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The precision of technical aspects in the minimally invasive Broström–Gould procedure: a cadaveric anatomical study

Guolei Zhang[1*], Wenqing Li[1*], Haibo Yao[1], Rongzhi Tan[1] and Chuyan Li[1]

Abstract

Background A comprehensive understanding of the anatomy of the anterolateral ankle joint and its interrelationships is essential for advancing the development of minimally invasive Broström–Gould procedure, thereby enhancing surgical efficacy and minimizing postoperative complications.

Methods Ten fresh human ankle specimens were dissected to observe the shape and trajectory of the lateral bundle of the inferior extensor retinaculum (IER) and its relationship with the deep fascia. To observe the relationship between the ankle capsule and the anterior talofibular ligament (ATFL). The center of the insertion point of ATFL at the lateral malleolus was used as the reference point. The vertical distance from the reference point to the fibula tip, the horizontal distance from the reference point to the lateral branch of the superficial peroneal nerve, the shortest distance from the reference point to IER, the narrowest width of the IER, the angle between the line connecting the shortest distance from the reference point to the IER and the longitudinal axis of the fibula were measured. The tension and elasticity of ATFL was understood. To describe the minimally invasive Broström–Gould procedure according to the anatomical characteristics of the anterolateral ankle joint.

Results Among the 10 cases, 8 cases (80%) had double bundles of ATFL, 2 cases (20%) had single bundle of ATFL, and no outer superior oblique bundle was observed in IER. The vertical distance from the reference point to the fibula tip was 1.2±0.3 (range 1.1–1.3) mm. The shortest distance from the reference point to the level of the superficial peroneal branch was 28.2±4.3 (range 24.5–32.4) mm. The shortest distance from the reference point to IER was 12.5±0.6 (range 12.1–12.9) mm, and the width of IER at this point was 7.2±0.3 (range 7.0–7.6) mm. The angle between the line connecting the shortest distance from the reference point to the IER and the longitudinal axis of the fibula was about 60°±2.8° (range 58.1°–62.1°) mm. The space between the anterolateral deep fascia of the ankle joint and the ankle capsule is very small, and only a few fat granules are separated between them. The ATFL is largely fused to the ankle capsule. The ATFL exhibited high tension and poor elasticity after traction with the probe hook.

Conclusions The results showed that in the minimally invasive Broström–Gould technique for lateral ankle stabilization, the Broström procedure actually sutured the insertion of the ATFL together with the ankle capsule to the anterior edge of the lateral malleolus. In the Gould procedure, the deep fascia was mostly reinforced with the ankle capsule.

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The minimum suture span was obtained when the Gould suture needle direction was at an Angle of 60° to the longitudinal axis of the fibula.

Keywords Broström–Gould, Cadaveric dissection, Ankle ligment, IER, Repair

Ankle sprain is a prevalent sports injury [1–3], with reports indicating that athletes have an incidence rate of lateral collateral ligament injuries as high as 45% [4, 5]. Chronic ankle sprains are primarily caused by inadequate treatment, mistreatment, or overuse of acute ankle sprains. Chronic lateral ankle instability (CLAI) is the most common cause of ankle sprain. It has been reported that up to 20–40% of ankle sprain will develop into CLAI [6–8]. Freeman [9] identified two types of chronic ankle instability: Mechanical Ankle Instability (MAI) and Functional Ankle Instability (FAI). MAI occurs when joint mobility exceeds the physiological range due to weak stable structures in the ankle joint resulting in patients feeling "joint laxity." FAI refers to subjective feelings of instability leading to weakened sensory movement and neuromuscular defects causing abnormal voluntary control of joint movement but normal range without mechanical instability.

Hinterman [10] classified the degree of CLAI injury into three grades through ankle arthroscopy: Grade I represents ligament strain without significant tear; Grade II indicates incomplete tearing of ligaments, resulting in mild to moderate ankle instability and partial loss of ankle function; Grade III signifies complete rupture of the ligament, leading to complete loss of function and instability. In clinical practice, conservative treatment is initially recommended for CLAI, with surgery being considered if symptoms do not improve or worsen after 3–6 months of conservative treatment. The surgical techniques include anatomical repair [11, 12], anatomical reconstruction [13–15], and non-anatomical reconstruction [16, 17]. Anatomic repair of the ATFL offers advantages such as minimal surgical trauma, simplicity in operation, and favorable postoperative recovery; thus it is currently regarded as the preferred choice for repairing the ligament. Broström [18] procedure has been widely adopted by foot and ankle surgeons as a classic surgical technique for ATFL repaired. With further understanding and research on CLAI, Broström–Gould [19] procedure has been recognized as a modified approach yielding optimal outcomes. Numerous clinical studies have also substantiated this viewpoint [20–22].

Currently, there is a substantial body of clinical and biomechanical research on the Broström–Gould procedure [23, 24]; however, there are few reports on the anatomical study of the anterolateral ankle joint at each anatomical level. The aim of this study is to conduct an anatomical investigation into the precise execution of the Broström–Gould procedure by examining the relationship between ATFL, IER, and anterolateral ankle joint. Additionally, we aim to elucidate the anatomical significance across different levels of the anterolateral ankle joint and evaluate the impact of meticulous clinical intervention.

Material and method

The rationale behind the shape and trajectory of the IER's lateral bundle and its association with the deep fascia remains unspecified in light of preceding studies and the distance of the ATFL insertion point to the tip of the fibula, the lateral branch of the superficial peroneal nerve, and the IER has been reported [25]. The data in our study were re-measured to ensure consistency between the measured data, anatomical levels, and described surgical procedures within the same cadaver specimen, thereby enhancing the accuracy of the study results.

Study design

Ten fresh human ankle specimens were selected based on the following inclusion criteria: intact skin and subcutaneous tissue, adult age, and absence of osteoporosis. Specimens with previous ankle injuries, minors, or osteoporosis were excluded. The dissected ankle joint specimens were used to examine the relationship between the layers of IER, deep fascia, ankle capsule, and ATFL. The anatomical characteristics of ATFL were assessed along with measuring the shortest distance from its insertion point at the lateral malleolus to IER. The tension and elasticity of ATFL was understood by traction with a probe hook. Based on these measurements and observations, a detailed description was provided for both suture layers and suture angles involved in Broström–Gould procedure while evaluating its precise effectiveness.

Anatomical procedures and data measurements

From the middle and lower part of the lower leg to the calcaneus, the skin and subcutaneous tissue were cut longitudinally along the middle side of the lower leg, the skin was opened to both sides, the fat tissue in the superficial layer of the deep fascia was removed, and the integrity of the superficial peroneal nerve of the dorsal foot was protected. To observe the shape and trajectory of IER lateral bundle and its relationship with the deep fascia. To observe the morphology and texture of the deep dorsal fascia of the foot and ankle. The deep fascia was

cut sharply at the anterior edge of the lateral malleolus, and the deep fascia was raised. The relationship between the deep fascia and the ankle capsule was observed. The ankle capsule was dissected longitudinally at the anterior border of the lateral malleolus to observe the relationship between the ankle capsule and the ATFL. The ATFL was exposed and observed to be composed of several bundles. The tension and elasticity of the ATFL was understood by traction with a probe hook. The insertion point of the ATFL at the lateral malleolus was determined, and the center of the insertion point was used as a reference point. The vertical distance from the reference point to the fibula tip, the horizontal distance from the reference point to the lateral branch of the superficial peroneal nerve, the shortest distance from the reference point to IER, the narrowest width of the IER, the angle between the line connecting the shortest distance from the reference point to the IER and the longitudinal axis of the fibula were measured.

Statistic analysis

The measurements were conducted in triplicate and the average value was utilized for data calculation. The collected data were analyzed and processed using SPSS-22.0 statistical software, with the results presented as mean ± standard deviation ($\bar{x} \pm s$). All descriptive statistics underwent normality testing through the S−W test.

Results

In all the ankle specimens of 10 cases in this study, only the lateral bundle of IER was observed, while no superior oblique bundle was detected. There is a distinct transitional region at the border of the lateral bundle of IER, gradually merging with the deep fascia. A resilient deep fascia exists between the lateral bundle of IER and the anterior edge of the lateral malleolus (Fig. 1). The horizontal mobility of this deep fascia is limited, making it challenging to pull the lateral bundle of IER towards the anterior edge of the lateral malleolus (Fig. 2). At the anterior edge of the lateral malleolus, there is an elevation in both layers: a raised deep fascia and a small amount of adipose tissue between it and ankle joint capsule. The differentiation between these two layers primarily relies on fiber texture. The majority portion (single or double bundles) of ATFL appears fused with joint capsule, making it difficult to completely distinguish from it. The ATFL exhibited high tension and poor elasticity after traction with the probe hook. (Fig. 3).

Regarding the morphology of the ATFL, 8 out of 10 specimens (80%) exhibited double fascicles, while the remaining 2 specimens (20%) had single fascicles. The vertical distance from the reference point to the fibula tip measured 1.2 ± 0.3 mm (range: 1.1–1.3 mm).
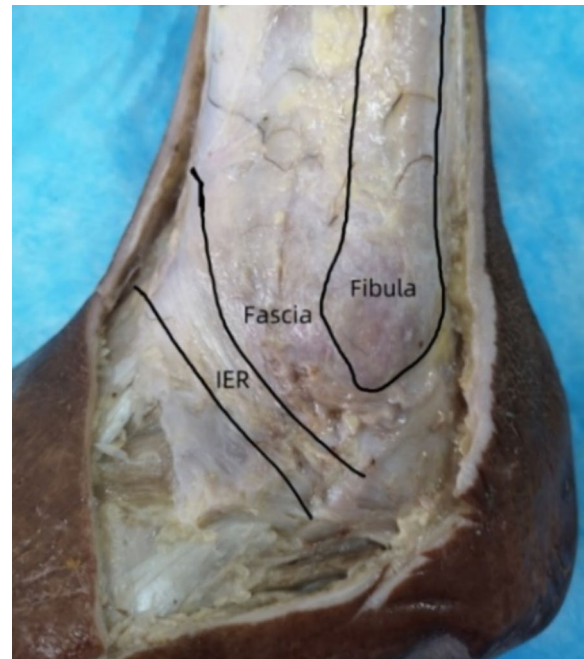

Fig. 1 The Fibula and IER are connected by the deep fascia
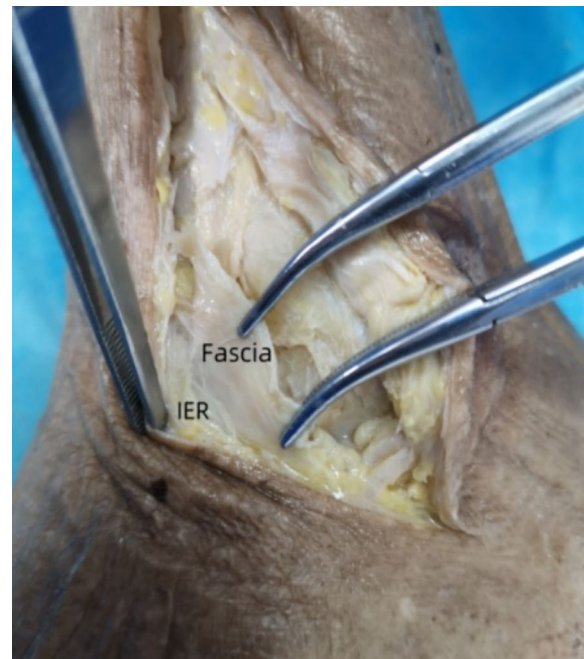

Fig. 2 The deep fascia exhibited a significant degree of mobility; the IER activity was minimal

The shortest distance from the reference point to the level of the superficial peroneal branch was found to be 28.2 ± 4.3 mm (range: 24.5–32.4 mm). Similarly, the shortest distance from the reference point to IER was

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Fig. 3 The gap between IER and joint capsule was small; THE joint capsule was partially fused to the ATFL; the ATFL is in high tension. (**A** joint capsule, **B** deep fascia, **C** ATFL)
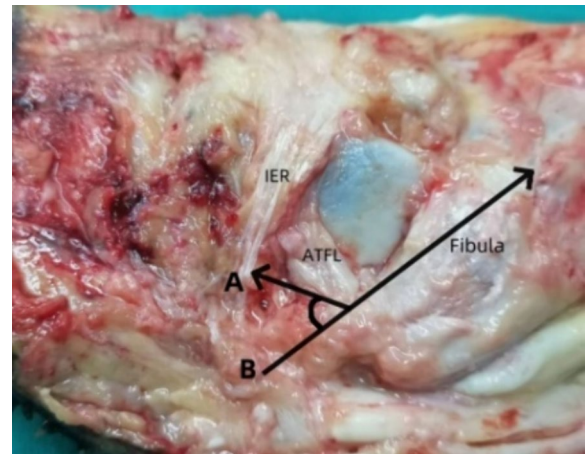

Fig. 5 The angle between A and B was measured. (**A**-The wire with the shortest distance from the insertion point of the ATFL to the IER) (**B**-Axis of fibula)

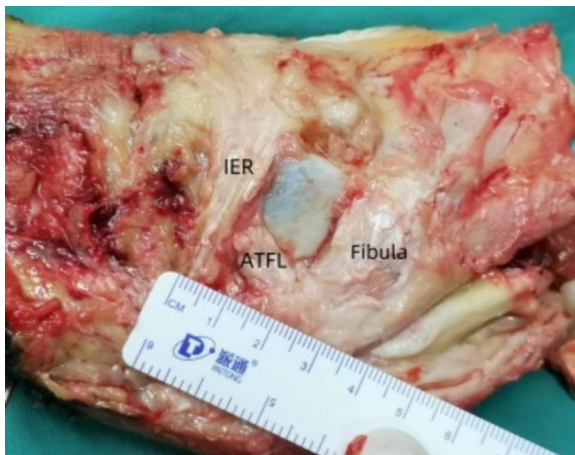**Fig. 4** The distance from insertion point of the ATFL to IER, SPN and lateral malleolus tip was measured; Width of IER was measured
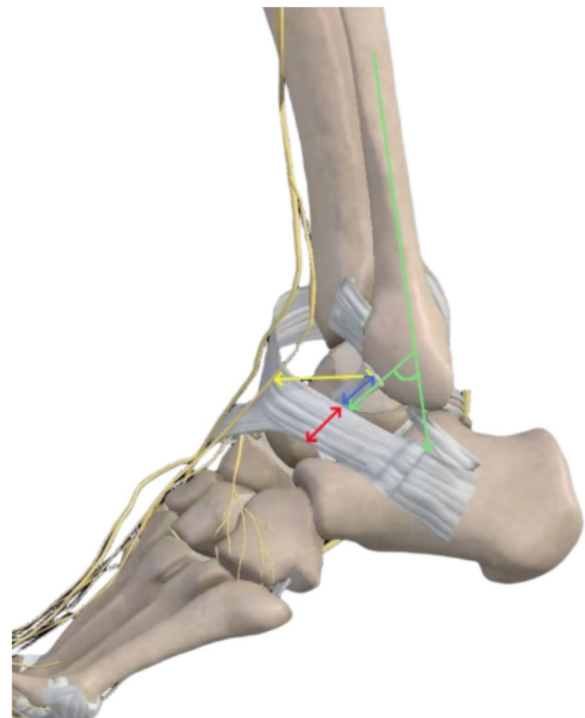

Fig. 6 Chart of data measurement mode in this study

determined as 12.5 ± 0.6 mm (range: 12.1–12.9 mm), with a corresponding width of IER at this location measuring approximately 7.2 ± 0.3 mm (range: 7 0.0–7 0.6 mm). Furthermore, an angle of approximately $60° \pm 2\ 0.8°$ (range: 58 0.1°–62 0.1°) mm was observed between this specific point and both ATFL insertion and fibula longitudinal axis orientations respectively (Figs. 4, 5, 6). All test data demonstrated adherence to normal distribution (Table 1).

Precise Broström–Gould procedure

The rupture of the ATFL and its fibular end insertion were identified during the minimally invasive all-inside arthroscopic surgery. An anchor was placed at the

Table 1 Measurements of the distance from the insertion point of the lateral malleolus of the ATFL (mm)

Specimen	Tip of malleolus	SPN	IER	Width of IER	Angle
1	1.2	28.6	12.5	7.2	60.3°
2	1.3	24.8	12.9	7.6	59.5°
3	1.1	29.7	12.1	7.3	62.1°
4	1.3	32.4	12.1	7.1	60.2°
5	1.2	26.8	12.5	7.3	58.1°
6	1.2	24.5	12.6	7.1	58.5°
7	1.2	25.6	12.4	7.2	59.3°
8	1.1	28.4	12.3	7.2	60.6°
9	1.2	25.6	12.5	7.3	59.8°
10	1.2	28.9	12.5	7	60.2°
Mean ± SD	1.2 ± 0.067	27.53 ± 2.513	12.44 ± 0.237	7.23 ± 0.164	59.86° ± 1.125°
Rang	1.1–1.3	24.5–32.4	12.1–12.9	7–7.6	58.1°-62.1°

SPN, superficial peroneal nerve; IER, inferior extensor retinaculum, ATFL, anterior talofibular ligament; SD, standard deviation

insertion site of ATFL, followed by suturing of both the ligament and joint capsule using a tail line technique. The other anchor was placed below the first one, and the IER was sutured at a 60° Angle with the fibula longitudinal axis in a "fan" shape. The suture depth reached the ankle capsule, and the suture distance was more than 12.5 mm and less than 19.7 mm. The ankle was knotted in dorsiflexion valgus position (Fig. 7).

Discussion

In the treatment of CLAI, the Broström–Gould procedure has demonstrated favorable surgical outcomes and has been widely adopted by scholars. Gould emphasized that suturing the ligament tissue of the anterior inferior part of the lateral malleolus to its anterior edge can effectively enhance lateral stability in ankle joint. However, Gould did not specify the exact location for reinforcing suture placement [19]. Most documented methods currently involve direct pulling of the lateral portion of IER to anchor it onto the periosteum of lateral malleolus [22, 26, 27]. Nevertheless, our experimental findings indicate that IER, particularly its lateral bundle, is highly resilient and challenging to elongate. Additionally, we observed a robust connection between IER and lateral malleolus through tough deep fascia tissue; furthermore, fibrous tissue density increases as it approaches IER. Dalmau [28, 29] noted that successful implementation of Gould's procedure relies on an "X" type retinaculum being present and ensures desired ankle stability after repair. In Abu's study, 5 (14) specimens exhibited an X-shaped structure of the IER. However, Abu [30] emphasized that the IER was formed by thickening of the deep dorsal fascia of the ankle. Our study did not observe an "X" shape in the lateral bundle of IER, which may be attributed to specimen quality;

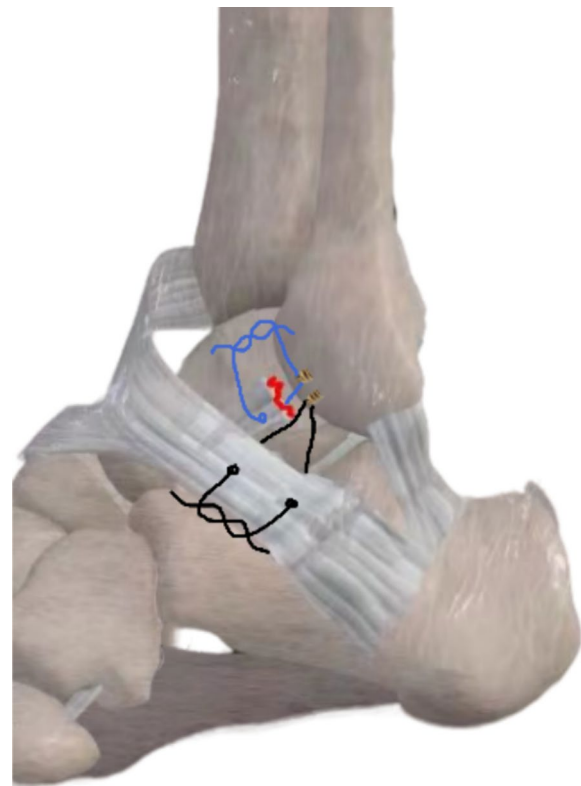**Fig. 7** Precise minimally invasive Broström–Gould procedure simulation diagram

nevertheless, this finding suggests that there is relatively dense fascial fiber connection between the lateral bundle of IER and the insertion point of the ATFL. In our study, we applied vascular forceps to tension and stretch the lateral bundle of IER to its maximum capacity. We believe that regardless of whether the shape of

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IER is "X" or "Y", as long as we sutured a wide area of deep fascia to connect with the lateral bundle effectively, we can achieve optimal tension.

In our study, we observed a narrow space between the deep fascia and the joint capsule in front of the lateral malleolus, with minimal fat tissue separating them. Consequently, distinguishing between these two layers of tissue structure becomes challenging. As a result, during the minimally invasive Gould procedure, it is common practice to suture together the ankle capsule and the deep fascia (specifically, the outer superior oblique bundle of IER) to the anterior edge of the lateral malleolus. Our study compared this combined stretch with that of solely stretching the deep fascia and found that the former exhibited greater tension. Therefore, we conclude that reinforcing sutures involving both joint capsule and IER can achieve maximum tension during minimally invasive Gould procedures.

In this study, we measured that the line connecting the shortest distance from the insertion of the ATFL to the IER was at an angle of approximately 60° with respect to the long axis of the fibula. In minimally invasive Gould procedure, it is recommended to maintain a suture angle of around 60° in order to facilitate drawing more fibrous tissue with enhanced texture. The shortest distance from the insertion point of the ligament to the IER was found to be 12.5 ± 0.6 mm. Therefore, if the length of suture needle exceeds this distance, it would enable effective pulling together of dense fibers within IER and enhance overall suture strength.

In cases of chronic lateral ankle instability with a prolonged duration of injury, we observed that the ATFL stump exhibited flocculation and significant tendon body contracture during arthroscopic or open surgery, rendering direct suturing of the ligament unfeasible. Consequently, it was often necessary to suture the joint capsule and ligament stump to the insertion site on the lateral malleolus during the procedure, resulting in favorable treatment outcomes. Feng [31] reported that there was no statistically significant difference in postoperative outcomes between ATFL stump repair and nonrepair when the all-arthroscopic Brostrom–Gould procedure was used to treat CLAI. In our study, we observed challenges in distinguishing the ankle capsule from the ATFL completely, as a considerable portion of them overlapped with each other. Additionally, we noted that the normal ATFL exhibited significant tension in its anatomical state, requiring substantial stretching to restore it to its original position after artificial cutting at the insertion point. Therefore, during the minimally invasive Broström procedure, we effectively sutured the capsule together with the disrupted end of the ligament to its insertion site. It is possible that the capsule plays a more crucial role in this process, which has been supported by previous reports [24, 32].

When performing minimally invasive Broström–Gould procedure, the crucial consideration lies in avoiding injury to the superficial peroneal nerve. The reported incidence of this complication ranges from 4.54 to 13.3% in clinical practice [32, 33], which may be attributed to factors such as the positioning of the arthroscopic anterolateral approach, the angle of the Gould procedure, and the distance covered by the suture needle. Jorge [34] introduced the concept of a "safe zone" and demonstrated that operating within this zone during arthroscopic Broström technique for lateral ankle stabilization ensures no damage is inflicted upon both the superficial peroneal nerve and tendon. The needle entry angle and suture distance indicated in this study also fall within the range defined by this "safe zone."

The minimally invasive arthroscopic Broström–Gould procedure is increasingly favored by ankle surgeons due to its aesthetic advantages, reduced trauma, and simplified operation. Moorthy [22, 35, 36] pointed out that compared to traditional open repair, arthroscopic repair yields similar clinical outcomes with a lower incidence of wound complications. In cases involving unfamiliar anatomical structures, improper suture techniques under the microscope may have no impact on mild injuries, low BMI or exercise requirements; however, it can increase the risk of failure in severe injuries, high BMI or exercise requirements [37]. Precise suture surgery can maximize reinforcement of the ATFL and IER while achieving favorable results across different patient populations.

Conclusion
The purpose of this study is to show that in the minimally invasive Broström–Gould technique for lateral ankle stabilization, the Broström procedure actually sutured the insertion of the ATFL together with the ankle capsule to the anterior edge of the lateral malleolus. In the Gould procedure, the deep fascia was mostly reinforced with the ankle capsule. The minimum suture span was obtained when the Gould suture needle direction was at an Angle of 60° to the longitudinal axis of the fibula.

Limitations
The freshness of the specimens in this study is suboptimal, which has a certain impact on the anatomical results. This study lacks simulated surgery and biomechanical tests on specimens, as well as sufficient data support for the accuracy of the research conclusions, which will be addressed in subsequent studies.

Abbreviations
ATFL   Anterior talofibular ligament
CLAI   Chronic lateral ankle instability

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IER   Inferior extensor retinaculum
MAI   Mechanical ankle instability
FAI   Functional ankle instability
S–W test Shapiro–Wilk test

Declarations

Ethics approval and consent to participate
The study protocol was established according to the ethical guidelines and was approved by the Ethic Committee of Huazhong University of Science and Technology Union Shenzhen Hospital.

Consent for publication
Not applicable.

Competing interests
We have no competing interests.

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