Allograft tendon reconstruction of the anterior talofibular ligament and calcaneofibular Ligament in the treatment of chronic ankle instability

Weikai Wang and Guo Hong Xu*

Abstract

Background: The purpose was retrospectively to investigate functional and clinical outcomes after anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL) reconstruction using a single allograft.

Methods: Patients with severe chronic lateral instability of the ankle underwent surgery after conservative treatment failed. Ultrasounds of the ankle were performed, and if the ATFL and CFL were completely torn without enough soft tissue for repair, the ligaments were reconstructed using allograft tendon. Outcomes were assessed by clinical examination, stress radiography, ultrasound, the American Orthopaedic Foot and Ankle Society score (AOFAS), and Karlsson Ankle Functional score (KAFS) before surgery and at final follow-up.

Results: Nineteen patients, ten men and nine women with mean age of 27.9 years (range, 19–41 years), underwent reconstruction. Mean follow-up was 30 months (range, 24–40 months). At final follow-up, all patients had returned to activity without instability, pain, or limited range of motion. On stress radiography, mean talar tilt angle decreased from 17.32° ± 3.58° before surgery to 4.16° ± 1.12° at follow-up (p < 0.001). Mean anterior drawer test (ADT) distance decreased from 9.79 ± 1.01 mm before surgery to 3.97 ± 0.99 mm at follow-up (p < 0.05). Mean AOFAS improved from 64.00 ± 18.43 to 90.32 ± 5.17 points (p < 0.001), and mean KAFS improved from 50.84 ± 16.73 to 90.89 ± 5.08 points (p < 0.001). Ultrasound showed the reconstructed ligaments maintained good continuity and excellent tension. No case of infection and immunological rejection was reported.

Conclusion: This novel reconstruction technique takes into account the anatomical specialty of ATFL and CFL. This case series showed increased stability of the ankle in clinical and functional outcomes.

Trial registration: The trial registration number (TRN) and date of registration: ChiCTR-ORC-17010796, Mar 6th 2017. Retrospectively registered.

Keywords: Lateral instability of the ankle, Ultrasound, Anatomical reconstruction, ATFL, CFL

Background

Ankle sprain is one of the most frequent sports injuries, which often results in ligament rupture, mainly the anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL) [1]. Because of poor healing, the injured ankle will gradually develop ankle instability, which is potentially devastating [2].

The collateral ligaments of ankle consist of three main ligaments, including the ATFL, CFL, and posterior talofibular ligament (PTFL) [3, 4]. The PTFL originates from the posteromedial surface of the fibula, stretching transversely and medially to insert broadly on the nonarticular posterior surface of the talus [5]. The ATFL, which originates from the fibular tip and courses to the talus neck, is an important stabilizer of the ankle, serving as the important restraint to ankle inversion. The CFL, which originates just below the AFL origin site and attaches to the lateral aspect of the calcaneus, provides...
static stability to the ankle and also safeguards the subtalar joint [6]. It has been reported that ATFL and CFL synergistically provide rotation and inversion constraints necessary for ankle stability [4].

Anatomic reconstructions aim to recreate the disrupted ATFL and CFL regarding the anatomic factors. Surgery mainly utilizes a tunnel through the fibular tip and talus neck to facilitate graft passage and reconstruction of both ATFL and CFL [7–11]. We developed a simple reconstructive technique, which does not require the use of an interference screw in the talus neck. Our technique uses one allograft tendon to reconstruct both ATFL and CFL.

In addition, there is a debate about which patients need both ATFL and CFL reconstruction. Traditional stress X-ray image of the talocrural joint provides evidence of the lateral ankle stability; however, it may not directly describe the condition of the ligaments. If the osseous architecture is abnormal or dynamic stabilizers are injured, stress radiography results will be positive even though the ligaments are normal [3, 4]. Therefore, it is necessary to use a diagnostic tool to directly evaluate the ligaments of the ankle.

Therefore, the aim of this study was to investigate the clinical and functional results in patients who underwent this novel technique of ATFL and CFL reconstruction and to also investigate the use of ultrasound to assess the ATFL and CFL.

Methods

Patients

This study was approved by the ethics committee of our hospital, and all subjects gave their informed consent. Patients with symptomatic unilateral chronic ankle instability between Aug 2012 and Jan 2014 decided to undergo surgery after long-term conservative treatment failed. They were carefully examined clinically and with stress radiography. The American Orthopaedic Foot and Ankle Society score (AOFAS) and Karlsson Ankle Functional score (KAFS) were used to assess the function of the ankle before the operation and at follow-up.

Decision regarding the ligaments for reconstruction

Before surgery, standard B-ultrasound of the ankle was performed to decide whether to perform reconstruction and, if so, which ligament to reconstruct. If the ATFL and CFL were completely torn and soft tissues were insufficient for repair, we decided to reconstruct both ATFL and CFL.

Surgical techniques

One senior surgeon experienced in this technique performed all of the reconstructions. The patient was positioned supine with a leg supporter holding the ipsilateral leg under general anesthesia. Arthroscopy was carried out on all patients, the anterior talofibular and calcaneofibular ligaments were evaluated, and any minor accompanying injuries were treated simultaneously.

After arthroscopy, an oblique incision, about 5 cm in length, was made from the fibular tip, ending at the talar neck. The proximal edge of inferior extensor retinaculum was mobilized and tagged for later use. The conjoined ligament insertion of the ATFL and CFL at the malleolus was exposed after incision of the capsule. The ATFL insertion at the talus neck was also exposed. Two oblique 3.5-mm tunnels were created to make a “V” shape bone tunnel at the ATFL and CFL fibular insertion site. Then, another two 3.5-mm converging tunnels were made at the ATFL talus insertion site. A third 6-mm bone tunnel was made at the CFL calcaneus insertion site (Fig. 1).

A fresh-frozen tendon allograft (semitendinosus tendon) was prepared. After soaking in sterile saline for 20 min at room temperature, the tendon was trimmed and rolled to approximately 3.5 mm in diameter and 20 cm in length. Each end of the graft was sewn using nonabsorbable #2 braided polyester sutures. After pretension for 15 min, the allograft was pulled into the calcaneus bone tunnel and fixed with a 7 mm milagro screw (DePuy Mitek, USA). The other end of the graft was routed beneath the peroneal tendons, and pulled into the inferior fibular tunnel. The graft was then routed back through the superior fibular tunnel, and passed though the two tunnels in the talus, and sutured to the tendon at the fibular insertion site in a neutral position. The capsule and inferior extensor retinaculum was sutured back to cover the graft, and the incision was closed.
Rehabilitation
All patients completed a same rehabilitation protocol, with the patient kept in the splint and nonweightbearing for 2 weeks and using crutches and the rehabilitation brace for next 6 weeks postoperatively. Full weightbearing was allowed at 2 to 3 weeks after surgery, and full range-of-motion exercises and triceps surae muscle were allowed accordingly. Patients were suggested to return to sports at 8 to 12 months, which is depended on their progress with physiotherapy.

Clinical assessments and follow-up
One physician, which was not involved in the patients’ rehabilitation, completed all clinical assessments. Ankle range of motion (ROM) was measured using a goniometer. Stress radiography was performed to assess laxity of the ankle. AOFAS and KAFS were used to assess functional outcomes. We performed ultrasound examination to evaluate the condition of the reconstructed graft after surgery.

Statistical methods
Statistical comparison was performed with STATA 10.0 software (Stata Corp, USA). The data was reported as mean ± standard deviation (SD). The paired Student t-test was used to compare the continuous variables between the groups. Statistical significance level was set at 0.05.

Results
The results of standard B-ultrasound identified 19 patients with complete tears of the ATFL and CFL, and during the operation, these results were confirmed by arthroscopy. The 19 patients (ten men and nine women) had mean age at operation of 27.9 years (range, 19–41 years). The left ankle was injured in eight cases, and the right, in 11 cases. The interval between the initial ankle sprain and the surgery time ranged from 12 months to 10 years (average, 2.4 years). All patients had completed long-term conservative treatment but still had recurrent ankle sprains with severe lateral ankle instability.

Mean follow-up time was 27 months (range, 24–30 months). There were no cases of postoperative infection or immunological rejection, and none of the patients had an ankle sprain during follow-up.

Ankle instability in all patients resolved. No patients had limited ROM. At the follow-up time, there was no significant difference of ROM between the injured and contralateral ankle (Table 1).

Stress radiography showed that the ankles of all patients were stable in the anterior drawer test (ADT) and inversion test. Mean talar tilt angle measured manually was 17.32° ± 3.58° (range, 13–25°) before surgery and 4.16° ± 1.12° (range, 3–7°) at follow-up (p < 0.001). Mean anterior drawer test distance decreased significantly from 9.79 ± 1.01 mm (range, 8–11 mm) before surgery to 3.97 ± 0.99 mm (range, 3–6 mm) at follow-up (p < 0.001).

Mean AOFAS improved significantly from 64.00 ± 18.43 points (range, 31–84 points) before surgery to 90.32 ± 17.17 points (range, 84–100 points) at follow-up (p < 0.001). Mean KAFS also improved significantly from 50.84 ± 16.73 points (range, 20–75 points) before surgery to 90.89 ± 5.08 (range, 85–100) at follow up (p < 0.001).

Ultrasound
Ultrasound showed that the reconstructed anterior talofibular ligament spanned across the anterolateral ankle joint from the fibular tip to the talus neck. The reconstructed calcaneofibular ligament originated below the ATFL origin site, coursed deep to the peroneal tendons, and inserted to the lateral aspect of the calcaneus. Both of the ligaments showed good continuity via ultrasound. With extension and flexion, the two reconstructed ligaments maintained excellent tension.

Discussion
Numerous procedures for ATFL and CFL reconstruction have been reported with various successful rate. Sugimoto and colleagues [10] used a bone-patellar tendon graft to reconstruct the ATFL and CFL in 13 patients with chronic ankle instability. At mean follow-up of 26.5 months, the average talar tilt degree improved from 18.4° ± 5.5° preoperatively to 4.9° ± 2.6° postoperatively, and the average ADT decreased from 9.1 ± 2.6 mm preoperatively to 5.8 ± 1.6 mm postoperatively. According to the score devised by Good, six patients had a Grade III clinical condition and seven had a Grade IV condition preoperatively. After surgery, all patients had a grade I condition.

Coughlin and colleagues [11] reported another surgical technique using a free gracilis tendon transfer to anatomically reconstruct the ATFL and CFL. At a mean follow-up of 23 months, the outcomes of 24 of 28 patients were regarded as excellent and four of 28 as good, according to subjective self-assessment, pain scores, AOFAS, and KAFS. Talar tilt degree decreased from 13° preoperatively to 3° postoperatively, and the ADT decreased from 10 mm preoperatively to 5 mm postoperatively.

Pagenstert and colleagues [12] described their technique to anatomically reconstruct ATFL and CFL using a free plantaris tendon graft without screw fixation. At a mean follow-up of 3.5 years in 50 patients, the mean
immunological rejection have been reported [13].

gery, especially in the knee joints, and no infections or
tendons have been widely used for reconstructive sur-
munological rejection occurred in our study. Allograft
to verify the benefits of our technique.
cal technique is lack of a biomechanical cadaveric study
ing reconstruction. The main disadvantage of this surgi-
are described by Burks and colleagues [9]. With the use of
of ATFL and CFL. This orientation and attachment of
constructive technique respects the anatomical feature
nel than a 6-mm or 7-mm diameter tunnel on the small
is much closer to the native anterior talofibular ligament.
Furthermore, unlike Coughlin and colleagues [11] who
m, anterior talofibular ligament was reconstructed in a
double fashion that respected the normal kinematics of
terior talofibular ligament. However, our technique is
unique in that the calcaneofibular ligament was recon-
structed with a single tendon graft with an interference
site of the patient’s
site of the patient’s

AOFAS was 97.9. In 39 cases (78%), the outcome was
graded as excellent, and in 9 cases (18%), as good. The
reconstruction addressed both ATFL and CFL in a
doUBLE fashion with great attention to normal kinematics
of the ankle.

In the present study, we report data consistent with
the previously described literature. The functional scores
improved significantly after compared with before sur-
gery. The reconstruction technique used was similar to
that described by Pagenstert and colleagues [12], in that
the anterior talofibular ligament was reconstructed in a
doUBLE fashion that respected the normal kinematics of
terior talofibular ligament. However, our technique is
unique in that the calcaneofibular ligament was recon-
structed with a single tendon graft with an interference
screw to fix the insertion. We believe that this is a simpler
and safer technique to firmly fix the tendon end, com-
pared with the procedure of Pagenstert and colleagues.
The single reconstructed calcaneofibular ligament is much
closer to the native calcaneofibular ligament.

Furthermore, unlike Coughlin and colleagues [11] who
performed single tendon reconstruction of the anterior
talofibular ligament with interference screw fixation on
the talar insertion, for several reasons, we prefer to cre-
ae a bone bridge on the talar neck and reconstruct the
terior talofibular ligament in a double fashion. First, it
is much closer to the native anterior talofibular ligament.
Second, it is much easier to drill a 3.5-mm diameter tun-

el than a 6-mm or 7-mm diameter tunnel on the small
fibular tip and maintain a strong bone bridge. Our re-
constructive technique respects the anatomical feature
of ATFL and CFL. This orientation and attachment of
the reconstructed ATFL and CFL are similar to those
described by Burks and colleagues [9]. With the use of
these specific anatomical data, the anatomical sites for
ligament attachment can be located more precisely dur-
ing reconstruction. The main disadvantage of this surgi-
cal technique is lack of a biomechanical cadaveric study
to verify the benefits of our technique.

With regard to allograft problems, no infections or im-
munological rejection occurred in our study. Allograft
tendons have been widely used for reconstructive sur-
gery, especially in the knee joints, and no infections or
immunological rejection have been reported [13–15].
Caprio and colleagues [2] described an augmented re-
constructive technique of the ATFL and CFL with a
semitendinosus tendon allograft, and they advocated this
procedure as a safe, effective method to manage lateral
ankle instability.

To decide the surgical treatment, increasingly accurate
diagnostic tests are necessary. Lateral ligament rupture
of the ankle has ever been diagnosed using stress x-ray
image of the talocrural joint. Takao and colleagues [16]
performed stress x-ray image of the subtalar joint to
decide which ligaments needed reconstruction. In 17 pa-
tients, with the talocalcaneal angle less than 10°, only the
ATFL was reconstructed; in 4 patients, with the talocal-
caneal angle of 10° or more, both ATFL and CFL were
reconstructed. After surgery, mean talar tilt angle on
stress x-ray image of the talocrural joint decreased sig-
nificantly in both groups. However, this approach pro-
vides only indirect evidence of the lateral stability of the
ankle, which may not directly describe the condition of
the ligaments. As described before, if osseous architecture
is abnormal or dynamic stabilizers are injured, stress radi-
ography results will be positive even though the ligaments
are normal. Therefore, it is necessary to use a diagnostic
tool to directly assess the ATFL and CFL.

In 2008, Takao and colleagues [17] used magnetic res-
onance imaging (MRI) to evaluate morphological
changes of the ATFL and CFL, demonstrating its usefulness
in evaluating the ligaments and directing treatment. The re-

It is the preferred tool for
evaluating tendons and ligaments [18], B-ultrasound is a
unique, powerful diagnostic tool, with the ability to in-
tensively examine an pathological area during motion
[19–22]. The commonly stated shortcoming of so-called
operator dependence, on the other hand, becomes a dis-
tinct advantage over any of the other radiology tests,
particularly in evaluation of the ligaments. The ATFL
and CFL have different anatomic characteristics in
different people, including origin, insertion, and course
direction. Because MRI is limited to three traditional
views (axial, sagittal, and coronal), this may unavoidably
lead to diagnostic errors because of the scanning slice
[23]. In this respect, ultrasound can evaluate the anterior
talofibular and calcaneofibular ligaments in any plane
and any angle, and trace the ligaments along their entire
course. In addition, ultrasound can target the specific
site of the patient’s symptom(s) and dynamically observe
the underlying structures during motion [24]. Such dy-
namic evaluation is very useful for the anterior talo-

fibular and calcaneofibular ligaments, because both
ligaments have different levels of tension in different
people. Therefore, we believe dynamic ultrasound can
provide important information for planning surgery.
Fibers of the tendons and ligaments can be visualized
clearly via ultrasound, both before surgery to assess the
extent of injury and after surgery to assess the condition
of the reconstructed ligaments.

There were several limitations in this present study,
including a relatively small sample size, lack of a stress-
testing device, no control group, and anatomical refer-
ence. When both the ATFL and CFL are injured, we first
consider direct repair. If there is not enough soft tissue for repair, we turn to reconstruction. According to the patients’ condition and willingness, the allograft tendon was preferred. Therefore, the number of patients who underwent reconstruction of the ATFL and CFL using allograft appears small. Additionally, we lack a stress-testing device to perform standard stress radiography. Instead, we performed standard stress radiography for the ADT and the inversion test manually. Finally, the anatomical data mentioned in our technique were based on adult patients with average body size. For others, the anatomical data should be adjusted correspondingly.

Conclusions
We describe a novel technique which takes into account the anatomical specialty of anterior talofibular and calcaneofibular ligaments. Our series showed increased stability of the ankle in clinical and functional outcomes.

Abbreviations
ADT: Anterior drawer test; AOFAS: American Orthopaedic Foot and Ankle Society; ATFL: Anterior talofibular ligament; CFL: Calcaneofibular ligament

Acknowledgements
Not applicable.

Funding
Not applicable.

Availability of data and materials
The datasets during and/or analysed during the current study available from the corresponding author on reasonable request.

Authors’ contributions
WW performed the follow-up experiments. GHX gave the experiment guidance during this study. WW analyzed and interpreted the data and was a major contributor in writing the manuscript. Both authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

Consent for publication
Not applicable.

Ethics approval and consent to participate
This study was approved by the ethics committee of Affiliated Dongyang Hospital, Wenzhou Medical University. Written consent to participate was provided by participants included in the study.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Received: 13 September 2016 Accepted: 16 March 2017
Published online: 08 April 2017

References
1. Jackson W, McGarvey W. Update on the treatment of chronic ankle instability and syndesmotic injuries. Curr Opin Orthop. 2006;17(2):97–102.
2. Schmidt R, Beneisch S, Friemert B, et al. Anatomical repair of lateral ligaments in patients with chronic ankle instability. Knee Surg Sports Traumatol Arthrosoc. 2005;13:231–7.
3. Hintermann B. Biomechanics of the unstable ankle joint and clinical implications. Med Sci Sports Exerc. 1999;31(supp):S459–69.
4. Penner MJ. Instability of the ankle. Practical orthopaedic sports medicine & arthroscopy. Donald H. Johnson, Robert A. Pedowitz. 2007:682–78.
5. Berlet GC, Anderson RB, Davis WH. Chronic lateral ankle instability. Foot Ankle Clin. 1999;4:73–8.
6. Tauxe F, Shafiq Q, Ebraheim NA. Anatomy of lateral ankle ligaments and their relationship to bony landmarks. Surg Radiol Anat. 2006;28(4):391–7.
7. Yong R, Lai KW, Ooi LH. Ankle ligament reconstruction for chronic instability. J Orthop Surg (Hong Kong). 2015;23(1):62–5.
8. Trc T, Handl M, Havlas V. The anterior talo-fibular ligament reconstruction in surgical treatment of chronic lateral ankle instability. Int Orthop. 2010;34(7):991–6.
9. Willigermann M, Benza E, Hitler L, et al. Biomechanical stability of tape augmentation for anterior talofibular ligament (ATFL) repair compared to the native ATFL. Knee Surg Sports Traumatol Arthrosoc. 2016;24(4):1015–21.
10. Sugimoto K, Takakura Y, Kumai T. Reconstruction of the lateral ankle ligaments with bone-patellar tendon graft in patients with chronic ankle instability. Am J Sports Med. 2002;30:340.
11. Coughlin MJ, Schenck RC, Grebing BR, et al. Comprehensive reconstruction of the lateral ankle for chronic instability using a free gracilis graft. Foot Ankle Int. 2004;25:231–41.
12. Pagenstert G, Valderrabano V, Hintermann B. Lateral ankle ligament reconstruction with free plantaris tendon graft. Tech Foot Ankle Surg. 2005;4(2):104.
13. Bottoni CR, Smith EL, Shaha J, et al. Autograft versus allograft anterior cruciate ligament reconstruction: a prospective, randomized clinical study with a minimum 10-year follow-up. Am J Sports Med. 2015;43(10):2501–9.
14. Foster TE, Wolfe BL, Ryan S, Silvestri L, Kaye EK. Does the graft source really matter in the outcome of patients undergoing anterior cruciate ligament reconstruction? An evaluation of autograft versus allograft reconstruction results: a systematic review. Am J Sports Med. 2010;38(8):189–99.
15. Barber FA, Cowden 3rd CH, Sanders EJ. Revision rates after anterior cruciate ligament reconstruction using bone-patellar tendon-bone allograft or autograft in a population 25 years old and younger. Arthroscopy. 2014;30(4):483–91.
16. Takao M, Oae K, Uchio Y, et al. Anatomical reconstruction of the lateral ligaments of the ankle with a gracilis autograft. Am J Sports Med. 2005;33:814–23.
17. Takao M, Inanami K, Matsushita T, Uchio Y, Ochi M. Arthroscopic and magnetic resonance image appearance and reconstruction of the anterior talofibular ligament in cases of apparent functional ankle instability. Am J Sports Med. 2008;36(8):1542.
18. Kong A, Cassumbhoy R, Subramaniam RM. Magnetic resonance imaging of ankle tendons and ligaments: part 1—anatomy. Australas Radiol. 2007;1:315–23.
19. Chew K, Stevens KJ, Wang TG, et al. Introduction to diagnostic musculoskeletal ultrasound: part 2: examination of the lower limb. Am J Phys Med Rehabil. 2008;87:338–48.
20. Rasumussen OS. Sonography of tendons. Scand J Med Sci Sports. 2000;10:360.
21. Bianchi S, Martinoli C, Gaignton C, et al. Ultrasound of the ankle: anatomy of the tendons, bursae, and ligaments. Semin Musculoskelet Radiol. 2005;9(3):243–59.
22. Khoury V, Guillilin R, Dhanju J, et al. Ultrasound of ankle and foot: overuse and sports injuries. Semin Musculoskelet Radiol. 2007;11(2):149–61.
23. Jan ST, Cameron B, Tobias DH, et al. Magnetic resonance imaging of the ankle at 3.0 tesla and 1.5 tesla in human cadaver specimens with artificially created lesions of cartilage and ligaments. Invest Radiol. 2008;3:604–11.
24. Kemmochi M, Sasaki S, Fujisaki K, et al. A new classification of anterior talofibular ligament injuries based on ultrasonography findings. J Orthop Sci. 2016;21(6):770–778.