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ORIGINAL PAPER

# All-arthroscopic anatomical reconstruction of anterior talofibular ligament using semitendinosus autografts

Bin Song[1] · Changchuan Li[2] · Na Chen[3] · Zhong Chen[1] · Yan Zhang[2] · Yunfeng Zhou[1] ·
Weiping Li[1]

## Abstract
*Purpose* We introduced a new technique of all-arthroscopic anatomical anterior talofibular ligament (ATFL) reconstruction using semitendinosus autografts.

*Methods* From June 2012 to June 2013, 28 patients with chronic ATFL rupture underwent arthroscopic anatomic reconstruction of the ATFL. They were divided into the Broström group ($n = 16$) and reconstruction group ($n = 12$). The American Orthopaedic Foot and Ankle Society (AOFAS) score and visual analogue score (VAS) was recorded before the operation, 12 months after the operation and 30 months after the operation. Physical examination and radiographs were performed in follow-ups.

*Results* The patients had higher AOFAS score after the operation in both the Broström group and the reconstruction group. 12 months after operation, the patients in the reconstruction group showed significantly higher AOFAS score and lower VAS score than those in the Broström group ($P = 0.003$ and 0.001, respectively), while the difference between the two groups was not statistically significant 30 months later ($P = 0.425$ and 0.323, respectively). Contemporary numbness of the lateral dorsal part of the foot appeared in one (8.3%) patient in the reconstruction group and two (12.5%) patients in the Broström group, and the symptoms diminished after neurotrophic treatment. No other complications, including recurrent instability, were encountered. No donor-side morbidity such as infection or delayed wound healing was observed.

*Conclusions* The novel surgical technique enhanced post-operative rehabilitation by providing better ankle joint function than modified Broström procedure at 12 months after operation, while the advantage was not statistically significant 30 months later. The long-term outcome requires further investigation. The technique of all-arthroscopic anatomical ATFL reconstruction using semitendinosus autografts proved to be a viable option for ATFL injuries.

**Keywords** Ankle instability · Sprain · Arthroscopy · Ligament reconstruction

✉ Weiping Li
sportsmedcenter@163.com

1 Department of Sports Medicine, Sun Yat-sen Memorial Hospital, No.107 on Yanjiang Road West, 510120 Guangzhou, Guangdong, China

2 Department of Orthopaedic Surgery, Sun Yat-sen Memorial Hospital, No.107 on Yanjiang Road West, 510120 Guangzhou, Guangdong, China

3 Department of GCP, Sun Yat-sen Memorial Hospital, No.107 on Yanjiang Road West, 510120 Guangzhou, Guangdong, China

## Introduction

Lateral ankle ligament injuries rank among the most common ankle injuries. They may progress to chronic ankle instability without appropriate treatment in many patients. According to previous studies, approximately 20% of these patients have symptoms and chronic instability [1], and as many as 20–40% of them require surgical treatment [2].

Various methods have been introduced for the surgical treatment of chronic lateral ankle instability. They can be categorized as nonanatomic tenodesis, anatomic ligament repairment and anatomic ligament reconstruction [3]. Although the nonanatomic tenodesis technique has been reported to show a high degree of patient satisfaction [4], it results in altered biomechanics and stress in the subtalar joint [5], which may result in numerous post-operative complications, such as reduced range of motion, instability of the subtalar joint, and ankle pain during walking,

which eventually lead to osteoarthritis [3]. Taking long-term complications into consideration, many surgeons suggest that nonanatomic reconstruction should now be avoided [6]. The modified Broström procedure, as an important method of anatomic ligament repair, is most widely used, and excellent post-operative outcomes have been reported [7–9]. Ankle arthroscopy has been more and more frequently performed in the past decade, for it provides a good view of the joint cavity with less trauma, and an opportunity to treat the injuries at the same time [6]. Arthroscopic modified Broström procedures have been performed in the arthroscopic construction of the anterior talofibular ligament (ATFL) and calcaneofibular ligaments (CFL) [10–13]. However, the modified Broström procedure was not favourable for some cases with the atactic ligament, where the anatomic reconstruction with tendon grafts to retrieve the stability of the ankle joint is necessary. In 2012, we proposed a new method of all-arthroscopic ATFL anatomic reconstruction using the semitendinosus tendon fixed with double suture anchors to the tibia, and carried out scheduled follow-ups to investigate the post-operative outcome. The purpose of this study was to compare the post-operative outcomes between the novel reconstruction method and the modified Broström method. Our hypothesis was that the post-operative outcomes of the anatomic reconstruction method was better than that of the modified Broström procedure.

## Materials and methods

We performed a retrospective study of 28 patients (28 ankles) who were diagnosed with ATFL injury and underwent ATFL reconstruction in our hospital from June 2012 to June 2013. They were divided into the Broström group ($n = 16$) and the reconstruction group ($n = 12$), according to the surgical technique of ATFL reconstruction. In the Broström group, an arthroscopic modified Broström procedure was performed; while in the reconstruction group, an arthroscopic double-band ATFL anatomic reconstruction using the semitendinosus tendon fixed with suture anchors was performed (elaborated in the "Surgical technique" section below). This study has been reviewed by the institutional review board of Sun Yat-sen Memorial Hospital, and therefore has been performed in accordance with the 1964 Helsinki declaration and its later amendments.

The inclusion criteria were as follows:

1. ATFL lesion without CFL injury, confirmed by magnetic resonance image (MRI), or varus stress test and anterior drawer test compared with the contralateral ankle joint
2. History of repeated ankle sprains for more than six months

3. Anterior talar translation exceeding 10 mm or a discrepancy greater than 3 mm, compared with the contralateral ankle joint

The exclusion criteria were as follows:

1. Previous lateral ankle ligament repairment or reconstruction
2. Severe cartilage injury or osteoarthritis of the ankle
3. Subtalar instability
4. Other conditions such as hyperlaxity syndromes, morbid obesity, paralysis, and reluctance to participate in follow-up

Patients were evaluated using visual analogue score (VAS) system, American Orthopaedic Foot and Ankle Society (AOFAS) score and anterior drawer sign. All the procedures were performed by the senior author.

## Surgical technique

### Graft preparation

The semitendinosus tendon graft was harvested through an anteromedial vertical tibial incision at the pes anserinus, about 3–4 cm long, at approximately 1.5 cm inside the tibial tubercle. The soft tissue, as well as the tapered part of tendon, was removed (Fig. 1). The tendon graft was pre-loaded under 15 lb for ten minutes.

### Debridement

The patient was placed in the supine position, and a tourniquet was applied. A 2.7-mm, 30° arthroscope was introduced through the standard anteromedial portal. And another standard anterolateral portal was made. A shaver was inserted into the anterolateral portal to debride the lateral groove. The inflammatory scar tissue around the
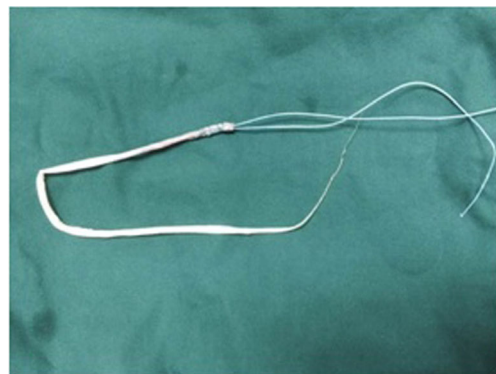


**Fig. 1** The semitendinosus tendon grafts were harvested, and the tendons were cleaned of soft tissue. Additionally, their tapered parts were removed

**Fig. 2** **a**, **b** The scarred ATFL is resected from its fibular insertion to its talar insertion, so as to expose its attachments clearly; **c** a shaver is transferred to this portal to make a groove of about 0.8 cm in length, **d** along the anterior inferior boarder of the fibula in the footprint of the ATFL
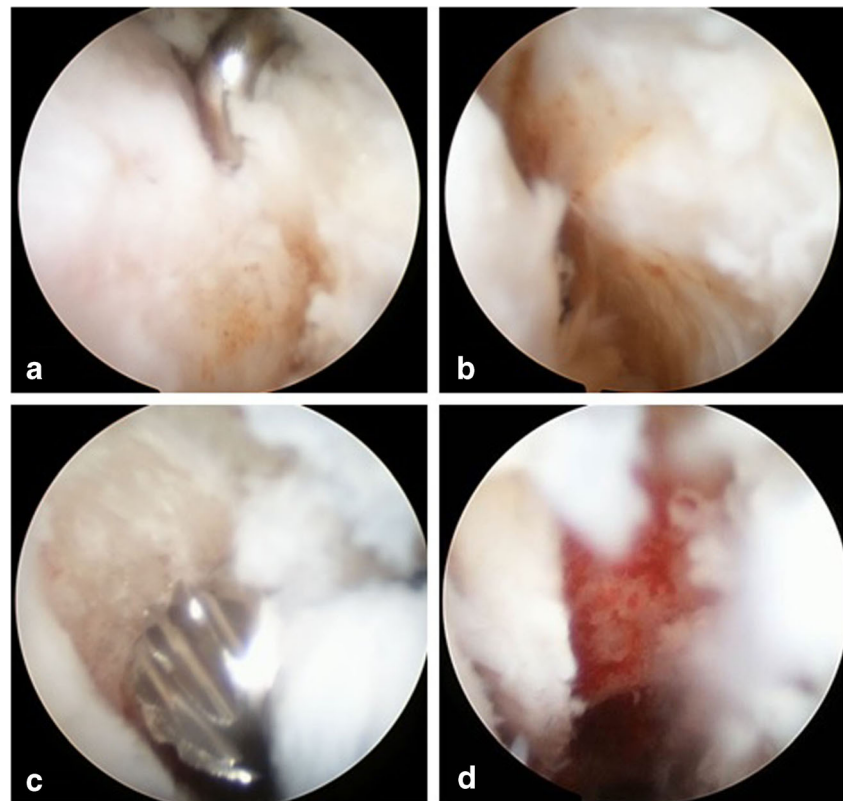
ATFL was resected, from the tibia to the lateral malleolus, until the fibular insertion was exposed. The scarred ATFL was then resected from its fibular insertion to its talar insertion, so as to expose its attachments clearly (Fig. 2a–b). The median portal was made, and the arthroscope could be transferred to the median portal to make the debridement much easier.

*Fibular groove preparation*

The forth portal is made at the sinus tarsi, in the two lines intersection of the anterior edge of the fibula and the superior edge of the peroneus brevis tendon. A shaver is transferred to the this portal to make a groove for about 0.8 cm in length along the anterior inferior boarder of the fibula in the footprint of the ATFL (Fig. 2c–d). A drill guide is inserted through the anterolateral portal to the inferior part of the groove to make the landmark for the first anchor (Fig. 3a–b), the second drill guide is inserted through the forth portal to the superior part as the landmark for the second anchor (Fig. 3c–d). The distance between the two anchors is about 0.6 cm. Two 2.8-mm suture anchors (Smith & Nephew, Andover, MA, USA) were inserted into the landmarks of the fibula respectively through the anterolateral portal and the forth portal (Fig. 3e).

*Talus groove preparation*

The arthroscope was transferred to the median portal and a shaver was put into the fourth portal to debride the ATFL's talar attachment (Fig. 3f). Then a groove was made in the footprint of the talar attachment, and a drill guide was inserted through the fourth portal to the talus footprint as a landmark. A 3.5-mm suture anchor was deployed and the suture released (Fig. 4a).

*The graft implantation*

The graft was inserted through the anterolateral portal, and led out through the fourth portal, then the graft was put into the groove, and the polyethylene suture materials attached to the anchors were sutured and tied in the middle 6 mm of the graft. The graft was loaded with the ankle slightly everted and fixed to the fibula, and the suture materials of the talar attachment were sutured and tied with the graft. Later, the redundant grafts were removed (Fig. 4b).

**Post-operative rehabilitation**

After the operation, the ankle was immobilized in a slightly everted position by Aircast™ (DJO, Vista, CA, USA). Rehabilitation exercises including isometric contraction of muscle groups around the ankle joint were started from the day after
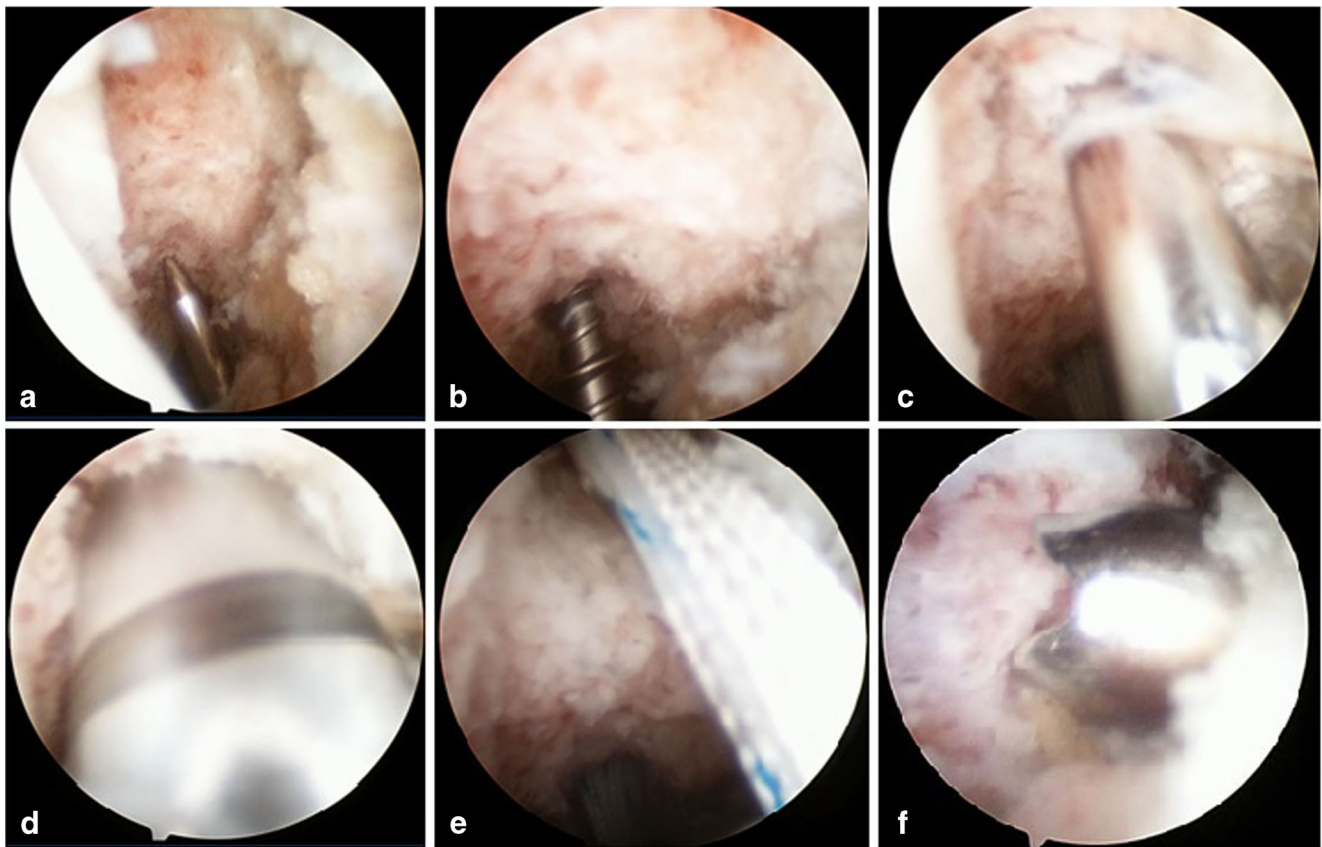
**Fig. 3** **a-e** A drill guide is inserted to the inferior part of the groove to make the landmark for the first anchor, the second drill guide is inserted to the superior part as the landmark for the second anchor. Two 2.8-mm suture anchors (Smith & Nephew, Andover, MA, USA) were inserted into the landmarks of the fibula respectively. **f** A drill guide was inserted to the talus footprint of ATFL as a landmark

surgery, and weight bearing was permitted after two weeks with the cast. The Aircast was removed six weeks after surgery.

*Follow-up*

The American Orthopaedic Foot and Ankle Society (AOFAS) score was recorded pre-operatively, 12 months after operation and 30 months after operation, to assess the ankle joint function. Clinical examination and conventional radiographs were performed in all patients (Fig. 5).

**Statistical analysis**

In order to compare the pre-operative and post-operative AOFAS score, Student's *t*-test for paired samples was applied for parametric data. Mann-Whitney *U* test was used for ranked

**Fig. 4** **a** *A* is the landmark for the superior anchor, and *B* is the landmark for the inferior anchor. The distance between the two landmarks is about 0.6 cm. **b** The graft was inserted into the groove and the polyethylene suture materials attached to the anchors were sutured and tied in the middle of the graft. The suture materials of the talar attachment were sutured and tied with the graft; finally, the redundant part of graft was cut
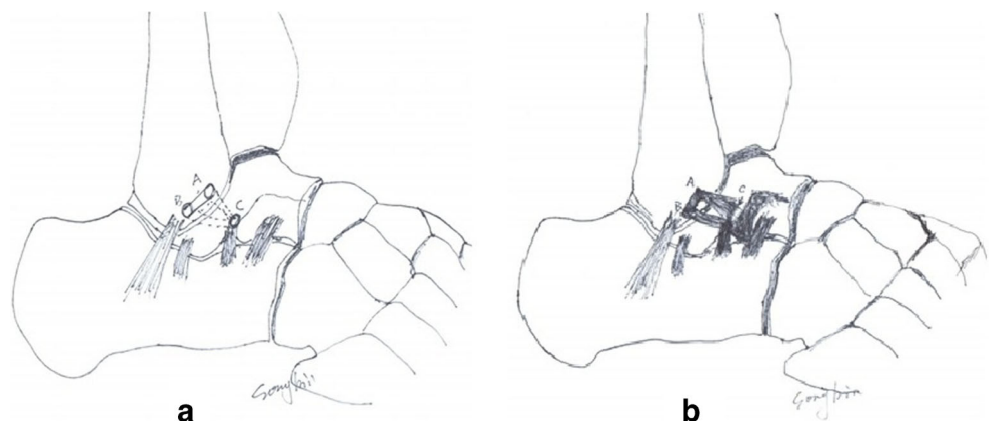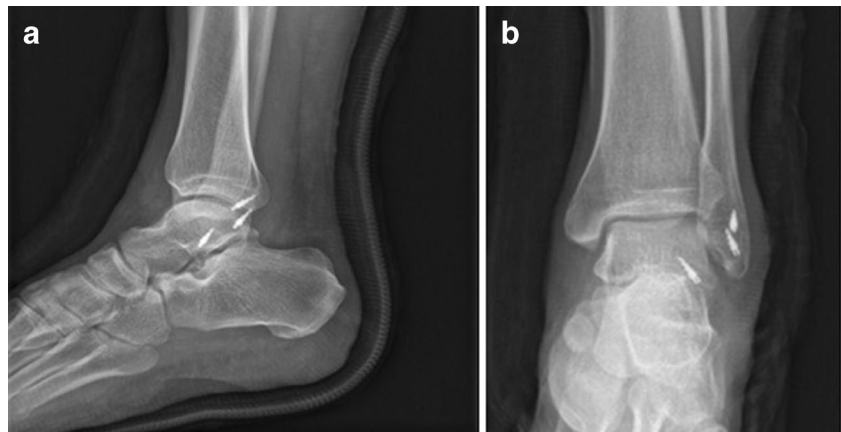
**Fig. 5** Conventional radiographs were performed postoperatively **a** in the lateral position and **b** in the anterior-posterior position



data. A value of $P < 0.05$ was considered statistically significant. Statistical analysis was performed by the computer program SPSS version 21.0 (SPSS, Chicago, IL, USA).

## Results

Demographic data, duration of follow-up, and pre-operative and post-operative AOFAS scores of the patients were summarized (Table 1). Sex distribution, age, duration of follow-up, VAS score and pre-operative AOFAS score of the Broström group and the reconstruction group were comparable. The patients had higher AOFAS score and lower VAS score after the operation in both groups. At the time point of 12 months after operation, the patients in the reconstruction group showed significantly higher AOFAS score and lower VAS score than those in the Broström group ($P = 0.003$ and 0.001, respectively), while the difference between the two

**Table 1** Demographic data, duration of follow-up, preoperative and postoperative AOFAS scores of the patients

| No. | Group | Sex | Age (years) | Follow-up (months) | VAS score | | | AOFAS score | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Preoperative | 6 months after operation | 12 months after operation | Preoperative | 6 months after operation | 12 months after operation |
| 1 | Reconstruction | M | 18 | 13 | 6 | 0 | 0 | 62 | 100 | 100 |
| 2 | Reconstruction | M | 32 | 13 | 6 | 2 | 1 | 64 | 94 | 96 |
| 3 | Reconstruction | M | 30 | 14 | 5 | 0 | 0 | 66 | 100 | 100 |
| 4 | Reconstruction | F | 31 | 15 | 7 | 3 | 1 | 49 | 82 | 86 |
| 5 | Reconstruction | M | 26 | 16 | 7 | 4 | 1 | 58 | 80 | 85 |
| 6 | Reconstruction | F | 28 | 18 | 4 | 1 | 0 | 65 | 97 | 95 |
| 7 | Reconstruction | F | 27 | 20 | 5 | 2 | 1 | 54 | 90 | 93 |
| 8 | Reconstruction | M | 19 | 22 | 4 | 1 | 0 | 65 | 97 | 95 |
| 9 | Reconstruction | M | 25 | 24 | 4 | 2 | 0 | 64 | 94 | 93 |
| 10 | Reconstruction | M | 27 | 25 | 6 | 3 | 1 | 58 | 85 | 90 |
| 11 | Reconstruction | M | 29 | 26 | 5 | 0 | 0 | 66 | 100 | 100 |
| 12 | Reconstruction | M | 20 | 26 | 5 | 0 | 0 | 64 | 100 | 100 |
| 13 | Broström | M | 17 | 14 | 5 | 4 | 1 | 63 | 86 | 95 |
| 14 | Broström | M | 26 | 13 | 4 | 3 | 0 | 66 | 91 | 100 |
| 15 | Broström | M | 28 | 12 | 4 | 3 | 0 | 68 | 94 | 100 |
| 16 | Broström | M | 26 | 16 | 6 | 4 | 0 | 54 | 89 | 95 |
| 17 | Broström | M | 36 | 14 | 5 | 4 | 1 | 53 | 85 | 91 |
| 18 | Broström | M | 35 | 13 | 5 | 4 | 0 | 66 | 88 | 97 |
| 19 | Broström | M | 19 | 18 | 6 | 4 | 0 | 51 | 80 | 95 |
| 20 | Broström | M | 18 | 16 | 5 | 3 | 2 | 68 | 86 | 89 |
| 21 | Broström | F | 34 | 22 | 5 | 2 | 1 | 68 | 91 | 93 |
| 22 | Broström | F | 32 | 26 | 5 | 3 | 1 | 66 | 84 | 91 |
| 23 | Broström | F | 19 | 21 | 6 | 3 | 1 | 53 | 83 | 90 |
| 24 | Broström | F | 18 | 20 | 4 | 3 | 2 | 60 | 85 | 89 |
| 25 | Broström | F | 36 | 18 | 6 | 3 | 1 | 49 | 80 | 88 |
| 26 | Broström | F | 35 | 13 | 5 | 3 | 0 | 53 | 86 | 90 |
| 27 | Broström | F | 32 | 12 | 6 | 4 | 1 | 51 | 81 | 89 |
| 28 | Broström | F | 33 | 13 | 4 | 2 | 0 | 60 | 90 | 96 |

groups was not statistically significant at the time point of 30 months after operation ($P = 0.425$ and 0.323, respectively) (Table 2). The anterior drawer test was negative in all patients of both groups.

At the last follow-up, 11 (91.7%) patients in the reconstruction group did not have any pain. All patients rated their outcome as excellent or good (75 and 25%, respectively), and none of the patients rated the outcome as fair or poor. In the reconstruction group, complications were observed in one (8.3%) patient, who had undergone transient sural neuritis, which diminished after neurotrophic treatment for about three months. In the Broström group, contemporary numbness of lateral dorsal part of foot appeared in two (12.5%) patients. The numbness in the two patients disappeared after neurotrophic treatment for three and 12 months respectively. Neither had recurrent sprains or instability. No other complications, including recurrent instability, were encountered. No donor-side morbidity, such as infection or delayed wound healing, was observed.

## Discussion

Ankle arthroscopy became more and more popular in the past decade, for it provides a good view of the joint cavity with less trauma, and an opportunity to treat the injuries at the same time [6, 14]. An arthroscopic modified Broström procedure has been applicated for ATFL injury, while restricted to some limitations. In this study, we proposed a new method of all-arthroscopic ATFL anatomic reconstruction, and achieved satisfactory post-operative outcomes.

**Table 2** Comparison of basic characteristics, duration of follow-up, pre-operative and post-operative AOFAS scores in the Broström group and the reconstruction group

|  | Broström | Reconstruction | P |
|---|---|---|---|
| Sex |  |  | 0.180 |
| Male | 8 | 9 |  |
| Female | 8 | 3 |  |
| Age (years) | 27.75 ± 7.34 | 26.00 ± 4.69 | 0.477 |
| Follow-up (months) | 16.31 ± 4.16 | 19.33 ± 5.14 | 0.097 |
| VAS score |  |  |  |
| Pre-operative | 13.72 | 15.54 | 0.541 |
| 6 months after operation | 18.75 | 8.83 | 0.001 |
| 12 months after operation | 15.69 | 12.92 | 0.323 |
| AOFAS score |  |  |  |
| Pre-operative | 59.31 ± 7.15 | 61.25 ± 5.39 | 0.440 |
| 6 months after operation | 86.19 ± 4.119 | 93.25 ± 7.338 | 0.003 |
| 12 months after operation | 93.00 ± 3.950 | 94.42 ± 5.316 | 0.425 |

Parametric data were expressed by mean ± standard deviation, and non-parametric data were expressed by mean of ranks

Postoperative outcomes assessed at the time point of 30 months after operation were similar among patients who received the modified Broström procedure and those who received all-arthroscopic ATFL anatomic reconstruction by the novel method. It is worth mentioning that patients who received ATFL reconstruction by the novel method showed better ankle joint function than those who received modified Broström procedure at 12 months after operation. The new surgical technique enhanced post-operative rehabilitation by providing excellent short-term post-operative outcome.

The excellent short-term outcome might be attributed to the thorough debridement of lateral ankle in the reconstruction surgery, where the inflammatory tissue was removed. Besides, patients who received ATFL reconstruction surgery could perform early-stage weight-bearing activity compared with those who received the modified Broström procedure. On the other hand, anatomical reconstruction technique instead of merely repairment of the ligament might also made a contribution to the excellent short-term outcome.

Nowadays, anatomic lateral ankle reconstruction as an important method has been widely accepted with the excellent outcomes. Several researchers have published their methods of anatomic lateral ankle reconstruction. Guillo et al. [12] described a novel technique for all-arthroscopic anatomical reconstruction of ATFL and the calcaneofibular ligament (CFL). According to the study, the ipsilateral gracilis tendon was harvested as the graft and three bone tunnels were made with a drill in the fibula, talus and calcaneus, respectively. Jason et al. [15] presented a new method of reconstruction, where an all-suture anchor was used arthroscopically to recreate the ATFL. In these studies, the ATFL was depicted as a single band, so the ligament was recreated by single band. But Sarrafian described the ATFL as being composed of two distinct bands, which was also corroborated by Golano et al. [16] later. According to the findings, ATFL is composed of two distinct fibrous bands—namely, superior and inferior—originating from the anterior aspect of the lateral malleolus and inserting slightly anterior to the lateral articular facet of talus. Each individual band was flat and quadrilateral in shape, and allowed for vascular branches of the perforating peroneal artery with its connection to the lateral malleolar artery [16]. Anatomic details on the superior and inferior bands of ATFL has been reported. The fibular footprint centers of the superior and inferior bands averaged 16.3 and 10.2 mm respectively at the anterior fibular border, and the distance between the two centers was about 6.9 mm in average. With regard to the talar attachment sites, the centers of the superior band footprints and the inferior band was 21.1 and 10.2 mm from the apex of the lateral talar process, with the distance between the two footprints 11.4 mm from each other on average [17]. In a prospective, randomized study, the researchers compared the clinical outcomes of the single-band and double-band modified Broström procedure for chronic lateral ankle instability,

and came to the conclusion that the mechanical stability of ankle was better in the double anchor group, even though both single and double suture anchor techniques seemed effective with similar clinical and functional outcomes [18].

On the basis of previous anatomical and clinical studies, we proposed the double-band ATFL reconstruction technique in this study. Two anchors were inserted into the landmarks of the anterior inferior boarder of the fibula, with the distance between each other about 6 mm in the footprint of the ATFL. Another groove was made in the footprint of the talar attachment, where one 3.5-mm suture anchor was inserted. The semitendinosus tendon autograft was attached to the three anchors by polyethylene suture materials. The 3.5-mm suture anchor had two polyethylene sutures, which fixed the two ends of the graft respectively. As a consequence, exact anatomic reconstruction of ATFL was accomplished. All the operative procedures were performed arthroscopically.

Several kinds of fixation technique have been used in reconstruction of the ankle lateral ligaments. In the transosseous tunnel fixation technique, the graft was routed through an osseous tunnel. It was a popular choice for lateral ligament reconstruction, which was used in many procedures, such as the modified Evans [19], Watson-Jones [20], and so on. The technique achieved a satisfactory surgical outcome. It promoted tendon-bone healing in the bone tunnel, and increased the pull-out strength [21], while the disadvantage was also obvious, for the surgical technique was quite difficult to handle, and thus increase the risk of the bony bridge fracture, especially in the talus. In 2003, Jeys et al. [22] first reported the use of interference screws for ATFL reconstruction, and got satisfactory clinical outcomes, which made the interference screws additional well-known candidates for ATFL reconstruction. Although interference screw fixation could provide higher failure strength [23], it is still limited by disadvantages of the transosseous tunnel fixation technique, such as increased risk of bony bridge fracture, and may disrupt the graft fibers, which may decrease the pull-out strength and increase the risk of recurrent injury [24].

Compared with the techniques mentioned above, the suture anchor technique has several advantages, such as shorter incisions, smaller range of dissection, less difficulty to handle, reduced risk of fracture, and good preservation of the range of joint motion [21]. In a biomechanical study, researchers compared the biomechanical characteristics of the suture anchor technique with transosseous tunnel fixation of the graft on the talus in ankle lateral ligaments reconstruction on human cadaveric ankles. The results showed that the failure loads of the two techniques were no less than that of normal ATFL. The suture anchor technique was effective for graft fixation in lateral ligament reconstruction [25]. In this study, we used three anchors to fix the graft (two anchors in the fibula and one in talus). The novel technique was quite easy, and required less dissection. The post-operative outcomes were satisfactory.

## Limitations

Limitations of our study include a relatively small sample size, the retrospective design, and a relatively short duration of follow-up. It is also recognized that the shape of the graft is more like a triangle, not exactly the same as the anatomical form of ATFL. Nevertheless, the double-band tendon graft in this innovative technique is much more similar to natural ATFL than the single-band technique. Furthermore, preoperative and postoperative stress radiography was not quantitative, and the AOFAS score was the only criterion to assess the functional status.

## Conclusions

We proposed a novel surgical technique for all-arthroscopic anatomical ATFL reconstruction using semitendinosus autografts fixed with double suture anchors. The novel surgical technique enhanced post-operative rehabilitation significantly. Meanwhile, it provided a relatively easy way to accomplish the anatomical reconstruction of ATFL, with low risk of complications and satisfactory long-term outcomes.

**Compliance with ethical standards**

**Conflict of interest**  The authors declare that they have no conflict of interest.

**Ethical approval**  This is a retrospective case-control study. For this type of study, formal consent is not required.

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