A calcaneal tunnel for CFL reconstruction should be directed to the posterior inferior medial edge of the calcaneal tuberosity

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Knee Surgery, Sports Traumatology, Arthroscopy

ISSN 0942-2056

Knee Surg Sports Traumatol Arthrosc
DOI 10.1007/s00167-020-06134-x

ONLINE FIRST

Springer

Knee Surgery, Sports Traumatology, Arthroscopy
https://doi.org/10.1007/s00167-020-06134-x

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A calcaneal tunnel for CFL reconstruction should be directed to the posterior inferior medial edge of the calcaneal tuberosity

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Received: 24 February 2020 / Accepted: 26 June 2020

Abstract

Purpose Anatomical reconstruction of the calcaneofibular ligament (CFL) is a common technique to treat chronic lateral ankle instability. A bone tunnel is used to fix the graft in the calcaneus. The purpose of this study is to provide some recommendations about tunnel entrance and tunnel direction based on anatomical landmarks.

Methods The study consisted of two parts. The first part assessed the lateral tunnel entrance for location and safety. The second part addressed the tunnel direction and safety upon exiting the calcaneum on the medial side. In the first part, 29 specimens were used to locate the anatomical insertion of the CFL based on the intersection of two lines related to the fibular axis and specific landmarks on the lateral malleolus. In the second part, 22 specimens were dissected to determine the position of the neurovascular structures at risk during tunnel drilling. Therefore, a method based on four imaginary squares using external anatomical landmarks was developed.

Results For the tunnel entrance on the lateral side, the mean distance to the centre of the CFL footprint was 2.8 ± 3.0 mm (0–10.4 mm). The mean distance between both observers was 4.2 ± 3.2 mm (0–10.3 mm). The mean distance to the sural nerve was 1.4 ± 2 mm (0–5.8 mm). The mean distance to the peroneal tendons was 7.3 ± 3.1 mm (1.2–12.4 mm). For the tunnel exit on the medial side, the two anterior squares always contained the neurovascular bundle. A safe zone without important neurovascular structures was found and corresponded to the two posterior squares.

Conclusion Lateral landmarks enabled to locate the CFL footprint. Precautions should be taken to protect the nearby sural nerve. A safe zone on the medial side could be determined to guide safe tunnel direction. A calcaneal tunnel should be directed to the posterior inferior medial edge of the calcaneal tuberosity.

Keywords Hindfoot instability · Calcaneofibular ligament · Ligament reconstruction · Bone tunnel · Neurovascular bundle

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Introduction

Chronic lateral ankle instability is a disabling complication after an acute ankle sprain, and surgery is indicated if conservative treatment fails [23]. In patients with generalized laxity or poor ligament quality and in revision cases, lateral ligament reconstruction of both the anterior talofibular ligament (ATFL) and the calcaneofibular ligament (CFL) should be considered [23].

The evolution towards more anatomical procedures to restore normal joint mechanics increases the need for detailed knowledge of the normal anatomy [21, 22, 25]. When performing a ligament reconstruction, bone tunnels are commonly used. The entrance of the tunnel should be at the normal anatomical footprint. However, the exact position of the calcaneal insertion of the CFL is difficult to locate, and no agreement exists about the optimal direction of the

Published online: 01 July 2020

calcaneal tunnel [17, 18]. The medial neurovascular bundle at the exit of a transosseous bone tunnel may be a point of concern. When choosing a transosseous bone tunnel, the tunnel exit should avoid the neurovascular bundle on the medial side. The advent of new endoscopic and percutaneous techniques to perform this procedure increases the need for anatomical landmarks and guidelines [5, 16, 21, 23].

Therefore, a cadaveric study was performed. Regarding the tunnel entrance on the lateral side, the hypothesis was that the CFL footprint could be located at the intersection of two lines based on the fibular long axis and local anatomical landmarks of the lateral malleolus. Regarding tunnel exit and orientation on the medial side, the hypothesis was that a safe area based on imaginary squares on the skin surface could be determined to avoid the important neurovascular structures. This information would be useful to offer some clinical recommendations to drill a calcaneal tunnel when performing a CFL reconstruction.

Materials and methods

Fresh-frozen anonymized specimens were obtained via the Human Body Donation Programme of the University. Informed consent for medical education and research was obtained. The specimens were segmented at the tibia and thawed at room temperature 24 h prior to dissection. Specimens showing musculoskeletal pathologies or deformities were excluded from the study. Due to practical reasons, not all specimens were available for both parts of the study resulting in two study groups. The first study group, used for the lateral assessment, consisted of 29 specimens (10 female and 19 male) with a median age of 84 (65–92) years. This group included three non-paired specimens. The second study group, used for the medial assessment, consisted of 22 specimens (16 female and 8 male) with a median age of 84 (67–92) years. This group included two non-paired specimens.

Total foot length was measured from the posterior side of the heel to the tip of the hallux. All measurements were performed with a Mitutoyo Absolute Digimatic IP67 digital calliper, accuracy 0.01 mm. All measurements were carried out twice, and the mean value of the two measurements was calculated. Measurements on the dissected specimens were assessed to 0.1 mm accuracy. Measurements based on palpations of anatomical structures were assessed to 1 mm accuracy. Pictures were taken at every step of the protocol.

Tunnel entry on the lateral side

Each specimen was positioned with the lateral side facing upwards and with the ankle joint in neutral position. To maintain the neutral position during the entire procedure, a rope was attached to the tibia and hallux positioning the ankle at 90°.

The hypothetical location of the CFL footprint, the ideal tunnel entry point, was based on two imaginary lines in relation to landmarks on the lateral malleolus (Fig. 1). The first line was parallel to the fibula's long axis, passing through the posterior point of the lateral malleolus. The second line at a 45° angle to the first one passed through the anteroinferior part of the lateral malleolus, which corresponds to the fibular obscure tubercle [17]. At the intersection of both lines, a 0.5-diameter Kirschner wire was drilled perpendicular to the lateral surface. The wire was passed through the calcaneus until it was no longer palpable on the lateral side. The Kirschner wire entrance was blinded to allow repeat CFL footprint localization with a second wire by a second investigator, who was blinded to the steps of the first procedure.

Before starting dissection, the first wire was drilled back into the initial position. Then a detailed dissection of the lateral ankle region was performed. First, the sural nerve was located proximally and distally from the footprint zone and followed along its course towards the lateral malleolus without displacing it. The distance between each wire and the sural nerve was measured, as well as the distance to the saphenous vein and the peroneal tendons. Next, the soft tissues covering the anterior tibiofibular ligament, the ATFL and the CFL were removed. The location of the K-wires was verified according to the centre of the insertion site. The distance between each K-wire and the centre of the insertion site of the CFL was measured. The distance between the two wires was measured to assess the inter-investigator reliability. The K-wire was considered to be in the centre of the footprint if it arrived in the circular central area with a radius

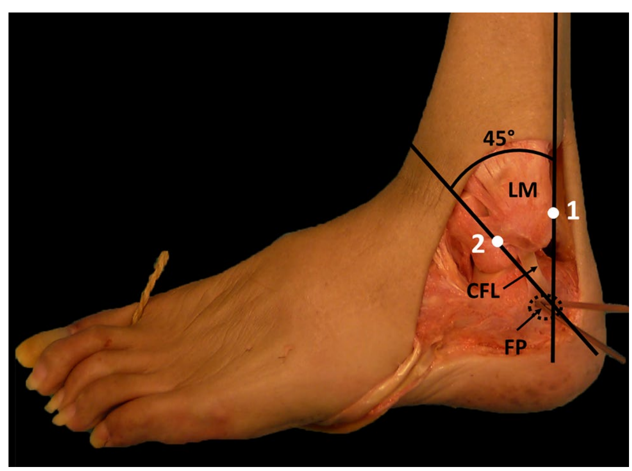

Fig. 1 Lateral procedure. Position of the landmarks and reference lines for the drilling procedure. *FP* calcaneal footprint, *CFL* calcaneofibular ligament, *LM* lateral malleolus. (1) Posterior point of the lateral malleolus, (2) anteroinferior part of the lateral malleolus which corresponds to the fibular obscure tubercle

of 1.5 mm around the CFL footprint centre. The measurement results were corrected by the radius of the K-wire.

Tunnel orientation and exit on the medial side

In order to evaluate safe tunnel orientation and exit with respect to the neurovascular structures, a square method was used on the medial foot surface. Each specimen was positioned with the medial side facing upwards and the ankle joint in neutral position.

A square was created using the following steps. First, two anatomical landmarks were indicated with percutaneously placed needles: the upper posterolateral edge of the calcaneus and the origin of the plantar aponeurosis at the medial anterior edge of the tuber calcanei (Fig. 2). In a next step, two horizontal lines were drawn parallel to the foot sole and passing through the indicated landmarks. Finally, two lines were added perpendicular to the first lines to obtain a rectangle. As the lengths of all sides were almost equal, a square was formed. In a next step, this square was then divided into four equal squares: an anterosuperior, a posterosuperior, an anteroinferior and a posteroinferior one. Dissection of the squares was performed to assess the presence of neurovascular structures. To avoid displacement of the neurovascular structures during the dissection, the dissection was started from the area proximal (superior) to the square. This allowed us to identify the most important anatomical structures. Next, the two superior squares were dissected. Then the two lower squares were dissected to track the smaller branches to their endpoints to differentiate between sensory nerves (to the fatty tissue and skin of the foot sole) and motor nerves (to the intrinsic foot muscles).

Data are presented as mean ± standard deviation. The sample size calculation was not a priori calculated and the largest number of available ankles was included.

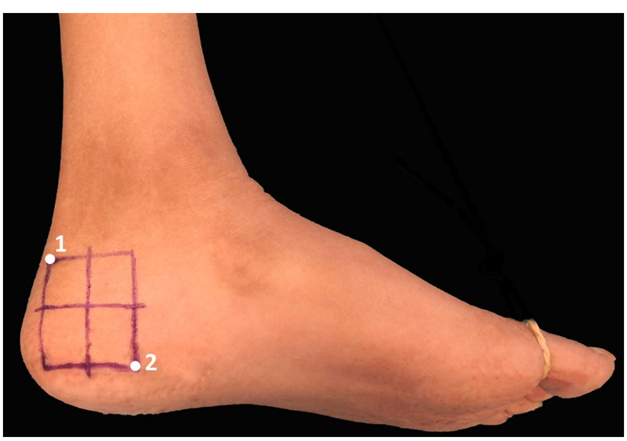

Fig. 2 Medial procedure. Anatomical landmarks and squares. (1) The upper edge of the calcaneum at the insertion site of the Achilles tendon. (2) The anterior edge of the tuber calcanei defined by palpation

Results

Tunnel entry on the lateral side

The mean distance to the centre of the CFL footprint was 3.6 ± 2.8 mm (0–10.4 mm). The mean distance between both wires (both investigators) was 4.2 ± 3.2 mm (0–10.3 mm). In 74.1% (43/58) of the attempts, the wire was drilled in the footprint of the CFL, including 8 attempts that arrived in the centre (Fig. 3). The mean distance to the sural nerve was 1.4 ± 2 mm (0–5.8 mm). In ten attempts, the sural nerve was pierced. In another 21 attempts, the wire touched the nerve without macroscopic damage. The mean distance to the small saphenous vein was 1.9 ± 2.3 mm (0–7.1 mm). The small saphenous vein was pierced in two cases. The mean distance to the peroneal tendons was 7.3 ± 3.1 mm (1.2–12.4 mm). The peroneal tendons were pierced in none of the cases.

Tunnel orientation and exit on the medial side

The average total foot length was 240 mm and ranged from 208 to 312 mm. The neurovascular bundle was located in both anterior squares in every specimen (Fig. 4). No major arteries or motor branches were found in the two posterior squares.

Sensory nerve branches could be identified in all squares. Division of the posterior squares into an anterior and posterior half allowed us to indicate areas without sensory branches (Fig. 4c). The average horizontal length

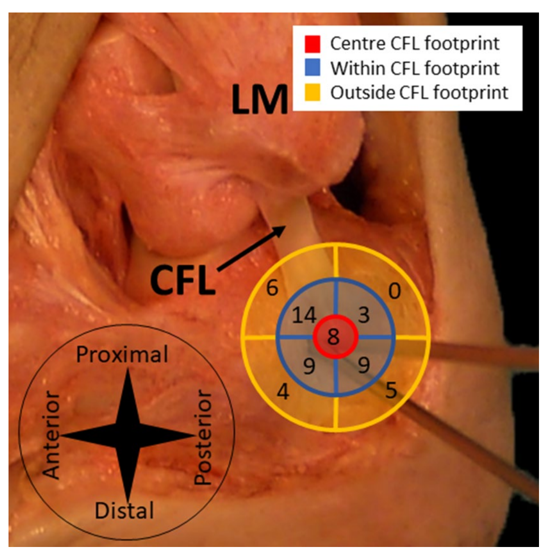

Fig. 3 Schematic illustration of the localization of the K-wires and relative position to the footprint and footprint centre

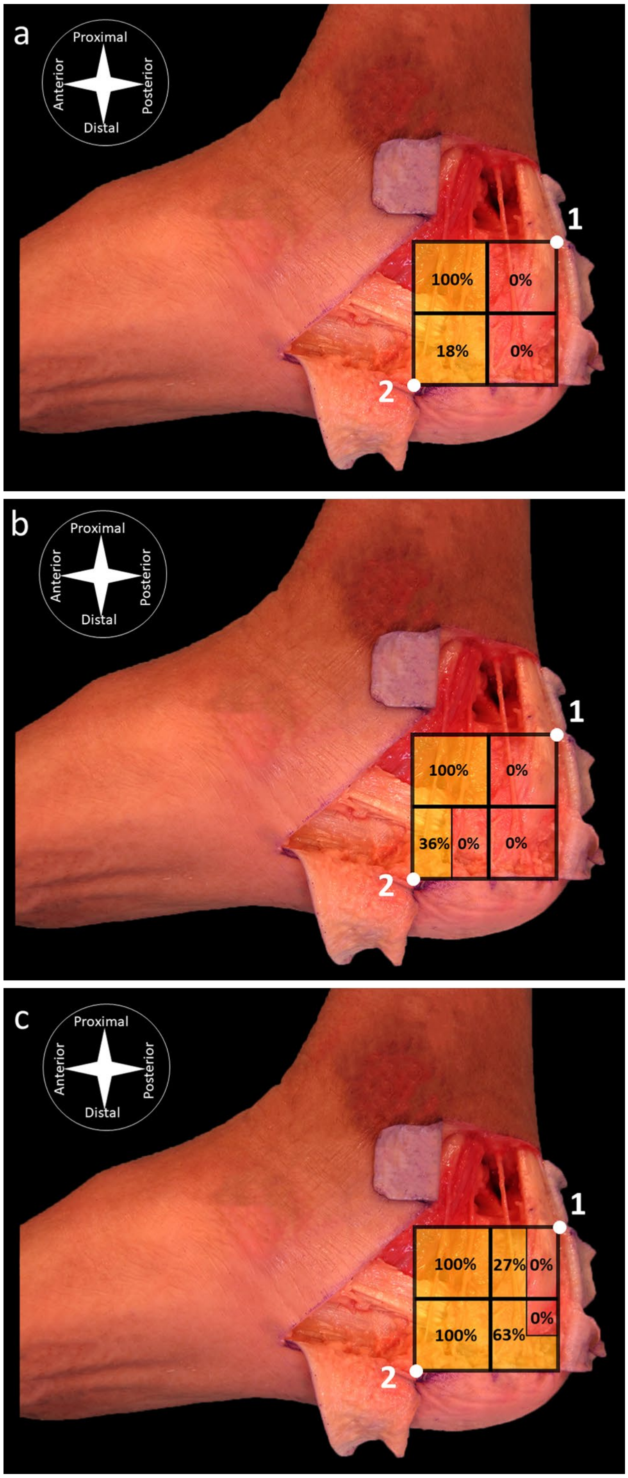

Fig. 4 Medial view of the hindfoot with four squares. (1) The upper edge of the calcaneum at the insertion site of the Achilles tendon. (2) The anterior edge of the tuber calcanei defined by palpation. **a** Arteries, **b** motor branches, **c** sensory branches

of the main rectangle was 52 mm (34–88 mm), and the vertical length was 50 mm (34–98 mm).

Discussion

The most important finding in this study is that anatomical surface landmarks can be very useful to obtain information about the location of the calcaneal CFL footprint on the lateral side and the neurovascular bundle on the medial side. This information is valuable with respect to the optimal tunnel entry point and safe tunnel orientation to reconstruct the CFL.

The different surgical techniques for treating chronic lateral ankle instability can be divided into two major groups [10]. First, anatomical repair has been commonly used and corresponds to suturing the torn lateral ligaments. Second, reconstruction refers to the replacement of chronically deficient lateral ligaments with other tissue, which can be local tissue, autograft or allograft [10]. Since 2006, anatomical reconstruction has become more popular [6, 28, 31]. According to a recent systematic review, anatomical reconstruction using a tendon graft seems to give the best results, but may be more invasive than anatomical repair [31]. Especially in patients with generalized laxity or poor ligament quality, lateral ligament reconstruction (with grafting) of both the ATFL and CFL should be considered [23]. The CFL, which is the only ligament bridging both the tibiotalar and subtalar joint is generally assumed to be an important stabilizer of both joints. Lesions of the CFL and the suspicion of subtalar instability serve as an extra argument for reconstructing the CFL in addition to the ATFL [11, 19, 23]. Pereira et al. described several distinct anatomical variants of the CFL: single bundle, Y-shape, V-shape and double bundle [26]. The contribution of the different bundles to the stability of the hindfoot is still unclear, but may be important when an anatomical reconstruction is being considered. In particular, the bundle towards the talus is probably important to provide stability of the subtalar joint. In contrast, the calcaneal footprint showed limited morphological variability, with a single calcaneal footprint in 89.4% of the specimens.

Takao et al. published the anatomical ankle ligament reconstruction method in 2005 [28]. They fixed a gracilis autograft in a calcaneal tunnel to reconstruct the CFL. In later years, similar open [6, 12], endoscopic [5, 9, 11, 20, 21, 27, 32, 34] and percutaneous [8] techniques of CFL reconstruction were published. However, those publications presented different tunnel directions and offered only limited information on finding the CFL footprint.

When performing an anatomical reconstruction of the CFL, the entrance of the calcaneal tunnel, which represents the fixation site of the graft, should be as close as possible to the anatomical footprint. In most cases, some tissue remnants are still present and can be used to determine the optimal position. However, this tissue can be difficult to dissect or difficult to recognize. A recent systematic review confirmed the need to find additional anatomical landmarks [16].

Two tubercles on the lateral calcaneal wall have been described as possible landmarks. Laidlaw et al. reported that the CFL inserted on a small tubercle, the tuberculum ligamenti calcaneofibularis (TLC) [13]. As this tubercle is often absent or difficult to detect, its clinical use is very limited [17, 18, 33].

Another tubercle, the peroneal tubercle, was also described as a reference point. This tubercle is located about 13.2–27.1 mm anteroinferior to the CFL insertion [4, 15, 18, 24].

Alternatively, the posterior facet of the subtalar joint can be used as a landmark. The CFL insertion is located on the perpendicular line from the midpoint of the subtalar joint at 17.2 mm, ranging from 14.4 to 21.0 mm [17]. Other studies report a distance of 12.1–13.2 mm [2, 3].

Best et al. used an image intensifier to determine radiographic landmarks that support the identification of the CFL footprint [1]. The intersection between a horizontal tangent aligned to the deepest visible concavity of the tarsal sinus and a vertical tangent aligned to the farthest posterior convexity of the talus on a standardized lateral radiograph in the neutral ankle position was used to indicate the CFL footprint. The reliability of this method was not assessed. Lopes et al. used the tip of the lateral malleolus as a landmark and related the CFL footprint to a point 1 cm distal and posterior to the tip of the lateral malleolus [14, 15]. The accuracy of this method was similar to the findings in our study. This confirms the reliability of the lateral malleolus as a reference point to locate the CFL insertion.

The method used in this study was based on earlier studies measuring the angle between the fibular axis and the CFL [1, 2, 30]. Burks et al. measured a CFL–fibular angle of 133° and Best et al. measured 131°. These results coincide with the 135° angle used in this study, which was transformed in an adjacent angle of 45° for practical reasons.

Although there are concerns about damaging the medial neurovascular structures during tunnel positioning, no studies have assessed the optimal directions to avoid this problem [8]. Earlier studies focused on the risk to medial neurovascular structures when applying fixation frames or performing osteotomies [7, 29]. The guidelines put forth by us correspond with those studies identifying the posterior part of the calcaneus as a safer zone.

The main limitation of this study was that the CFL–fibular angle was not measured. It is assumed that the variability of this angle is the most important limitation to determining reliable guidelines to find the CFL footprint. Geometrically, the CFL–fibular angle corresponds to the orientation of the CFL in the sagittal plane. As a consequence, this angle should be correlated with the location of the calcaneal footprint. A small angle will correspond to a more posteriorly located calcaneal footprint. As this angle was only measured in few of the specimens, these findings were not included in this study. Future studies could investigate the morphological factors that are correlated with this angle.

Another limitation to this study is the use of superficial landmarks to determine a deeply located footprint, which can be difficult in certain patients with a thicker layer of soft tissues. In those patients, a fluoroscopic technique can be very useful.

This study does not offer any guidelines on the tunnel length and diameter. As the calcaneus is a bulkier bone than the talus and fibula, the tunnel dimensions are probably less of a concern.

The results of this study are useful in the day-to-day clinical practice. The described guidelines to locate the CFL footprint can be used when reconstructing the CFL and offer several advantages. No fluoroscopy is needed. The proposed landmarks are easy to palpate. As the landmarks are superficial, they can be used without the need for surgical exploration. The proposed landmarks avoid the use of absolute distances, which can be essential in situations with an unusual foot size.

Nevertheless, there are some risks when using minimally invasive techniques. In percutaneous techniques, the peroneal tendons and sural nerve can be damaged due to their close position to the CFL footprint. These structures should be protected using the “nick and spread” technique for dissection and a drill guide during drilling [8]. When using endoscopic or open procedures, a more anteriorly located approach allows the surgeon to start from a safe zone free from important neurovascular structures [20]. This can be combined with a small percutaneously placed needle at the estimated location of the footprint to find the remnants of the CFL insertion.

The results of tunnel orientation and exit on the medial side are useful to avoid damage to the most important structures at risk—the posterior tibial neurovascular bundle. We recommend directing the calcaneal tunnel to the posterior inferior medial edge of the calcaneal tuberosity, which is located in the posteroinferior square. This offers a long tunnel and avoids arteries and motor branches. Alternatively, a blind-ended tunnel can be used to avoid damage on the medial side. The safe zones found in this study are also useful when performing other surgical procedures in this area, e.g. osteosynthesis of a calcaneal fracture, calcaneal osteotomy, or external fixation frame on the hindfoot.

Conclusion

Anatomical landmarks on the lateral malleolus allowed to locate the CFL footprint. Precautions should be taken to protect the nearby sural nerve. A medial safe zone could be determined to guide tunnel direction. A calcaneal tunnel should be directed to the posterior inferior medial edge of the calcaneal tuberosity.

Acknowledgements We thank Marie Vanhoof and Elise Lesage from the Jan Palfijn Anatomy Lab of the Kulak (KU Leuven) for their support with specimens and infrastructure. We thank the following students for their collaboration in this project: Baekelandt Loïc, Callens Klaas, Matthys Emiel, Van Compernolle Kevin, Borgonie Tine, Maene Korneel, Verhulle Nele, Speecke Philippe, Vandenabeele Pieter, Vanwymelbeke Jana.

Compliance with ethical standards

Conflict of interest No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

Funding There is no funding source.

Ethical approval This study has been performed with human specimens donated to the Anatomy Unit of the KU Leuven KULAK. Ethical approval was granted.

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