A New Landmark for Positioning the Anatomical Insertions of Lateral Ankle Ligaments under Arthroscopy: A Preliminary Study

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Abstract

Background: Several landmarks are used to ascertain the insertions of lateral ankle ligaments, however, few could be discerned under arthroscopy. The objective of this study was to assess the feasibility and reliability of labeling the anterior process of fibular cartilage surface (FCAP) under arthroscopy, and to compare the distances from the new or conventional landmark to the ligament insertion.

Methods: Twenty paired ankles from ten Chinese cadavers were included. A senior and a junior surgeon randomly performed the arthroscopic FCAP marking procedures for the paired ankles of a single cadaver using a Kirchner wire. The distance and direction from the anatomical FCAP' to the marked FCAP were recorded after open dissection. Reliability analysis were calculated using the intraclass correlation coefficient (ICC) and independent sample *t* test. Moreover, the distance from the upper landmarks (anterior fibular tubercle or FCAP) to the anterior talofibular ligament (ATFL) insertion center (distance “a” or “c”), and from the ATFL to calcaneofibular ligament (CFL) footprint center was measured at the anterolateral side (distance “b”) and lateral groove (distance “d”), respectively.

Results: The FCAP was located 1.23±0.29 (range, 0.77–1.67) mm) and 1.52±0.41 (range, 0.92–2.03) mm from the anatomical FCAP' in the senior and junior surgeons’ operations, respectively, which showed no significant difference between the two groups (t=-1.773, P=0.093). And the calculated ICC was 0.767 (P=0.003). The average distance “a” was 19.03±1.47 (range, 16.29–21.3) mm, significantly longer than distance “c”, 15.98±0.97 (range, 14.48–18.02) mm (t=-7.72, P<0.001). However, the distance “b” (7.43±0.54 mm; range, 6.47–8.47) and distance “d” (7.78±0.67 mm; range, 6.42–9.03) showed no statistical difference (t=1.8, P=0.08).

Conclusions: The FCAP may be a useful landmark that can be utilized to ascertain anatomical insertions of lateral ankle ligaments under arthroscopy. The measured distances from the landmark to the ligament footprint center could provide spatial information that assist in endoscopic anatomical repair or reconstruction.

Background

Ankle sprain are common injuries associated with sports activities, with anterior talofibular ligament (ATFL) being the most frequently involved structure followed by the calcaneofibular ligament (CFL) [1]. Operative intervention should be indicated if conservative treatment is unsuccessful. Different operative procedures, including tenodesis (nonanatomic reconstruction), anatomic repair or reconstruction, ligament augmentation, have been described and developed in the past [2, 3]. According to a systematic review comparing the different operative techniques, Vuurberg et al. [4] reported that anatomic repair and anatomic reconstruction provide better functional outcome after operative treatment compared with tenodesis. In their study, anatomic repair showed the highest postoperative functional scores, and anatomic reconstruction showed the highest score increase after surgery. A biomechanical study revealed that anatomic repair could restore the kinematics of the ankle, whereas the nonanatomic repair demonstrated significant inversion and internal rotation kinematics and internal rotation laxity when compared with the intact state [5]. Furthermore, it has also been reported that anatomical repair resulted in a better functional outcome and less secondary osteoarthritis than non-anatomical repair after a minimum follow-up of 10 years [6]. Thus, currently, to repair the ligament injury in an anatomic manner is the preferred treatment. Furthermore, with the development of arthroscopic technique, more and more surgeons are attempting to perform operative procedures under arthroscopy [7–10].

Because of the different histological ingredients and structural characters of the entheses of the ligament, avulsion fractures or tears are more common at the fibular end of the ligament [11]. Consequently, the ligament repair on the fibular attachment has always been of great concern to the surgeons. When an anatomic repair or reconstruction is performed, the ligament remnant or graft should be attached to the original attachments of these ligaments. In open surgeries, the ligament origins and its surrounding structures could be clearly identified under direct visualization, however, which seems to be a somewhat challenging process under arthroscopy [5, 12, 13]. For example, because of the limitation in the range of the ankle arthroscopic view, adequate visualization of the tip of the lateral malleolus and the entire ATFL attachment site may not be obtained from a standard portal in ankle arthroscopy [13]. Moreover, the CFL insertion on the fibula is more distal than that of ATFL, which can only be seen when the ATFL is dissected and the anterior talofibular space is opened [12]. Consequently, there is a potential risk of failing to properly accomplish an anatomic ligament repair or ligament reconstruction.

Several landmarks were proposed to assist in positioning the lateral ligaments, such as the anterior fibular tubercle, the fibular obscure tubercle and the fibular tip [14]. However, these landmarks were located at the anterolateral side of the fibula, and covered by the joint capsule. Researchers always investigated them in open anatomic study to explore their relationship to the ligament attachments or used them as landmarks under fluoroscopy when performing ankle stabilizations [15]. Nevertheless, it is impossible to recognize the anatomical fibular tip or the articular inferior tip through the arthroscopic image [13]. Therefore, it seems still to be a puzzle in precisely ascertaining the anatomical attachments of lateral ligaments, as well as in performing anatomic repair or reconstruction under arthroscopy. We have noted the articular surface of the lateral malleolus that near the fornix of the talus could be detected under arthroscopic examination. Thus we proposed that the anterior process of fibular cartilage surface (FCAP) might serve as an instructive landmark for identification of the ATFL and CFL attachments on the fibula. This study was undertaken to check the feasibility of labeling the FCAP under arthroscopy, and to preliminarily verify the reliability and repeatability of positioning this landmark. Meanwhile, to compare the distances that measured from the new or conventional landmark to the ligament insertion.

Materials And Methods

This study was approved by the ethics committee of our institution. Twenty paired ankles from ten frozen cadavers (six men and four women) without ankle scars, obvious preexisting ankle diseases were used, as donated to the Department of Anatomy of our university. The specimens were all of Chinese origin with the mean age at the time of death was 74.1 years. The paired specimens were divided into 1 of 2 groups using a random number generator (www.Random.org). A senior surgeon with a high volume of ankle arthroscopy performed the arthroscopic procedures for ankles in group 1, while a junior resident without extensive experience for ankles in group 2.

Ankle arthroscopy was performed with the cadaver in the supine position using 4.0-mm arthroscope and standard anteromedial and anterolateral portals. First a general check was performed to ensure that there were no degenerative changes in the ankle joints. Usually, the articular surface of lateral malleolus could be identified with visualization from the anteromedial portal. The FCAP was defined as the anterior process of the fibular cartilage surface, which refers to the most anterior position on the cartilage surface. The anterosuperior corner was a curve that connected the superior edge and anterior edge of the surface, and the anteroinferior edge inclines from anterosuperior to posteroinferior. Consequently, the junction of the anterosuperior curved edge and the anteroinferior oblique edge referred to the most anterior position of the cartilage surface, which was defined as the anterior process (Fig. 1a). Thus, the lower point of the curved edge represented the FCAP, which could be recognized under arthroscopy (Fig. 1b). Dynamic observation and repeated confirmation by adjusting the arthroscope might be helpful for the positioning process. A1.0-mm diameter Kirschner wire was then used to label the landmark under arthroscopy.

After that, the lateral ankle was dissected by an experienced surgeon who was blinded to the arthroscopic marking procedures. A circular skin window was incised on the lateral malleolus with the Kirschner retained (Fig. 2). The soft tissue overlaying the lateral ankle ligaments was removed to confirm the ATFL and the CFL, and their attachments to the fibula. The distance from the anterior fibular tubercle to the ATFL insertion footprint center (distance “a”) and from the ATFL insertion footprint center to the CFL insertion footprint center (distance “b”) were measured on the anterolateral side as previously reported method [14], which were performed using a digital vernier caliper (Guanglu Digital Ltd., Guilin, China) with an accuracy value 0.01 mm. Consequently, the anterior tibiofibular ligament was dissected from its fibular insertion, and the distal attachments of ATFL and CFL were separated from talus and calcaneus, respectively. Thus, the fibula could be turned posteriorly and laterally to reveal the cartilaginous surface of the fibula, to confirm the anatomical FCAP (FCAP') and the entire ATFL and CFL attachments on the lateral groove. The distance and direction from the anatomical FCAP' to the arthroscopic FCAP were assessed (Fig. 3). In addition, the distance from the FCAP to the midpoint of ATFL attachment (distance “c”) and distance from the ATFL to the CFL insertion footprint center (distance “d”) on the lateral groove were measured (Fig. 4). Three separate measurements for each value were taken, and the results were averaged.

Statistical analysis was performed using SPSS 22.0 software. The distances were expressed as mean ± standard deviation. To assess the reliability and repeatability of the positioning methodology, the distance from FCAP to FCAP' was selected to calculate the intraclass correlation coefficient (ICC) between the senior and junior operators. The independent sample *t* test was used to compare the variation between the two groups, and the distances that measured at the anterolateral side and the lateral groove.

Results

The marking procedure was successfully performed in all ankles. No chondral lesions were identified based on careful inspection of talocrural or fibular cartilage during open anatomical dissection following the arthroscopic procedure. The Kirschner marked FCAP, anterior fibular tubercle, and both the ATFL and CFL were visualized in all specimens after dissection.

The anatomical FCAP' was confirmed on each ankle after open dissection, which was located 1.23 ± 0.29 (range, 0.77–1.67) mm from the arthroscopic FCAP in group 1, and 1.52 ± 0.41 (range, 0.92–2.03) mm in group 2. But the direction was varied, more cases were identified proximally under arthroscopy (6 in group 1, 7 in group 2) (Table 1). The ICC was calculated as 0.767 ($P = 0.003$). And the variation showed no significant difference between the two groups (t=-1.773, $P = 0.093$).

Table 1
The direction and distance between the anatomical FCAP' and the arthroscopic FCAP [a]

Cadaver Number	Age of death	Sex	Group 1		Group 2	
			Direction	Distance (mm)	Direction	Distance (mm)
1	82	M	Proximal	1.56	Distal	2.03
2	71	F	Proximal	1.67	Distal	1.58
3	67	F	Distal	1.06	Distal	1.43
4	69	M	Distal	0.77	Proximal	0.92
5	63	M	Proximal	1.45	Proximal	1.95
6	80	M	Distal	1.08	Distal	0.96
7	86	M	Distal	1.44	Distal	1.89
8	82	F	Distal	1.19	Distal	1.75
9	74	F	Distal	1.21	Proximal	1.61
10	67	M	Proximal	0.89	Distal	1.05

[a] Direction referred to the position of the arthroscopic FCAP relative to the anatomical FCAP'. FCAP: anterior process of fibular cartilage surface. M, male; F, female

After being measured on the anterolateral fibula as previous method, the average distance “a” was measured as 19.03 ± 1.47 (range, 16.29–21.3) mm and the average distance “b” was 7.43 ± 0.54 (range, 6.47–8.47) mm. On the other hand, the distance “c” and “d” that measured on the lateral groove after the distal insertion dissection were 15.98 ± 0.97 (range, 14.48–18.02) mm and 7.78 ± 0.67 (range, 6.42–9.03) mm, respectively. The distance “a” and distance “c”, corresponding to the distance from the upper landmark that out/in the joint to the ATFL footprint center, showed significant difference (t=-7.72, $P <$

0.001). However, the distance "b" and distance "d", both representing the distances between ATFL and CFL insertions that measured at the anterolateral side or the lateral groove, showed no statistical difference (t = 1.8, $P = 0.08$).

Discussion

The main finding of the preliminary study was that the FCAP could be feasibly and reliably ascertained under arthroscopy. The distance that based on this landmark measured at the lateral groove was varied from that from the conventional landmark at the anterolateral side. The distances from the FCAP to the ATFL footprint center and then to the CFL explicated the positional relationship between the FCAP and the ligament insertions.

Different operative procedures have been published to treat the chronic lateral ankle instability [7–10]. Currently, repair and reconstruction are the two preferred operative techniques: repair corresponds to a suturing of the torn lateral ligaments, while reconstruction refers to the replacement of the irreparable or chronically deficient lateral ligaments with other tissue [2]. Thus, anchors or tunnels should be inserted or established on the fibula to fix the ligament or its substitutes. Shoji's investigation [5] revealed that the nonanatomic tunnel position in ATFL repair resulted in significant inversion from 5° to 15° of dorsiflexion and significant internal rotation at neutral position. Besides, internal rotation laxity was significantly increased relative to the intact state in the nonanatomic repair. In addition, it has also been reported in a systematic review comparing the different operative techniques that anatomic stabilization techniques provided superior results in terms of functional outcome compared to non-anatomic techniques [4]. Therefore, an anatomic ligament repair or reconstruction was the most popular and effective treatment to solve lateral ankle instability.

In both ligament repair and ligament reconstruction, it is crucial to accurately ascertain the ligamental attachment sites to achieve proper anchor insertion or tunnel creation at the distal fibula [13]. Anterior fibular tubercle, fibular tip and fibular obscure tubercle were the most commonly used landmarks to describe the ATFL and CFL attachments, and to assist in positioning during ligament stabilization [14, 15]. However, these landmarks could only be recognized when performing open surgeries or radiographic perspectives [15]. Teramoto et al. [13] performed a study to evaluate the relationship between the lateral malleolus view under ankle arthroscopy and the ATFL attachment site. They found that standard ankle arthroscopy portals might not allow for complete visualization of the tip of the lateral malleolus. Meanwhile, it might not be feasible to thoroughly observe the CFL attachment site [12, 13]. Therefore, it might still be a huge challenge to accurately confirm the ATFL attachment, as well as the further CFL attachment under arthroscopy, especially for junior surgeons without extensive experience for ankle arthroscopy.

The shape of the fibular articular surface is approximately triangular, with the anterior edge slopes from anterosuperior to posteroinferior direction. Meanwhile, the upper edge is connected to the anterior edge through a curved margin [16–18]. Thus, a process is formed in the junction of the anterosuperior curved edge and the anteroinferior oblique edge, which represents to the most anterior position of the articular surface. In the present study, both the experienced senior surgeon and the inexperienced junior resident have successfully marked the FCAP with a Kirschner wire without sufficient debridement under the arthroscopic image. This landmark was confirmed after open dissection, and the distance between the anatomic FCAP' and the marked FCAP varied from 1.23 mm to 1.52 mm, both of which were less than the deviation value of the marked ATFL insertion after establishing accessory portal and thorough dissection under arthroscopy (1.7–2.9 mm) [12]. Therefore, it might be much easier and more accurate to ascertain the upper FCAP than the ATFL insertion at the lateral groove. Moreover, the deviation that performed by the junior resident showed no significant difference compared with that measured after the senior's operation, and the ICC was more than 0.75, both indicating that the identification and marking manipulation of the FCAP under arthroscopy was reliable and repeatable. Consequently, it is reasonable to believe that the FCAP could be regarded as a landmark to assist in positioning the insertions of the lateral ligaments under arthroscopy, especially for junior surgeons who lack extensive experience.

To maximally simulate and restore the perspectives of the arthroscope, the ATFL and CFL footprint centers were ascertained at the lateral groove where the bone hole or tunnel was made to fix the ligament remnant or graft in arthroscopic surgeries. Compared to the distance that measured at the anterolateral side from the anterior fibular tubercle, the distance from the FCAP to the ATFL footprint center was slightly shorter. This phenomenon corresponded to the previous studies that showing the position of FCAP was lower than that of anterior fibular tubercle [16, 17]. The FCAP could be detected much easier than the anterior fibular tubercle under arthroscopy [12, 13], indicating the superiority of regarding the FCAP as a landmark. On the other hand, the distance from ATFL to CFL that measured at the anterolateral side or lateral groove was similar, which confirmed the internal consistency of the methods for ligament footprint discerning and distance measurements. Because the isolate ATFL repair was the most popular and commonly used method to treat lateral ankle instability under arthroscopy [6, 19], and the ATFL reconstruction or in combination with CFL reconstruction was considered in patients with poor ligament quality or severe instability [4, 19]. That meant the intervention of CFL was usually selectively performed followed the ATFL management. Thus, we intended to first ascertain the ATFL footprint center based on the FCAP, and then measured the ATFL-CFL distance so as to ascertain the latter's position on the basis of the ATFL fibular insertion. Since the anterior fibular edge was a curved rather than a straight line [15], the direct linear measurement from the landmarks (whether the anterior fibular tubercle or the fibular tip) to the ligament insertions seemed to shorten the distances. Because the lateral malleolus can't be completely exposed in arthroscopic surgeries, the sectional measurement for the distances from FCAP to ATFL, then to CFL on the lateral groove would be more helpful to accurately mark the native ligament insertions. Additionally, measuring the distance at the lateral groove would be closer to clinical practices because the hole or tunnel ready for ATFL (and CFL) stabilization was prepared at the lateral groove.

The clinical relevance of this study is that FCAP could be used as a landmark or a supplementary reference to position the lateral ligaments under arthroscopy, thus arthroscopic techniques of anatomic repair or reconstruction might be accurately developed or improved. However, this study just preliminarily verified the feasibility and reliability of ascertaining the FCAP under arthroscopy, and revealed the positional relationships between the landmark and the ligament insertions. These findings provided a possibility of using the FCAP as a landmark to label ligament insertions on the fibula. The actual maneuverability should be further confirmed in ankle specimens, and whether using the auxiliary landmark was better than using the traditional method also needs further exploration. Second, since it was not applicable to repeat the arthroscopic marking operations in a single specimen, we performed the ICC analysis in paired ankles of a cadaver to reduce variation between the specimen individuals as previously [20], the reliability and repeatability analysis might not be extremely rigorous. Moreover, twenty specimens may not be enough to represent the general population, especially with regard to the landmark labelling manipulation.

Conclusion

The FCAP may be a useful landmark that can be utilized to ascertain anatomical insertions for lateral ankle ligaments under arthroscopy. The measured distances from the FCAP to the ATFL insertion center, and then to the midpoint of CFL footprint can provide spatial information that assist in endoscopic anatomical lateral ligament repair or reconstruction. Further studies would be worth carrying out to explore the accuracy and repeatability of using this landmark to assist in positioning the anatomical ligament insertions and performing arthroscopic anatomic ankle stabilization.

Abbreviations

FCAP, Anterior process of fibular cartilage surface; ATFL: Anterior talofibular ligament; CFL: Calcaneofibular ligament; ICC: Intraclass correlation coefficient.

Declarations

Ethics approval and consent to participate

This study has obtained ethics approval and consent of the ethics committee in our hospital.

Consent for publication

Not applicable.

Availability of data and materials

All data used are included in the article.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

SB and SHY conceived the study. ZYF and ZZZ participated in the study design. The arthroscopic procedure was performed by SB and ZZZ, respectively. XDZ, an experienced anatomist, performed the open dissection and measurement. XRQ and WMW contributed to measurement and recording. ZYF, SB, ZZZ carried out the data collecting, data analysis, and drafted the manuscript. LWP contributed to manuscript editing. SHY played a role in reviewing and editing the manuscript and providing a critical review of the manuscript.

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Figures

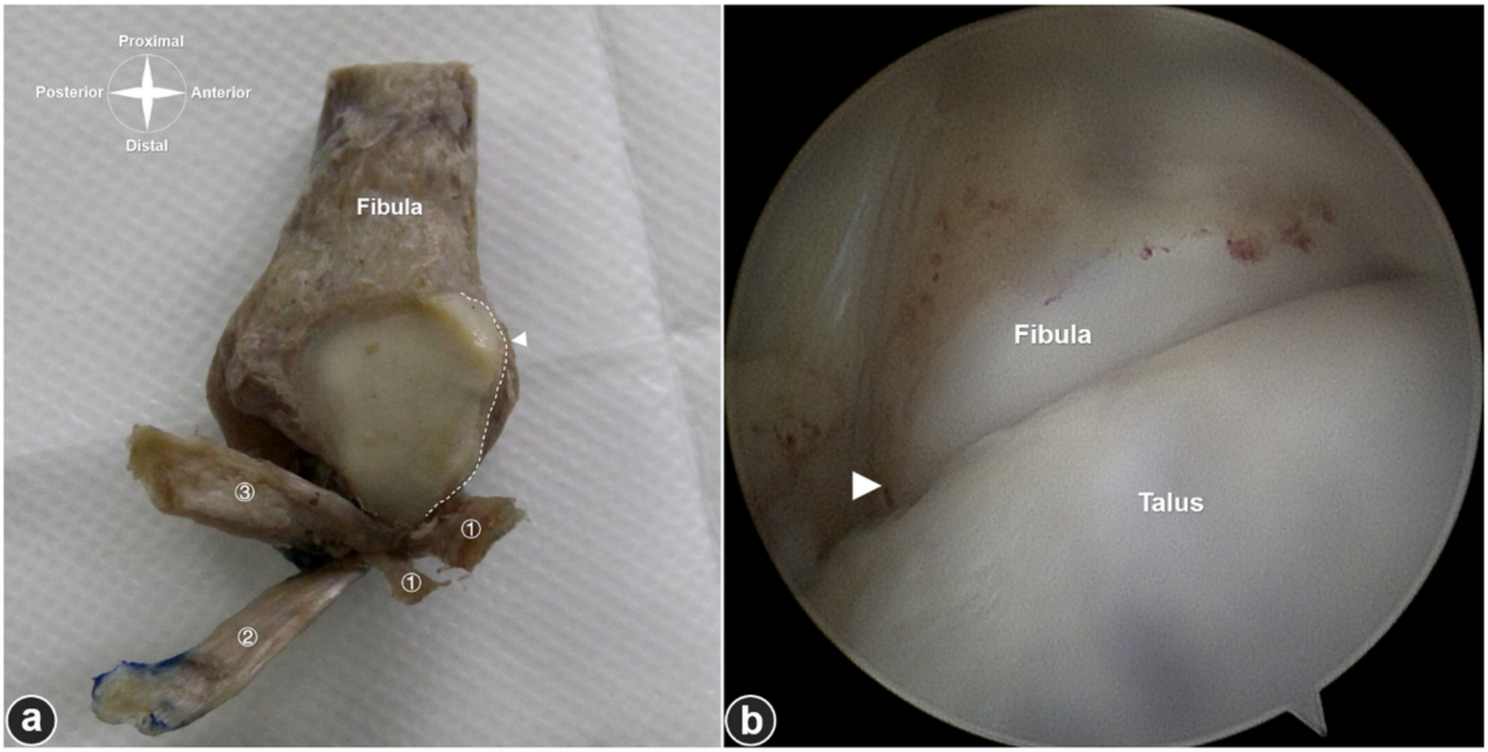

Figure 1

The illustration of the anterosuperior corner of the anterior process of fibular cartilage surface (FCAP, white arrow head) at a fibula specimen (a, left fibula) and in arthroscopic image (b, right ankle). White dotted line: anterior edge of the fibular cartilage. anterior talofibular ligament; calcaneofibular ligament; posterior talofibular ligament

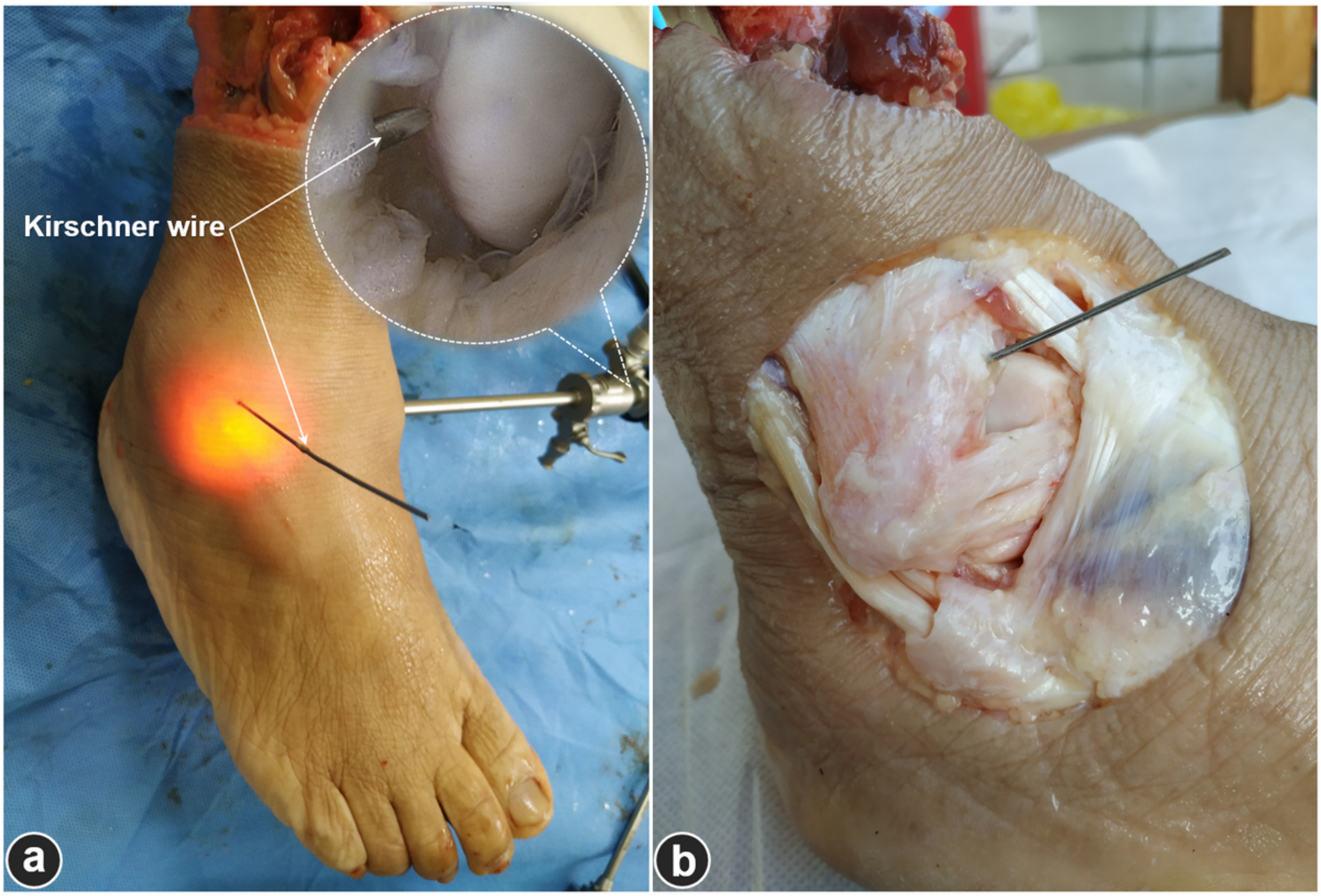

Figure 2

a Marking the anterior process of fibular cartilage surface (FCAP) with a Kirschner wire in an ankle specimen under arthroscopy, with the arthroscopic image being showed in the white dotted round frame (right ankle). b The gross appearance after circular skin window incision (right ankle)

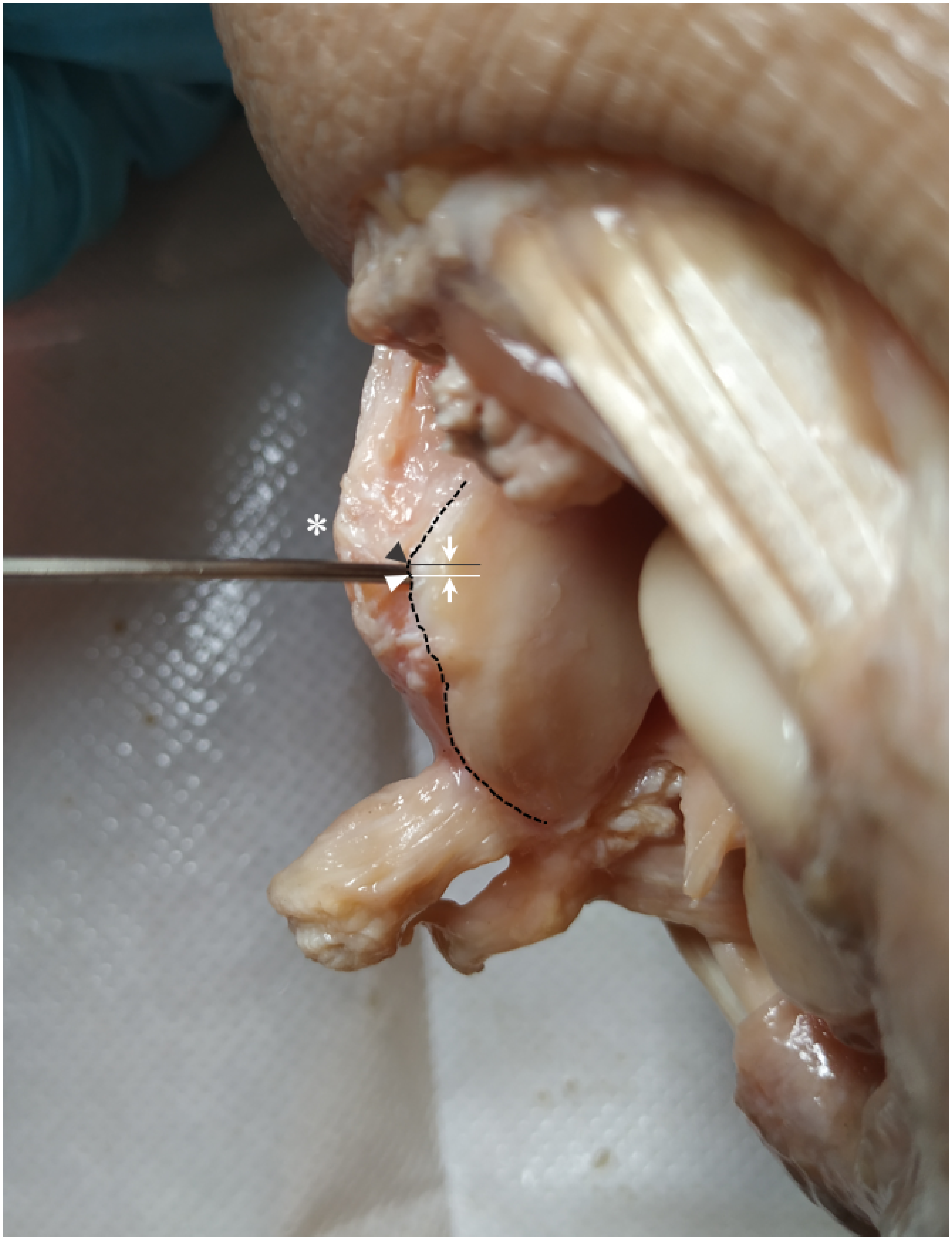

Figure 3

Anterolateral view of the lateral malleolus after dissecting the ligaments with the fibula being turned posteriorly and laterally (right ankle). The relationship between the anterior fibular tubercle (asterisk), FCAP that being marked with Kirschner wire (white arrow head) and the anatomical FCAP' (gray arrow head). The distance between the FCAP' and FCAP was measured. Black dotted line: anterior edge of the fibular cartilage

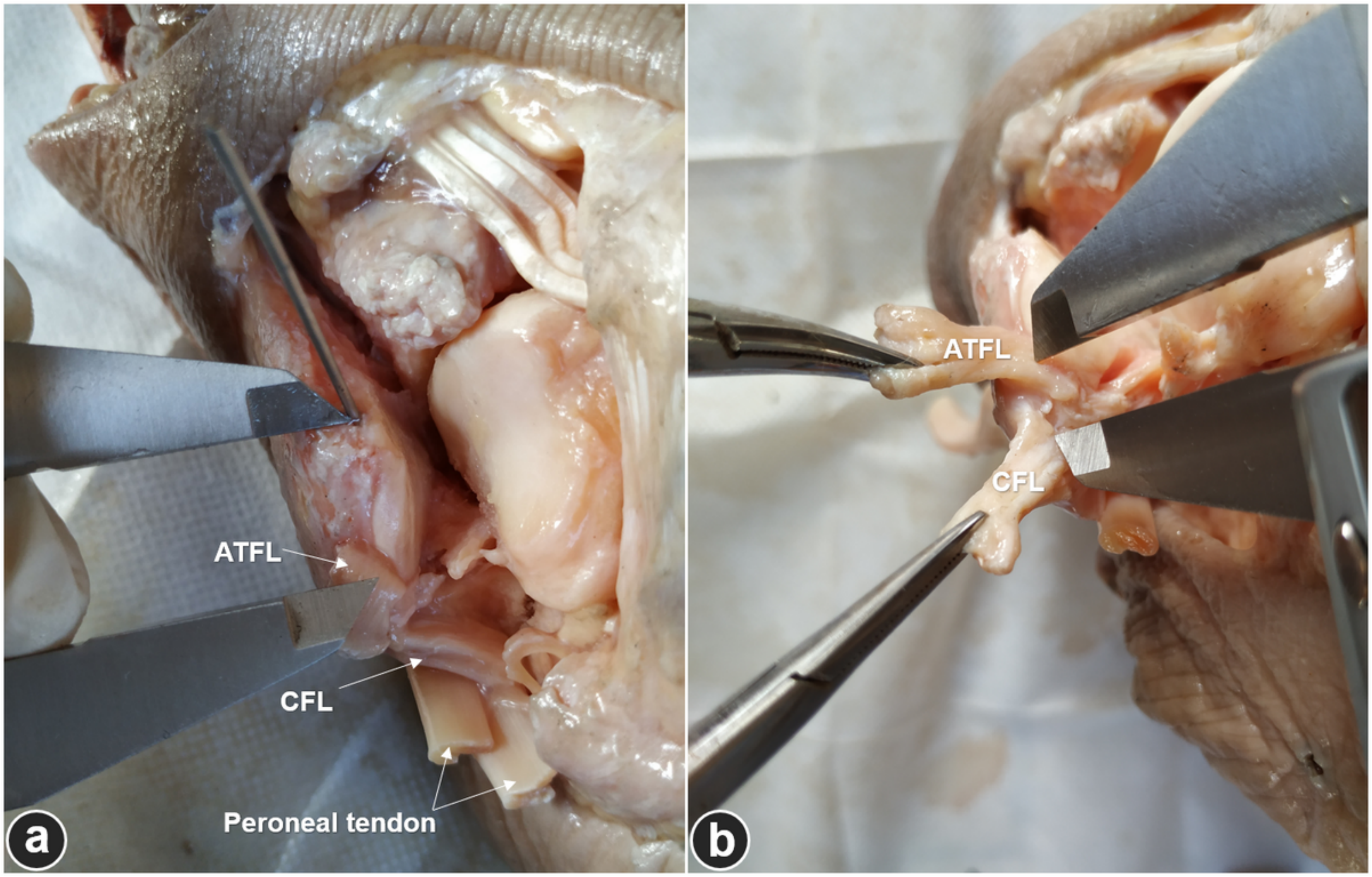

Figure 4

The distance was measured on the lateral groove after dissecting the ligaments distal insertions (right ankle). a The distance between the FCAP and the ATFL footprint center. b The distance from the ATFL footprint to CFL insertion