

ORIGINAL ARTICLE

CONTENTS

Features of the macroscopic structure of the posterior inferior tibiofibular ligament based on anatomical study

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ABSTRACT
Aim: To study the anatomy of the posterior inferior tibiofibular ligament (PITFL) and specify the features of its morphology and linear parameters.
Materials and Methods: The peculiarities of morphology and linear parameters of PITFL on 10 fresh amputated lower limbs were studied. The average age of the patients was 64.7 ± 9.3 (7 males, 3 females). Macroscopic characteristics, insertion, orientation in relation to the corresponding bony and ligamentous anatomical structures were studied, and linear parameters of PITFL were measured using a caliper. Average values were calculated.
Results: PITFL was detected in all the studied samples. It represented a strong, compact anatomical structure of a trapezoidal or triangular shape. The proximal width of the PITFL averaged 20 ± 3.65 mm, while the distal width was 36.6 ± 4.62 mm. The attachment length of PITFL to the posterior part of the tibia was 28.6 ± 5.13 mm and to the fibula was 17.4 ± 3.2 mm. The ligament is closely connected to the posterior intermalleolar ligament, the inferior transverse ligament, and the tendinous sheaths of the posterior tibial and fibular muscles.
Conclusions: The obtained results of the study of linear and morphological parameters of PITFL should contribute to a better understanding of the anatomy of the posterior part of the ankle joint and improve surgical approaches to the treatment of posterior malleolus fractures and related PITFL injuries.

KEY WORDS: ankle joint, posterior malleolus fracture, distal tibiofibular syndesmosis, posterior inferior tibiofibular ligament, anatomical study

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INTRODUCTION
Ankle fractures are one of the most common injuries of the ankle joint, with 40% of the cases being associated with posterior malleolus fractures (PMF) and 20% with injuries of the distal tibiofibular syndesmosis (DTFS) [1]. The anatomical features of the structure of the DTFS ligament complex are closely related to the biomechanics of ankle injuries, which significally explains the patterns of occurrence of PMF and forms the basis for proper approach to the treatment of these injuries. Despite the fact that the structure of the DTFS has been sufficiently covered in a number of scientific publications in recent years [2–5], there are still disagreements in the terminology, naming, and morphology of certain anatomical formations, in particular, the posterior inferior tibiofibular ligament (PITFL). The current interest in the study of the anatomy of DTFS can be explained by its influence on the stability of the ankle joint, which, even with the precise restoration of the position of ankle fractures, often requires additional surgical treatment. A detailed study of the anatomical features of the PITFL may clarify the pathogenesis of PMF and may help to resolve a number of debatable practical issues regarding the treatment of these injuries.

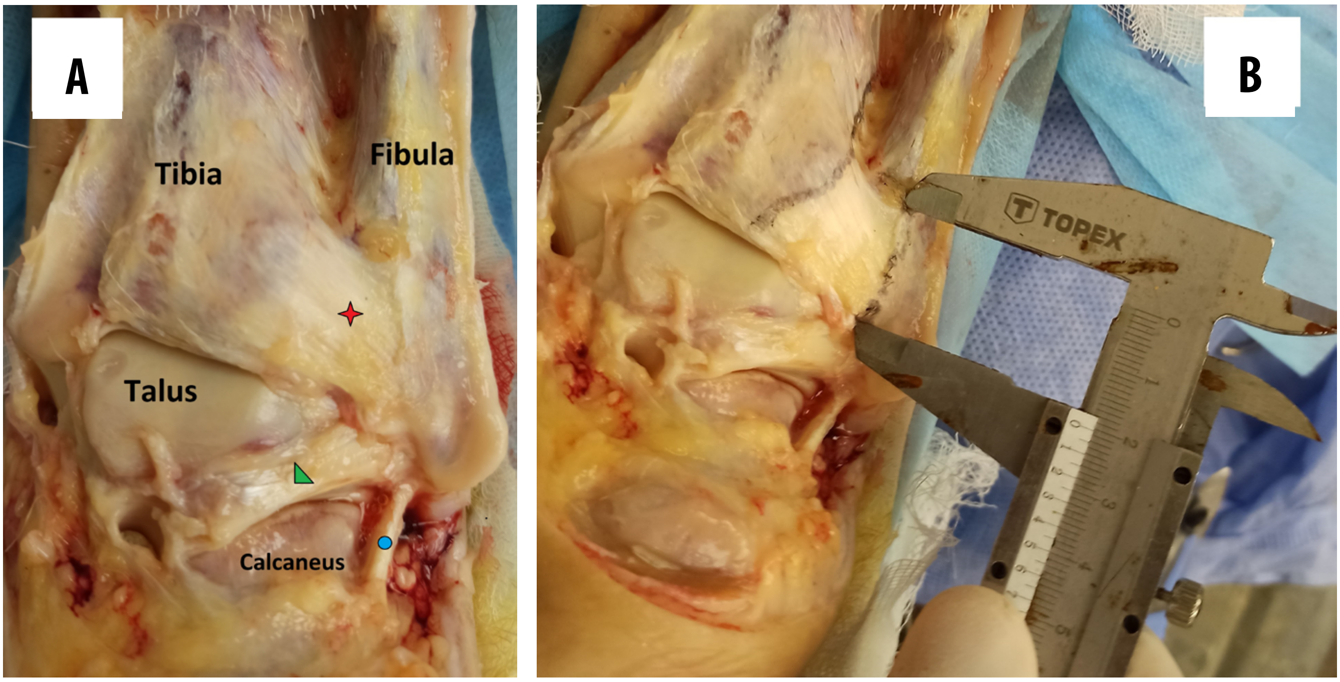
AIM
The aim of the work was to analyze the anatomy of the posterior inferior tibiofibular ligament and clarify the features of its morphology and linear parameters.

MATERIALS AND METHODS
The material for the study consisted of 10 fresh amputated lower limbs, on which the anatomy of the posterior inferior tibiofibular ligament was examined. The average age of the patients was 64.7 ± 9.3 (range 50-78 years). There were 7 male, 3 female patients. The nosological forms that led to the amputation of the lower limb were obliterating angiopathy of the arteries of lower limbs and consequences of injuries. Inclusion criteria for amputated lower limbs in the study: absence of anatomical defects and tissue damage in the area of the tibiotalar joint, absence of contractures of the ankle and foot joints, and pronounced necrotic changes in the soft tissues of the ankle and foot. All anatomical specimens had no external signs of previous surgical intervention, congenital or acquired deformities, or signs of rheumatic diseases. The use

Table 1. The results of measurements of angular and linear parameters of the posterior inferior tibiofibular ligament according to the results of the study

Parameters	Measurement results in mm (M ± σ; min–max)
Proximal width of PITFL	20 ± 3.65; (15-26)
Distal width of PITFL	36.6 ± 4.62; (30-44)
The length of PITFL on the tibia	28.6 ± 5.13; (20-36)
The length of PITFL on the fibula	17.4 ± 3.2; (12-22)
Angle°	30° ± 4.35°

Notes. M ± σ – mean and standard error; min–max — minimum and maximum values.



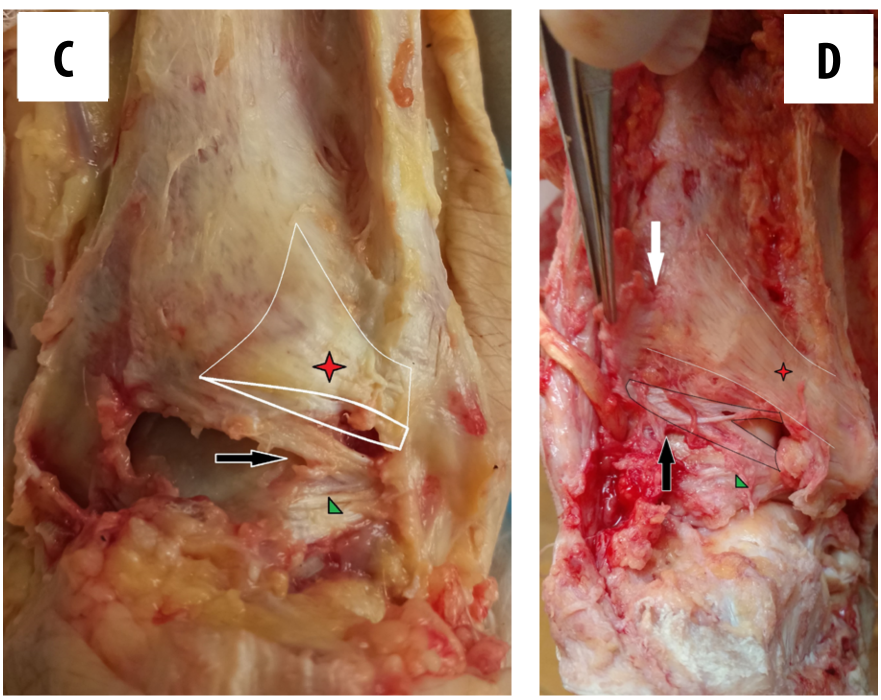


Fig. 1: A. View of the anatomical preparation posterior aspect of the ankle joint : red star – posterior inferior tibiofibular ligament, green triangle – posterior talofibular ligament, blue circle – calcaneofibular ligament; B. Method of determining the length of PITFL attachment on the fibula; C. The posterior intermalleolar ligament (black arrow); D. Connection of PITFL with the tendon sheath of the posterior tibial muscle (white arrow).

of patient medical history data was carried out in accordance with the requirements of the Bioethics Committee of the State Institution "The Institute of Traumatology and Orthopedics of NAMS", and all procedures performed with the patients met the ethical standards of the institutional and/or national research committee, as well as the Helsinki Declaration of 1964 and its later amendments.

Preparation (dissection) was carried out in order to identify the morphology of the posterior inferior tibiofibular ligament (Fig. 1A). The amputated segment of the lower limb was fixed to the table with the ventral surface of the ankle, while the ankle joint was in a neutral position outside the dissection table. Among the 10 ankle and foot joints studied, 6 were left and 4 were right. The results of the preparation were recorded in digital format for comparing the morphological characteristics of the studied samples. All anatomical specimens were prepared in the same sequence. In the first stage, the skin was removed from the posterior surface of the tibia along with the subcutaneous adipose tissue. The Achilles tendon was cut off from its attachment point on the calcaneus in a proximal direction along with the gastrosoleus complex and the Kager's fat pad. Deep fasciae of the ankle, muscles and tendons such as m. flexor hallucis longus, mm. peronei, m. flexor digitorum longus and m. tibialis posterior, along with the vascular and nerve bundles, were carefully removed in all samples. The tendon sheath was cut in the midline and the tendons were removed, leaving the base of the sheath. A caliper (calibrated to 0.1 mm) was used to conduct direct measurements of the linear parameters of PITFL (Fig. 1B). The results of the dissection of all anatomical specimens were assessed by both authors. Macroscopic characteristics, insertion, orientation in relation to the corresponding bony and ligamentous anatomical structures, as well as linear measurements of PITFL, and were performed in an identical sequence. Each measurement was repeated three times, and the average values were calculated. The calculated data were entered into an electronic spreadsheet and descriptive statistics were calculated.

RESULTS

In our study, PITFL was detected in all anatomical samples. Visually, the ligament consisted of well-defined fibers throughout its length and presented a multifascicular, strong, compact anatomical structure of a trapezoidal or triangular shape. The PITFL originated on the posterior surface of the lateral malleolus and extended in the upper medial direction, attaching along the posterior border of the tibia (Volkman's triangle) with a gradual transition to the posterior surface of the distal epimetaphysis of the tibia, integrating into the periosteum in the periphery. In the proximal direction, the PITFL had a strong connection with the posterior fibers of the interosseous ligament. The average proximal width of the PITFL was 20 ± 3.65 mm, the distal width was 36.6 ± 4.62 mm. The attachment length of the PITFL on the posterior part of the tibia was 28.6 ± 5.13 mm, and on the lateral malleolus was 17.4 ± 3.2 mm. The data from our anatomical study is consistent with the data of Jayatilaka et al. [6], indicating that the PITFL has a dense connection with the tendon sheath of the posterior tibial muscle medially and with the tendon sheath canal of the peroneal muscles laterally (Fig. 1D). The mentioned study by Jayatilaka categorizes the surface of PITFL into oblique and transverse portions, which, in our opinion, is challenging to differentiate in anatomical preparations due to the lack of clear defined anatomical landmarks of the transition of the surface of the PITFL to the specified segments and the gradual integration of the ligament into the periosteum. However, it should be noted that the lateral part of the PITFL had a thicker structure, which thinned as it spread medially to the distal epimetaphysis of the tibia. The angle between the vertical axis of the lateral bone and PITFL was 30° ± 4.35°. The data on the results of the linear parameters of PITFL are presented in Table 1.

DISCUSSION

The measurements of the linear parameters of PITFL in our study correlate well with the study by Martins et al. [7], however, the authors provide slightly smaller values of the linear parameters, which may be due to anthropometric features and different measurement methodologies. Ebraheim et al. [8] described the shape of PITFL as triangular, narrowing at the point of transition to the lateral malleolus, while Williams et al. [3] indicate a trapezoidal shape, which is consistent with the results of our study.

There is a discussion in the scientific literature regarding the anatomical definition of the inferior transverse ligament (ITL). A number of anatomical, radiological and clinical studies describe the inferior transverse ligament as a component of PITFL, while others indicate the inferior transverse ligament as a separate anatomical structure [9]. For example, Lilyquist et al. [10] showed that the ITL is found in 70% of anatomical preparations and is a well-defined anatomical structure. Ebraheim et al. also describes the ITL as a separate anatomical structure, and indicates that there is an additional fibrous and adipose connective tissue between the PITFL and ITL [8] . Lee et al. [11] demonstrated that MRI arthrography allows distinguishing between the superficial and deep components of the posterior tibial ligament. Similar findings are reported by Muhle et al. [12], who, using high-resolution MRI, clearly distinguish between PIT-

FL and ITL in all examined samples during dorsal or plantar flexion of the foot. In contrast to these studies, Bartonícek et al. [13] distinguish the superficial and deep fibers of PITFL, without describing the ITL as a separate ligament. Martins et al. [7], agree with this view, pointing to the morphological and functional homogeneity of these structures. The controversial nature of these data, in our opinion, may be due to the different methodologies of the conducted studies and the corresponding criteria for assessment these structures. In our study, the inferior transverse ligament was found in all cases and was closely adjacent to the PITFL. The ligament is originated below the attachment of PITFL in the area of the lateral malleolar fossa with further attachment in the medial parts of the distal epimetaphysis of the tibia. ITL was placed more horizontally and visually characterized by denser fibers.

Some anatomical studies show that PITFL and ITL form a distinct joint lip or "meniscus-like addition" to the ankle joint, which allows to increase the articular surface and improve the congruence of the tibial plateau [13–15]. It remains interesting that the posterior intermalleolar ligament, which is characterized by a significant anatomical variability [7], has a place of adjacent attachment to the posteromedial edge of the tibial plateau. The anatomical study of Edama M. et al. [16] shows that in 70.3% of cases these anatomical structures have additional connections. According to some authors, the given morphological features can be important factors influencing the pathophysiological mechanism of the occurrence of the posteromedial fragment of the PMF in ankle fractures [17,18]. In our study, the posterior interosseous ligament had a variable morphology from a thick "rope-like" structure to separate thin bundles, and represented a distinct anatomical structure that, together with ITL, was attached to the posteromedial part of the posterior margin of the tibia (Fig. 1C, D).

Obtained in our study results of the linear mearurements of the PITFL demonstrate a significant area of ligament attachment to the distal tibia and its close relationship with the dynamic (ligamentous) stabilising complex of the ankle joint. Taking into account these data, it`s logical to assume, that different morphological types of PMF may be accompanied by concomitant injuries of the PITFL and anatomically related structures of the posterior aspect of the ankle joint, which vary significantly in each case and, accordingly, affect the stability of the DTFS. Fujimoto et al. [19] demonstrated the need to assess the size of the PMF in the mediolateral dimension, which allows to analyse the possibility of additional damage to the PITFL and, accordingly, increase syndesmotic instability. Beumer et al. [20] showed that, along with the highest biomechanical strength and stiffness of the PITFL among the ligaments of DTFS, the predominant type of damage to this ligament, along with avulsion, is substance ruptures. Warner et al. [21] showed that in rotationally unstable ankle fractures, even in the absence of a PMF, in 97% of cases, the PITFL was delaminated from the posterior malleolus, which necessitates additional surgical treatment. Another study by Warner SJ et al. [22] showed that PER IV ankle fracture-dislocations have worse functional outcomes and a higher risk of malreduction, which may be associated with substantial articular damage.

The majority of studies have demonstrated the advantages of using a buttress plate in the treatment of PMF compared to screws [23–25]. In our opinion, the studied morphological features of the PITFL, confirm the advantages of osteosynthesis of even small fragments of the PMF with the buttress plate, which provides not only stable fixation of PMF, but also, due to the larger contact area, improves the stability of the DTFS, due to additional stabilisation of the damaged PITFL and its related components («articular lip of the ankle joint»).

Our study had several limitations. Firstly, a relatively small number of specimens of anatomic preparations were studied, the studied ankle joints were obtained from patients of a similar age and racial origin. Further studies evaluating a larger sample of preparations in different age groups and races are needed. Secondly, PITFL was studied by means of a macroscopic examination, which may create an additional probability of error in the assessment by researchers. Thirdly, the insertion sites of PITFL during macroscopic examination may differ from histological ones, which requires further histological examination.

CONCLUSIONS

PITFL is a strong, compact anatomical structure of a trapezoidal or triangular shape, which has a wide attachment in the posterior malleolus area. The ligament has a tight fusion with the interosseous ligament, inferior transverse ligament, as well as with the tendon sheaths of the posterior tibial and fibular muscles. The anatomical features of the PITFL indicate that osteosynthesis of PMF with plate and screws indirectly creates additional stabilisation of the PITFL and associated ligamentous structures, which can improve the syndesmotic stability of the ankle joint.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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