Comparison of the intensity of the anterior talofibular ligament repaired by LARS artificial and natural ligaments: a biomechanical study

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Abstract

Background: There are numerous surgical options for anterior talofibular ligament injury, but new biomechanical studies have demonstrated that existing surgical options cannot entirely restore the initial ATFL's biomechanical indensity. The goal of this study was to determine the biomechanical indensity of LARS talofibular ligament artificial ligament repair.

Methods: 12 fresh frozen human ankle specimens, average age 57±25.1 years (range 44~63 years), 12 cases of specimens sorted into two groups using the random number table approach, each group of 6 specimens, LARS group A, natural ligament group B, two groups of the identical biomechanical studies, evaluation of the highest failure load and stiffness in the two groups, respectively.

Results: The mean final failure load of the LARS repair group (378.6±25.7N) was significantly higher than that of the intact ATFL group (146.7±38.1N)(P=0.032). The mean stiffness of LARS group (27.6±4.7N/mm) was significantly higher than that of intact ATFL group (15.7±2.2N/mm) (P=0.022).LARS repair group failed because of suture pullout of the anchor at the fibula (4/6) and the talus (2/6)

Conclusions: In fresh frozen cadaver models, the indensity and stiffness of ATFL restored by LARS ligaments are much higher than natural ligaments. Although the therapeutic benefit of LARS artificial ligaments has yet to be determined. Before this approach may be used in the therapeutic treatment of ankle ligament injuries, more study is needed.

Background

Anterior talofibular ligament(ATFL) injury is a common ankle injury (1). Chronic ankle instability can lead to ankle cartilage damage and traumatic ankle arthritis (5, 6, 7). The majority of cases can be addressed without surgery, but recurring ankle pain and persistent ankle instability require surgery. Currently, there are many surgical methods for anterior talofibular ligament injuries, and traditional Brostrom surgery is widely regarded as the gold standard for the treatment of ankle instability (10, 23). However, recent biomechanical studies have shown that current surgical methods cannot fully restore the biomechanical indensity of the original ATFL (16, 17, 18). Viens et al. (9) studied the biomechanical characteristics of the ankle repaired by suture anchors in anatomic reconstruction techniques. They found that the reconstructed ATFL was less biomechanically stable than the original ATFL.Waldrop et al. (15) demonstrated that the indensity of direct suture repair of ATFL and the use of suture anchors in the fibula or talus was significantly lower than that of intact ATFL.Gould et al. (19) described the Brostrom repair combined with the inferior extensor support band indensityening technique as an effective solution to inadequate ligament tissue in order to avoid strenuous rehabilitation activities early after ATFL repair, but the indensity of the early repair remains unknown. For special groups with high training intensity, such as soldiers or athletes, the pressure on the ankle joint is higher than that of the general population (24, 25). Therefore, we proposed the concept of LARS artificial ligament repair for anterior talofibular ligament, which has previously been used in anterior cruciate ligament reconstruction surgery. As far as I know, no biomechanical experiments on LARS artificial ligament repair of the anterior talofibular ligament have been conducted.

The purpose of this study was to compare the biomechanical comparison of LARS artificial ligament repair ATFL and original ATFL in a controlled laboratory biomechanical model, with the assumption that LARS artificial ligament is stronger and more elastic than original ATFL.

Materials And Methods

Sample

Twelve fresh frozen human ankle specimens with an average age of 57.2±5.1 years (range from 44 to 63 years) were selected and divided into 2 groups with 6 specimens in each group by random number table method. The LARS group was in group A, and the normal ligament group was in group B. The two groups had comparable age distributions. Ankle specimens were frozen at -20°C and thawed for 24 hours at room temperature before use.

Operation method

Group A: A 3cm arc incision was performed from the anterior and inferior fibula in Group A. The subcutaneous tissue was separated layer by layer to expose the anterior talofibular ligament and the inferior extensor retinoid. Examine all ligaments for visible injury and proper tension, exposing ATFL attachment points on the fibula and talus. The anterior fibular ligament is severed at the fibula attachment. A LARS ligament (LARS®) with a length of around 60mm was produced and marked. A 3.0mm needle was used to drill the fibula tunnel and talus tunnel. The fibula tunnel is placed in the anterolateral fibula at the origin of the anterior talofibular ligament(ATFL), and direction from front down to back up, at a 45°angle to the horizontal line. The talus tunnel was located near the cervical junction of the talus bone, pointing to the tip of the medial malleolus. Make sure the LARS ligament is 20mm long in the talus, fibula, and joint. The LARS ligament was tensioned and fixed with two 3.7mm interference screws (LARS®) after successful installation(Fig 3) . All of the procedures were carried out by a renowned sports medicine surgeon.

Group B: The anterior talfibular ligament and the subextensor retinacular band were exposed in the same manner without the talfibular ligament being cut.

Sample preparation

All natural soft tissue was completely removed on the tibia and fibula prior to biomechanical testing. All muscle and soft tissue should be removed. Tibia, posterior talar fibular ligament, calcaneal fibular ligament, and other soft tissue and joint capsule should all be removed. Only the ATFL that has been fixed is kept. In a similar method previously described (20), each specimen was rigorously fixed to a plate with five screws (6mm in diameter), two screws for the instep and two screws for the calcaneus. A 6mm screw was used to secure the subtalar joint. The foot was loaded with 20 degrees of valgus and 10 degrees of flexion relative to the vertical fibula, and all specimens were put on a custom-made steel frame. Two vertical Kirschner pins are used to secure the fibula in a customized model, ensuring that it is perpendicular to the ground during stress(Fig 5). Before the test, the steel frame is finally installed on the test machine. A dynamic tensile test machine was used to conduct biomechanical tests (Motorized PulsE1000, Instrumental Systems, Norwood, MA).

Biomechanical test

The distance between the fibula and the talus was measured (Instron Systems). The foot is placed in 20°of inversion and 10°of plantar flexion relative to the vertical fibula. To eliminate slack, the sample was prestretched to 5N and then gradually loaded to 15N over 10 seconds. This load was then held for 5 seconds to remove potential creep and then loaded to failure by displacing the fibula at a rate of 20 mm/min. The instrument BlueHill 2 software recorded time, load, and displacement data (instrument system). Excel was used for additional calculations and statistical analysis (Microsoft, Seattle, Washington). According to the load-displacement curve, the final failure load was recorded, the stiffness (N/mm) was computed based on the slope of the curve, and the cause and type of failure were documented.

Statistical methods

All analyses were performed using SPSS 20.0 for Windows (SPSS Inc., Chicago, IL, USA), and significance levels were set at $P < 0.05$. All data were normally distributed in Kolmogorov - Smirnov test. Independent T test was used to analyze the differences between groups of maximum failure load and stiffness.

For t tests that demonstrated a statistically significant difference, A post hoc Tukey's honestly significant difference test was conducted to assess the location of the means that were statistically significant between the groups.

Fig5 Left ankle specimen secured in a custom fixture and mounted to the load actuator of a dynamic tensile testing machine before biomechanical testing. The foot is placed in 20°of inversion and 10°of plantar flexion relative to the vertical fibula.

Results

Table 1 shows the final failure load and stiffness of the LARS group and the natural ligament group. The mean final failure load of the LARS repair group (378.6±25.7N) was significantly higher than that of the intact ATFL group (146.7±38.1N)($P=0.032$). The mean stiffness of LARS group (27.6±4.7N/mm) was significantly higher than that of intact ATFL group (15.7±2.2N /mm)($P=0.022$). The failure was caused by the failure of the fibula side extrusion nail (4/6) and the failure of the talus side extrusion nail (2/6).

Discussion

This research gives crucial biomechanical data for ATFL reconstruction with LARS artificial ligaments. The indensity (378.6±25.7N) and stiffness (27.6±4.7N/mm) of ATFL repaired by LARS ligament were significantly higher than the indensity (146.7±38.1N) and stiffness (15.9±2.2N/mm) of original ATFL, however increased indensity and stiffness do not always translate into better patient treatment options. Further studies and follow-up are needed before LARS artificial ligaments can be used to repair ATFL. Before LARS artificial ligaments may be utilized to

repair ATFL, more research and follow-up is required.

To my knowledge, there are many ways to repair the anterior talofibular ligament, but there is no biomechanical analysis of LARS artificial ligament repair of the anterior talofibular ligament, and the Brostrom technique has been considered the "gold standard" for patients with chronic ankle instability over the past few decades (11,12). However, many biomechanical studies have

TABLE 1

Demographics and Mean Ultimate Load to Failure and Stiffness Compared With the Intact ATFL

	Demographics	Ultimate Load to Failure		Stiffness	
Group	Age, Mean (Range), y	Mean±SD, N	P Value	Mean±SD, N/mm	P Value
Intact	58.5（49-65）	146.7±38.1	—	15.7±2.2	—
LARS ligment	55.9（52-59）	378.6±25.7	0.032	27.6±4.7	0.022

shown that traditional surgical methods cannot fully restore the biomechanical indensity of original ATFL (16, 17, 18). There are also some authors who compare the biomechanics of anchor repair of the anterior talofibular ligament with that of the natural ligament. The biomechanical stability of ATFL after repair was lower than that of natural ATFL. Waldrop et al. (15) conducted a biomechanical study of anchor repair ATFL and found that the final failure load of the anchor group (79.2 ±34.3N) was lower than that of the natural ATFL group (160.9±72.2N).

it was suggested that ATFL repair or reconstruction procedures that were near to the original ATFL indensity be investigated. Takao et al.(2)described a specific type of knotting that had good clinical results. Cottom et al. (3)used 2-suture anchors sutured into the ankle ligament and the inferior extensor support band to repair full ankle ligament injuries in an open manner with a failure load of 156.43±30.39 N. Lohrer H et al.(26) proved suture tape augmentation of the ATFL effectively protects the unstable anterolateral ankle in the sagittal plane. Giza et al. (4) used two 3.0mm suture anchors to repair the lateral ankle ligament arthroscopically, and sutured the ATFL with the inferior extensor support band. The average maximum failure load was 154.4±60.3N. Li et al. (8) repaired ATFL with the knotting and suture anchor technique, and reported that ATFL was repaired under arthroscopy, and its function was significantly improved. Clanton et al. (21) evaluated the indensity of the regenerated ATFL in semitendinosus allograft to the original ATFL in another investigation. Although studies have demonstrated that the ultimate failure load and stiffness of allografts are comparable to natural ATFL, clinical trials of allografts are uncommon due to the risk of immunological rejection. Therefore, we find that at least two anchors or graft reconstruction ATFL may be necessary to obtain indensity comparable to that of the original ATFL.

The purpose of our study was to evaluate the indensity of LARS artificial ligaments for ATFL repair and original ATFL repair. In previous studies, LARS artificial ligaments are commonly used for anterior cruciate ligament reconstruction and are different from previous artificial ligaments. It is made of polyethylene terephthalate polyester(22). Since the indensity and stiffness of LARS artificial ligament at 0 are significantly higher than that of the original ligament, early rehabilitation training and muscle indensity training can theoretically be carried out, but whether the increased intensity and stiffness can be translated into clinical efficacy remains to be seen. Further studies and follow-up observations are needed.

The study has limitations. First, the average age of these specimens was 57.2±5.1 years, and the quality of ATFL may be poorer than the soft tissue quality of younger patients. Second, the bone quality of the specimen may be poorer than that of a younger population. Furthermore, utilizing the procedures used in this investigation, the bone mineral density of the samples could not be controlled.

Conclusion

The intensity and stiffness of ATFL repaired by LARS ligaments in fresh frozen cadaver models are significantly higher than those of natural ligaments, but the clinical role of LARS artificial ligaments remains to be determined. Further research is needed before this technique can be applied to the clinical treatment of ankle ligament injuries.

Declarations

Authors' contributions

All authors read and approved the final manuscript. All authors have agreed both to be personally accountable for their own contributions and ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

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All funding bodies did not influence the design of the study and collection, analysis, and interpretation of data and writing the manuscript.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The ethics committee of the General Hospital of the Northern Theater Command approved the study. Y(2021)131

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Figures

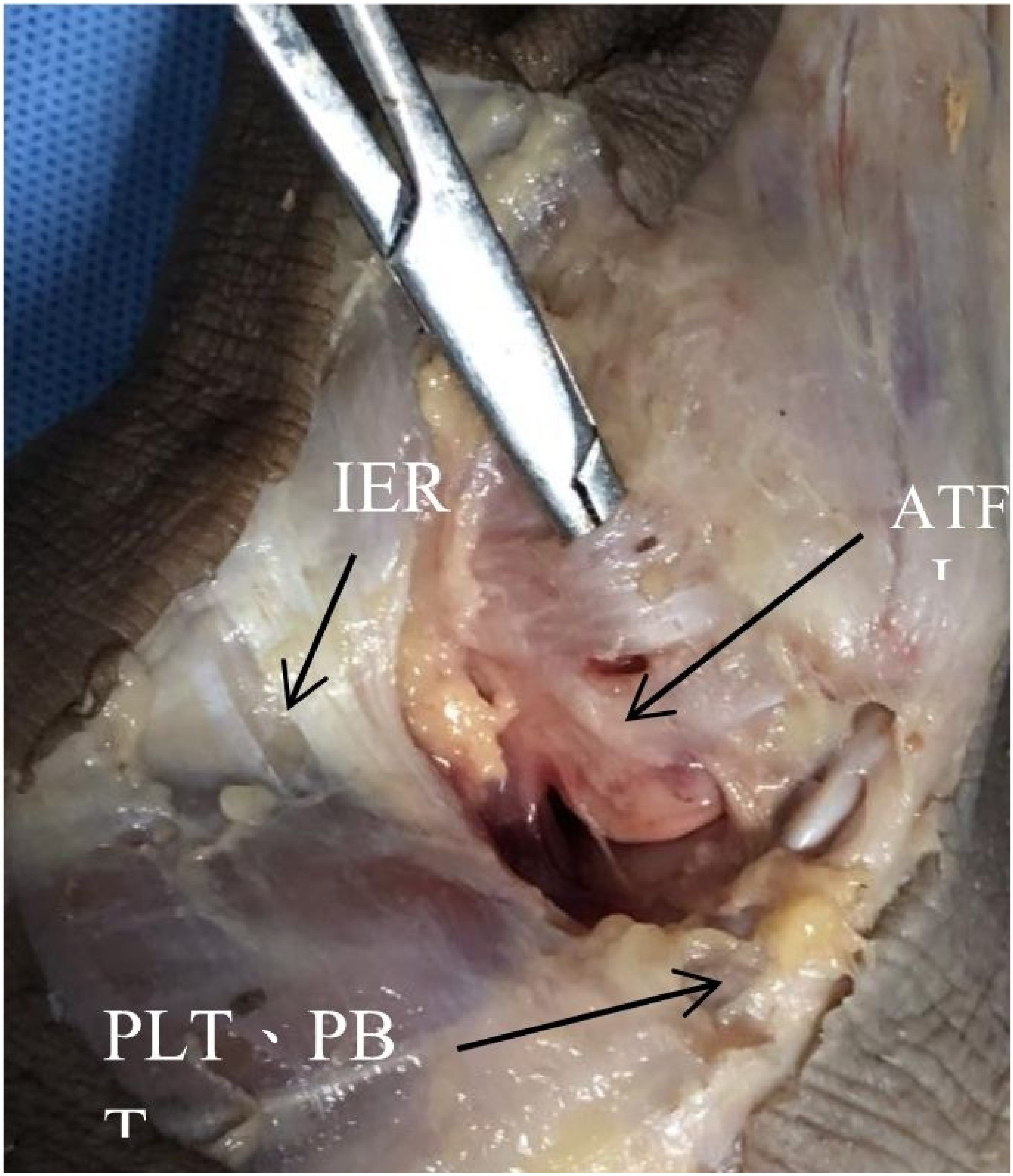

Figure 1

Surgical exposure before dissection of the ATFL in a left ankle specimen from the IB group. A curved haemostat is placed under the anterior talofibular ligament (ATFL). IER inferior extensor retinaculum, PLT peroneus longus tendon, PBT peroneus brevis tendon

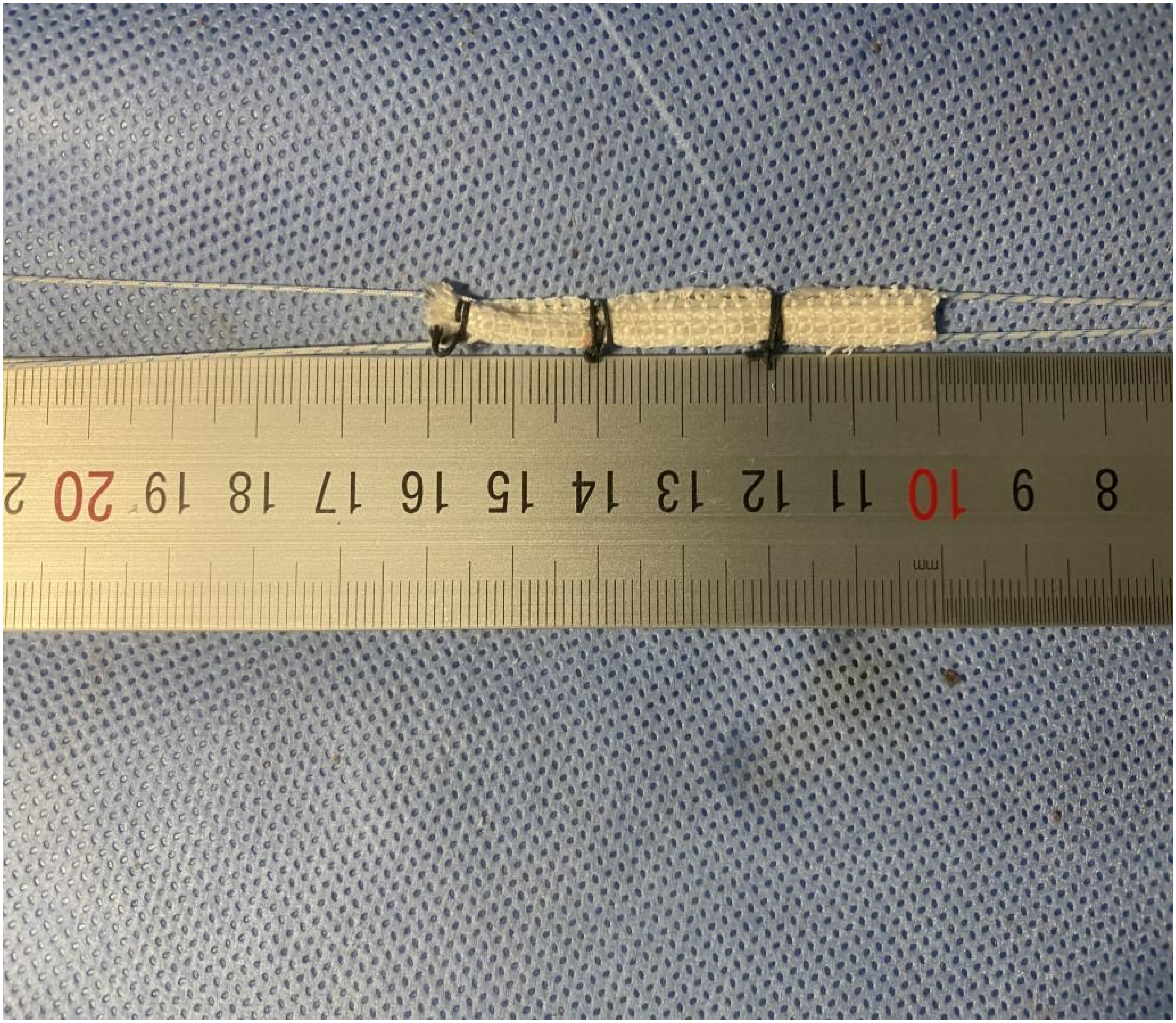

Figure 2

The length of LARS ligament was 60mm, marked at every 20mm, and the lengths of fibula, talus and joint were all 20mm

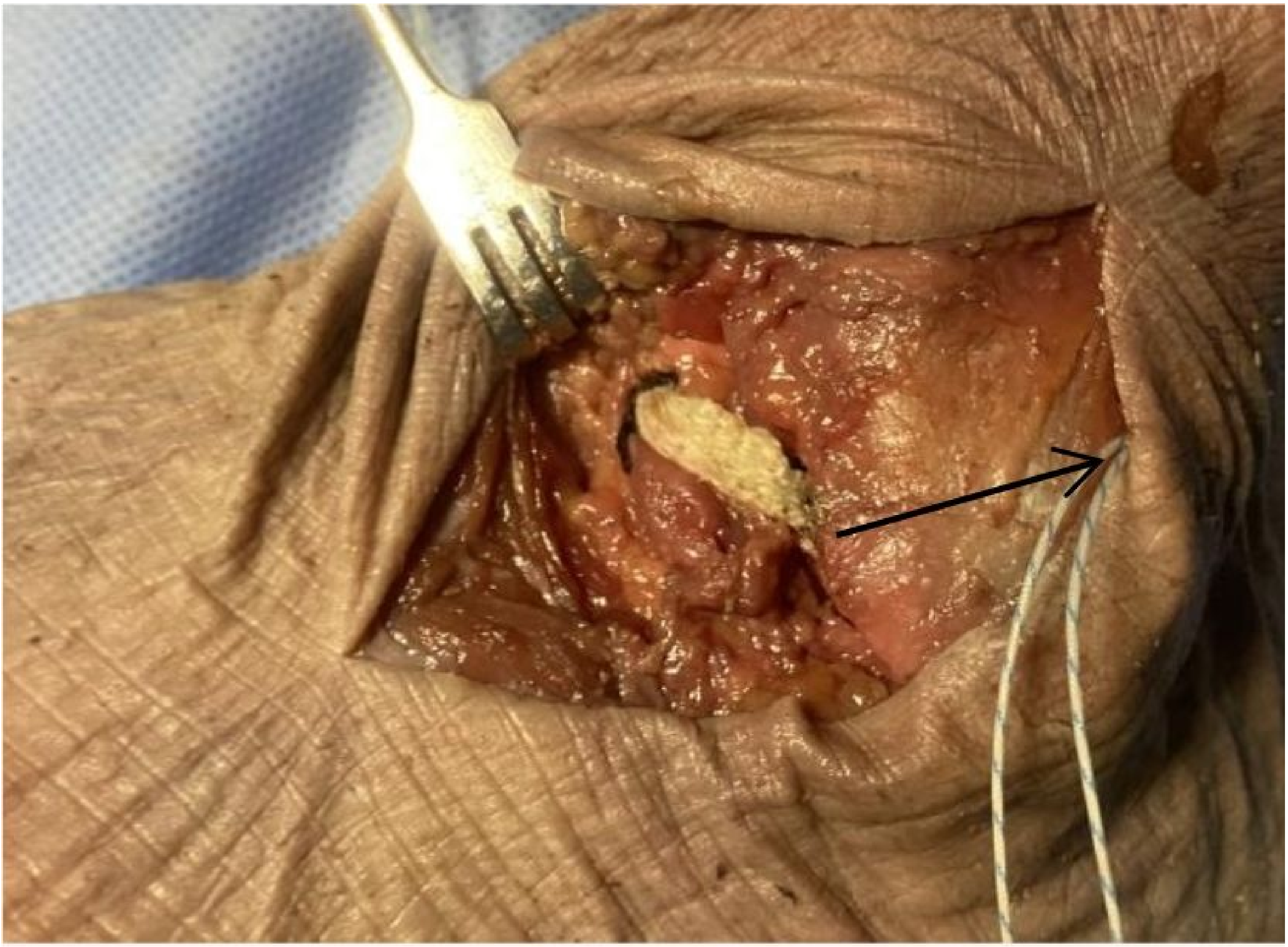

Figure 3

Tunnels are placed in the anterolateral fibula at the origin of the anterior talofibular ligament(ATFL) . The black arrow indicates the direction of the tunnel

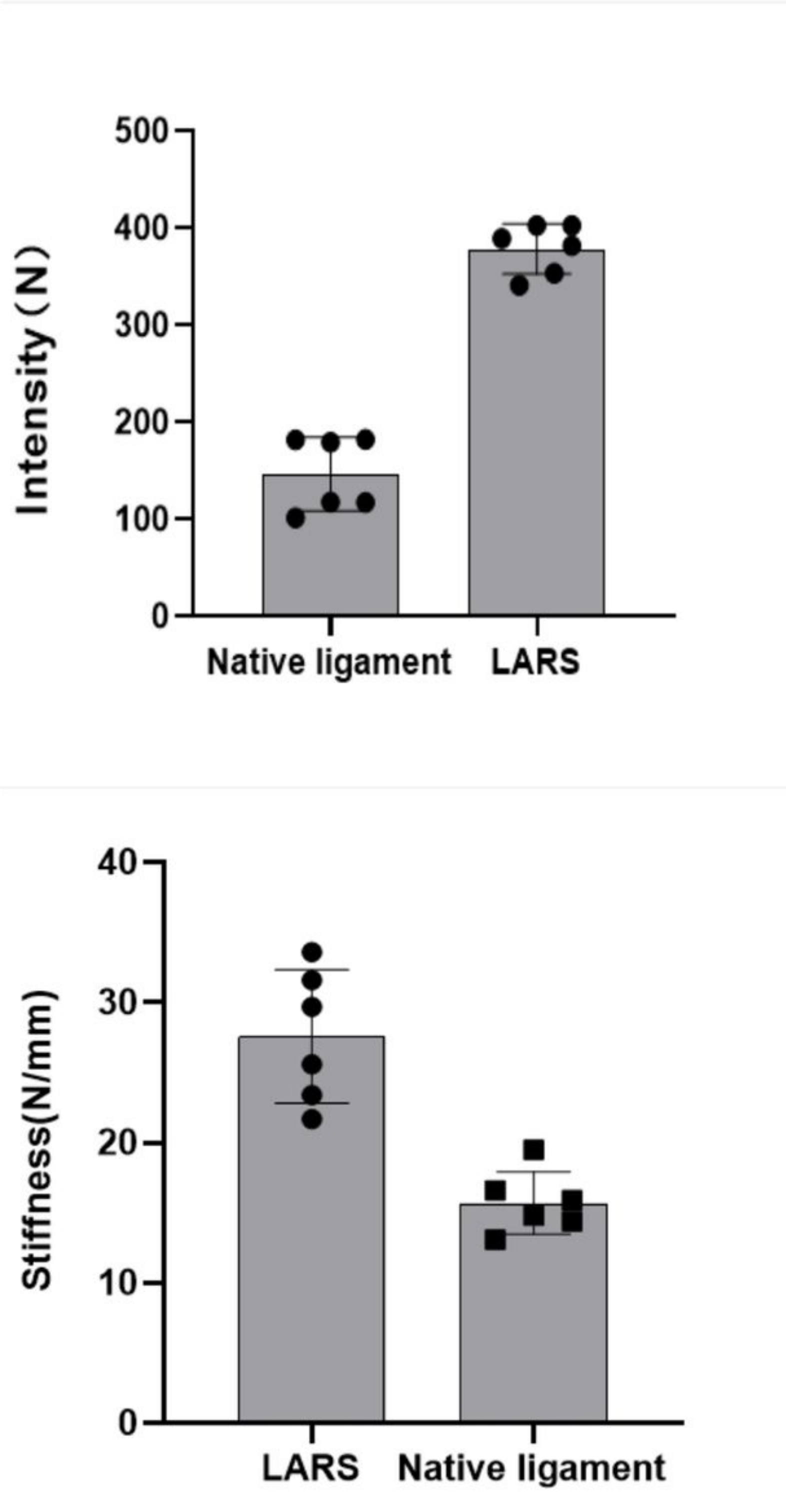

Figure 4

Box plots comparing biomechanical data between the intact anterior talofibular ligament(ATFL) and the LARS ligament-repaired ATFL

Figure 5

Left ankle specimen secured in a custom fixture and mounted to the load actuator of a dynamic tensile testing machine before biomechanical testing. The foot is placed in 20°of inversion and 10°of plantar flexion relative to the vertical fibula.