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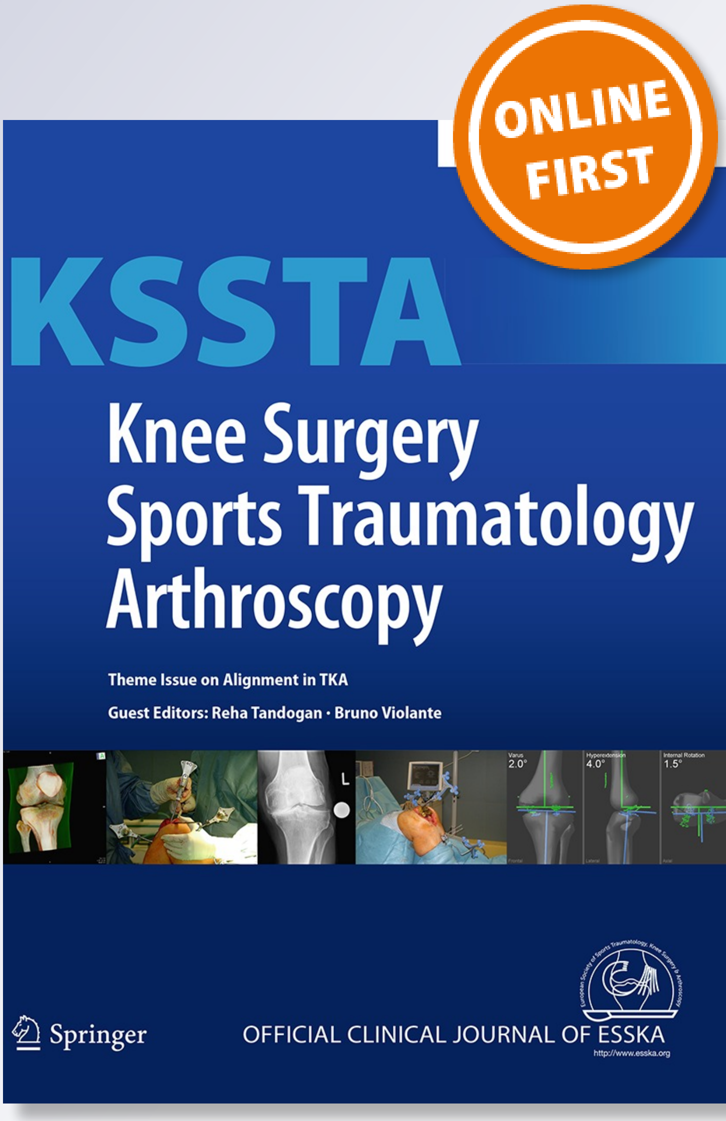

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Anatomic validation of the lateral malleolus as a cutaneous marker for the distal insertion of the calcaneofibular ligament

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Abstract
Purpose An anatomic study was performed to confirm whether the lateral malleolus could serve as a simple and reproducible anatomic reference for the distal insertion of the calcaneofibular ligament (CFL).
Methods Dissection was performed after placement of a Kirschner wire to simulate the calcaneal tunnel for the distal insertion of the CFL. The skin was penetrated 1 cm distal and posterior to the tip of the lateral malleolus. The main information recorded was the distance from the Kirschner wire to the centre of the distal insertion of the CFL. Other elements were noted (characteristics of the CFL, distance between the distal insertion of the CFL-peroneal tubercle, nerve or tendon injuries).
Results Thirty ankles were dissected. The mean distance from the Kirschner wire to the centre of the distal insertion of the CFL was 2.4 ± 1.8 mm. Only one case of peroneal injury was noted. The sural nerve was usually located a mean 1.8 ± 1.1 mm from the Kirschner wire. The posterior tibial vascular pedicle was a mean 27.8 ± 3.5 mm from the point of exit of the Kirschner wire.
Conclusion Using the lateral malleolus as the cutaneous reference for the distal insertion of the CFL seems to be more reliable than the pure arthroscopic technique. This study describes a percutaneous technique to obtain a calcaneal tunnel for distal insertion of the CFL. The sural nerve is at the greatest risk of injury with this technique and requires careful subcutaneous incision to prevent injury. This new percutaneous technique is less invasive than a purely arthroscopic technique and more accurately identifies the location of the tunnel. It can be used to do calcaneal tunnel in clinical practice during anatomic ligament reconstruction for chronic ankle instability.

Keywords Calcaneofibular ligament · Ligament reconstruction · Anatomy of the ankle · Anatomic reference

Abbreviations

CFL	Calcaneofibular ligament
DAR	Direct anatomic repair
NAR	Non-anatomic reconstruction

Introduction

A lateral ankle sprain is the most frequent cause for consultation in the emergency trauma unit, and residual lateral instability is found in 15–30 % of these cases [4, 11].

Numerous surgical techniques have been described, and they can be divided into two groups: ligament repair and ligament reconstruction [2, 7, 8, 12, 15, 19, 22, 29]. The goals of surgical treatment are to treat tibiotalar and subtalar instability as well as associated injuries to limit the risk of secondary osteoarthritis [10, 13, 18, 42, 46]. The long-term risk of ligament repair is secondary laxity of the repaired scar tissue [21, 27, 34], and radiological assessment of non-anatomic reconstructions shows secondary osteoarthritis of the tibiotalar joint [17, 21, 29, 36, 54]. In the first decade of the twenty-first century, Coughlin et al. [9] then Takao et al. [49] described an anatomic ligament reconstruction technique with a gracilis autograft that was attached to the

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ligament insertions by interference screws. Anatomic ligament reconstruction for chronic instability of the ankle provides satisfactory intermediate term results and preserves ankle kinematics [9, 42]. This technique has gradually evolved, and an arthroscopic technique has been developed [13, 26, 32]. The goal of the arthroscopic technique is to reduce the morbidity of the surgical procedure and restore the anatomic attachments, in particular of the distal calcaneofibular ligament (CFL) [14, 26]. The CFL is the main stabilizing bundle of the lateral collateral ligament [20, 24, 31, 43], but arthroscopic visualization is difficult [51].

This cadaveric study is a necessary and preliminary step to confirm the reliability of a percutaneous calcaneal tunnel for distal insertion of the CFL in anatomic lateral ankle ligament reconstruction. At present, the arthroscopic technique is the first-line surgical option for many teams, although it has been shown to lack precision and does not favour preservation of mechanoreceptors. Validation of a reliable and more precise anatomic reference would make it possible to obtain a percutaneous calcaneal tunnel for the distal insertion of the CFL and improve anatomic lateral ankle ligament reconstruction.

The hypothesis of this study was that the lateral malleolus could be used as an anatomic reference to locate the distal insertion of the CFL. The secondary goal was to confirm that this percutaneous technique was safe for the different adjacent anatomic elements.

Materials and methods

This cadaveric study was performed between March and July 2015 on fresh unembalmed anatomic subjects (preserved at +4°) according to a standard protocol by two independent senior surgeons. The dissection protocol was the same for all ankles and was validated after a test in 4 ankles. The only inclusion criteria were cadaveric ankles with no history of surgery or trauma. Ankles with lateral collateral ligament tears, a history of fracture, the presence of scar tissue and inflammatory synovial disease making dissection of the distal insertion of the CFL impossible were excluded from the study.

The contours of the lateral malleolus were identified with a dermographic pen. A vertical line was drawn along the axis of the posterior diaphyseal fibular cortex, and a line perpendicular to this was drawn passing through the inferior tip of lateral malleolus (Fig. 1). These 2 lines made it possible to create a fixed reference 1 cm distally and 1 cm posterior from the tip of the lateral malleolus.

After making a 1 cm incision and an incision with a Halstead haemostatic forceps to the bone, a diameter 18 Kirschner wire was inserted using the inferomedial calcaneum as a reference. The Kirschner wire was placed at the hypothetical distal insertion of the CFL to simulate the pathway of the calcaneal tunnel that would be created in case of anatomic reconstruction of the CFL by a transcalcaneal pathway inside, downwards and behind.

Fig. 1 .

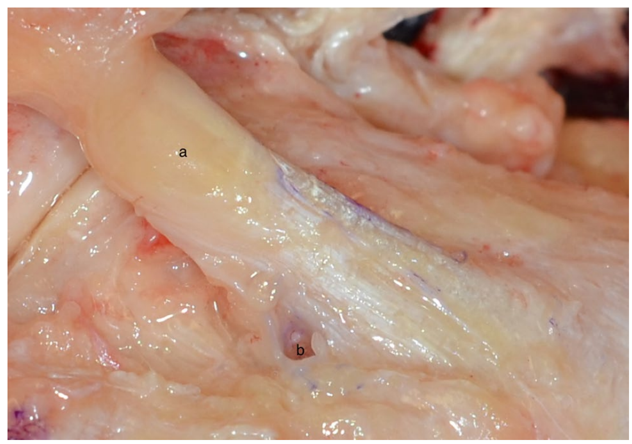

Fig. 2 .

The dissection was then performed with a microsurgical magnifying glass (Keeler®, Clewer Hill Road, Windsor, Berkshire, SL4 4AA, UK) according to a standardized protocol. The main measurement obtained was the distance from the Kirschner wire to the centre of the distal insertion of the CFL (Fig. 2). The following additional data and measurements were also obtained:

- Distance in millimetres (mm) between the distal insertion of the CFL and the peroneal tubercles,
- Presence of peroneal tendon injury,
- Characteristics of the CFL (length, width) and
- Distance in mm between the Kirschner wire and lateral (sural nerve) and medial (distal posterior pedicle) neurovascular elements.

All of these measurements were obtained using a manual sliding ruler with a reading error of 0.5 mm. (Wilmart®, ZI Les portes du Nord, 62820 LIBERCOURT, France) and a dual axis goniometer with graduation marking CE (Robé Médical®, 26 rue des Poncées—BP 90061, 88202 SAINT ÉTIENNE LES REMIREMONT CEDEX France) then recorded on an Excel™ spreadsheet (Microsoft, Redmond, WA, USA) by the operator himself. Photographs were taken with a Nikon® Reflex D3300 camera (Shin-Yurakucho Bldg., 12-1, Yurakucho 1-chome, Chiyoda-ku, Tokyo 100-8331, Japan).

Statistical analysis

Data are presented as mean ± SD. The sample size calculation was defined arbitrarily.

Results

Thirty ankles were included in the study (15 left ankles, 15 right ankles), 4 ankles were excluded. The mean age of the anatomic subjects was 72 (63–85). There were 20 men and 10 women. The subjects were preserved a median of 1 month (0–3) between death and dissection.

The mean distance between the Kirschner wire and the centre of the distal insertion of the CFL was 2.4 ± 1.8 mm. The sural nerve was found a mean 1.8 ± 1.1 mm from the Kirschner wire. The mean distance from the peroneal tubercles was 23.2 ± 3.4 mm. One case of peroneal injury caused by the Kirschner wire was identified during dissection in a morbidly obese patient (BMI >40). The posterior tibial pedicle was a mean 27.8 ± 3.5 mm from the orifice of the medial exit point of the Kirschner wire. The CFL was a mean 27.2 ± 2.9 mm long and 6.4 ± 1.2 mm wide.

Discussion

The most important finding of the present study was that lateral malleolus can be used as an anatomic reference to locate the distal insertion of the CFL.

The lateral malleolus is a reliable and reproducible percutaneous reference to guide anatomic arthroscopic reconstruction of the calcaneofibular ligament.

Lateral instability of the ankle develops in 15–30 % of cases following a lateral ankle sprain [11, 46]. Numerous surgical techniques have been described in the literature [7, 8, 17, 22, 29, 42] and can be divided into direct anatomic repair (DAR) with or without secondary reconstruction, non-anatomic reconstruction (NAR) and anatomic reconstruction (AR) of the lateral collateral ligament (LCL). Intermediate and long-term results are satisfactory [2, 19, 23]. Anatomic ligament reconstruction has been an option for more than 10 years and allows anatomic reconstruction of the lateral collateral ligament with an autologous gracilis graft providing satisfactory resistance [9, 48].

Numerous anatomic studies have specified the location and the different insertions of the ligaments [5, 30, 31, 33, 35, 43, 52, 53], and biomechanical studies have confirmed the role of each in lateral stability of the ankle [16, 25, 43]. The origin of the LCL or the fibular collateral ligament is found at the fibular malleolus and includes three distinct bundles.

- The anterior talofibular ligament whose pathway is horizontal in the neutral position and vertical during plantar flexion [44]. There are two distinct fibrous bundles separated by a vascular pedicle for the tibiotalar articulation which explains the lateral haematoma in case of a severe ankle sprain.
- The calcaneofibular ligament, which is thick and resistant, is attached to the distal part of the anterior lateral malleolus. It participates in the stability of the tibiotalar and subtalar joints [47] and possesses a unique isometry: tense in the neutral position while it relaxes during plantar flexion and stretches during dorsal flexion [24, 37, 38, 53].
- The posterior talofibular ligament originates in the fossa of the lateral malleolus and extends downwards and behind and attaches to the lateral tubercle of the posterior talar process [31, 33].

The CFL is the most important bundle of the LCL for lateral stability of the ankle, and its biomechanical characteristics have been described in numerous studies in the literature [16, 20, 24, 25, 40, 45]. It plays a major role when the ankle is in the neutral position and during dorsal flexion, which are positions favouring lateral ankle sprains [39]. The CFL includes a single bundle in a posterior inferior position with a mean width of between 4.57 mm [52] to 5.3 mm [5] and a mean length of 26.7 mm [52] to 35.8 mm [5] in the literature, creating a mean angle of 133° with the axis of the fibula [5]. The results of present study are similar to those in the literature (Table 1).

The distal calcaneal insertion is located 27.1 mm posterior and proximal to the peroneal tubercle [35] and 13 mm below the subtalar joint [5]. The surface measures between 0.97 and 2.68 cm^2 [35, 43].

Arthroscopic reconstruction is a reliable technique [1] that allows evaluation of associated injuries with less postoperative morbidity [28], but the calcaneal insertion of the CFL is difficult to visualize [51]. Neuschwander et al. [35] suggested using the peroneal tubercles as anatomic references, 3 cm anterior and distal from the centre of the calcaneal insertion of the CFL. In the present study, the lateral malleolus appears to be a reliable and easily palpable reference of the distal attachment of the CFL. Arthroscopic

Table 1 Characteristics of the CFL in the literature

	Length of the CFL	Width of the CFL	Surface of the calcaneal insertion of the CFL (cm^2)
Milner et al. [33]	19.5 (±3.9)	5.5 (±1.6)	
Siegler et al. [43]	27.7 (±3.3)		0.97 (±0.65)
Burks et al. [5]	35.8	5.3	0.82
Sarrafian et al. [41]	30	4.5	
Testut et al. (1948)	35	4.5	
Buzzi et al. [6]	24.3	6.7	
Urgulu et al. [52]	26.67	4.57	
Taser et al. [50]	31.94 (±3.7)	4.68 (±1.3)	
Neuschwander et al. [35]	24.8 (±2.4)		2.68 (±0.2)
Present study	27.4	4.9	

anatomic reconstruction of the CFL can be guided by the percutaneous position of a Kirschner wire, 1 cm distal to and 1 cm posterior from the tip of the lateral malleolus. Injury to the sural nerve is the greatest risk of this technique and requires a careful subcutaneous incision to prevent this.

These results seem to be in agreement with the recent anatomic study by Best et al. [3] who concluded that the distal insertion of the CFL could be identified on lateral X-rays of the ankle at the intersection of two lines, one perpendicular to the posterior part of the articular surface of the talus and the other at a right angle passing through the most distal part of the tarsal sinus of the tarsus.

The main limitation to this study is determining the location of a deep bone from a superficial cutaneous marker which can be difficult in obese patients because of the thick layer of subcutaneous tissue.

Conclusion

This cadaveric study seems to confirm the reliability of the lateral malleolus as a cutaneous reference of the distal insertion of the CFL. This reference can be useful in the day by day clinical work to avoid iatrogenic lesions. In clinical practice, this percutaneous technique is little invasive and accurate which seems to be an interesting technical alternative to a purely arthroscopic technique to identify the location of the calcaneal tunnel.

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Author's contributions Dr Lopes gave the principle idea of the study, drafted the dissection protocol, obtained the approvals from the laboratory, participated in cadaver dissection and corrected the article; Dr. Noailles and Dr. Brulefert performed the bibliographic search and drafted the article; and Dr. Geffroy and Dr. Decante participated in the dissection of the cadaver.

Compliance with ethical standards

Conflict of interest None.

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