilitation time up to 3 months for regaining the ankle range of motion. All the patients in this study received ligament reconstruction based on the preoperative image evaluation and careful physical examination. Thus, dynamic ultrasound may be an optimal imaging modality for selecting the treatment option for CLAI. A prospective study should be conducted to objectively evaluate the utility of dynamic ultrasound in preoperative surgical decision making for the treatment of CLAI.

### Limitations

The design of our study has several limitations. First, the sample size of the study was quite small, possibly because arthroscopic reconstruction surgery for CLAI is a newly developed technique. A lasting consecutive project or multicenter study enrolling an adequate number of patients is required. Second, the mean follow-up period was only 2 years. Future studies should perform a chronological and objective assessment of clinical and functional outcomes. Third, the mechanical strength of the ankle joint was not examined during follow-up. Although no recurrence of lateral ankle instability was found postoperatively, mechanical force evaluation can provide more evidence with respect to the use of this arthroscopic reconstruction technique.

## CONCLUSION

All-inside arthroscopic ligament reconstruction has been reported for CLAI treatment, and in this study we described an alternative method that involved the use of the tendon allograft to reconstruct the lateral ankle ligament. We found that the arthroscopic reconstruction group had better activity-related outcomes, no donor-site morbidity, satisfactory functional results, and few wound complications compared with the open group. Thus, tendon allografting can play a vital role in arthroscopic ankle ligament reconstruction.

## ACKNOWLEDGMENT

The authors thank Ching-I Hu for the drawings and I-Shiang Tzeng for the statistical analysis.

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