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The ramus sustentacularis of the tibialis posterior tendon: An anatomical and histological cadaveric study

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ABSTRACT

Background: The tibialis posterior tendon (TPT) is a crucial dynamic stabilizer of the medial longitudinal arch, facilitating midfoot locking and efficient propulsion during gait. While the navicular and cuneiforms are well-established distal insertion sites, an additional posterior band inserting onto the sustentaculum tali—historically termed ramus sustentacularis—has been inconsistently described and never histologically verified.
Methods: Twenty lower limbs from adult cadavers (mean age 81.7 ± 8.6 years; 8 female) were dissected using a standardized protocol. The distal TPT and its sustentacular band were exposed, and the width of the ramus sustentacularis was measured. Representative samples were processed for histological analysis to assess tissue composition and the tendon–bone interface.
Results: A distinct posterior band of the TPT inserting onto the anterior surface of the sustentaculum tali was present in all specimens. The band's mean width was 13.9 mm (range 10–17 mm), with no variation by sex or laterality. Histology confirmed dense, longitudinally oriented collagen fibers with parallelly arranged fibrocyte nuclei and no vascular or inflammatory features, consistent with mature tendon tissue.
Conclusion: This study provides the first histological confirmation of the ramus sustentacularis as a true tendinous structure and a constant component of the TPT's distal footprint. Its consistent presence suggests an overlooked role in hindfoot stabilization and adult-acquired flatfoot deformity pathomechanics. Classical anatomical descriptions should be updated to include the sustentacular band as a standard element of the TPT.

1. Introduction

The tibialis posterior tendon (TPT) is a key dynamic stabilizer of the medial longitudinal arch during gait, contributing to arch elevation, forefoot adduction, hindfoot inversion, and midfoot plantarflexion (Basmajian and Stecko, 1963; Johnson, 1983; Johnson and Strom, 1989; Guyton et al., 2001; Myerson et al., 2004; Semple et al., 2009; Coughlin et al., 2013).

The TPT locks the midtarsal joint through hindfoot inversion, converting the midfoot into a rigid lever after heel strike. This facilitates efficient transfer of plantarflexion forces from the triceps surae to the forefoot, thereby optimizing propulsion during ambulation (Basmajian and Stecko, 1963; Johnson and Strom, 1989; Guyton et al., 2001; Coughlin et al., 2013).

The TPT originates from the interosseous membrane and adjacent surfaces of the tibia and fibula, forming its myotendinous junction in the distal third of the leg. It courses sharply behind the medial malleolus, positioning itself posterior to the tibiotalar joint axis and medial to the subtalar axis, thereby gaining a mechanical advantage for inversion and arch support (Coughlin et al., 2013). It then traverses the tarsal tunnel and passes beneath the calcaneonavicular ligament before branching distally across the midfoot (Supple et al., 1992). Its vascular supply is derived from the posterior tibial artery (Frey et al., 1990; Desai and Cohen Levy, 2019).

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There is considerable variation in the literature regarding the distal insertions of the TPT. Although most anatomical studies agree on the navicular bone as the primary insertion site, descriptions diverge regarding the number, location, and relative prevalence of additional insertions. Among these, the medial and lateral cuneiforms are most frequently reported (Musiał, 1963; Sarrafian, 1993; Mosier et al., 1998; Bloome et al., 2003; Olewnik, 2019; Swanton et al., 2019; Willegger et al., 2020; Park et al., 2021; Uchiyama et al., 2022).

To the best of our knowledge, an attachment of the tibialis posterior (TP) tendon to the sustentaculum tali was first described by G. Hermann von Meyer in 1888. At that time, this structure was referred to as a "retinaculum" that "can also exert traction on the calcaneus (von Meyer, 1888). This sustentacular insertion, although known as the ramus sustentacularis was later acknowledged in only a few studies and remains poorly defined, not only because the description of this structure is extremely heterogeneous but also as most descriptions are based on anatomical inference rather than histological confirmation (Musiał, 1963; Bloome et al., 2003; Willegger et al., 2020). To date, no systematic analysis has examined its prevalence, morphology, or biomechanical role, leaving its contribution to foot stability and pathology largely unclear.

Therefore, the present study addresses the anatomical gap by combining anatomical dissection with histological analysis of the TPT insertion onto the sustentaculum tali. By investigating whether this structure represents a distinct tendinous entity, we aim to deepen anatomical insight and contribute to the clinical understanding of TPT dysfunction and adult-acquired flatfoot deformity.

2. Materials and methods

This cadaveric study was conducted in accordance with the Declaration of Helsinki. All cadavers were obtained from the Institute of Anatomy and Cell Biology, Saarland University, Campus Homburg through a regulated donation program, with written informed consent provided by the donors or their legal next of kin for the use of their bodies in medical research and education. All specimens were anonymized prior to analysis to ensure donor confidentiality.

A total of 20 lower limbs from adult human cadavers were included in this investigation. Specimens were selected from both male and female donors, with an age range of 62–96 years (mean age: 81.7 years, standard deviation: 8.6 years). Right and left feet were sampled, with the side distribution recorded (Table 1). Specimens were excluded if there was evidence of significant trauma, previous orthopedic surgery in the region, congenital deformities, severe degenerative changes, or poor preservation compromising anatomical identification.

2.1. Specimen Preparation and Dissection Protocol

All limbs were fixed according to a protocol from a previous study by Janczyk et al. (Janczyk, 2011). This protocol uses nitrite pickling salt as an alternative to formaldehyde for embalming. Therefore, the specimens were not thawed. Pictures were taken with permission to describe the procedure, but all photographs were anonymized and carried no patient identifiable data. Specimens were positioned in the supine position to facilitate exposure of the posterior compartment of the leg and plantar aspect of the foot. First, the relevant anatomical landmarks on the foot were identified and marked, specifically the navicular bone and the medial malleolus. A longitudinal, slightly curved skin incision was made along the course of the tibialis anterior tendon. The subcutaneous tissue layers were then carefully dissected, both bluntly and sharply, in a stepwise manner until the tendon was exposed. This allowed for clear visualization and identification of the tendon of the tibialis posterior muscle. Distal to the medial malleolus, the tendon lies within its sheath beneath the flexor retinaculum. To expose the sustentacular branch, the peritendineum of the flexor digitorum longus muscle was incised, and the tendon was retracted plantarly. This maneuver enabled visualization of the ramus sustentacularis of the tibialis posterior tendon. This branch extends before the talonavicular joint in a dorsoplantar direction toward the sustentaculum tali. It was carefully passed underneath with forceps to ensure safe and precise identification. The course of the tendon was then followed further distally to its insertion on the navicular bone. The anatomical landmarks - the os naviculare as the distal insertion site of the tendon and the sustentaculum tali as the insertion of the sustentacular branch - were marked. Subsequently, photographic documentation was performed using a measuring gauge to determine the width.

Table 1
Characteristics of patients included in the present study.

Age	81.7 years
Male / female	12 / 8
Left / right lower extremities	10 / 10
Width of the ramus sustentacularis	13.9 mm
Prevalence of the ramus sustentacuaris	100%

2.2. Morphometric and Quantitative Analysis

After complete exposure, the dimensions of each bony attachment site were measured using calipers. The width of each ramus sustentacularis of the TPT was recorded. Frequency and prevalence of the ramus sustentaculum was calculated as percentage of the total sample size. The presence of sex, side, or age differences in tendon insertion patterns was assessed.

2.3. Histological Processing and Analysis

Representative tissue blocks were harvested from the distal tibialis posterior tendon at the point of insertion onto the sustentaculum tali as well as adjacent muscle-tendon junctions when present. Samples were fixed in 10% neutral buffered formalin. Serial 3-μm thick sections were cut and stained with hematoxylin and eosin for the assessment of their histomorphology. Slides were examined using a light microscope and documented. The presence or absence of muscular fibers at each insertion site, the nature of the muscle-tendon-bone transition, and the overall histoarchitecture were systematically evaluated. Photomicrographs were acquired with a digital imaging system and analyzed for qualitative features.

3. Results

All lower extremities ($n = 20$) showed an insertion of the TPT in the area of the sustentaculum tali, the ramus sustentacularis (Figs. 1 and 2). The attachment of the tendon had an average width of 13.9 mm (range 10–17 mm). All body donors had a uniform attachment to the sustentaculum tali, regardless of sex. Even considering the side of the body, there was no difference between the left and right side. Histological examination showed that the attachment to the sustentaculum tali, the ramus sustentacularis, was tendon tissue in all cases (Fig. 3).

4. Discussion

The proximal origin of the tibialis posterior muscle from the posterior surfaces of the tibia, fibula, and interosseous membrane is well established in the literature. In contrast, the morphology of its distal insertion remains a subject of debate. While classical anatomical descriptions consistently identify a main insertion at the navicular tuberosity and the medial or lateral cuneiform, cadaveric evidence has revealed substantial variation in the number and location of accessory slips. These additional insertions have been observed across other tarsal bones, metatarsal bases, and even soft tissue structures, reflecting the anatomical complexity of the tendon's distal footprint (Musiał, 1963; Mosier et al., 1998; Bloome et al., 2003; Olewnik, 2019; Swanton et al.,

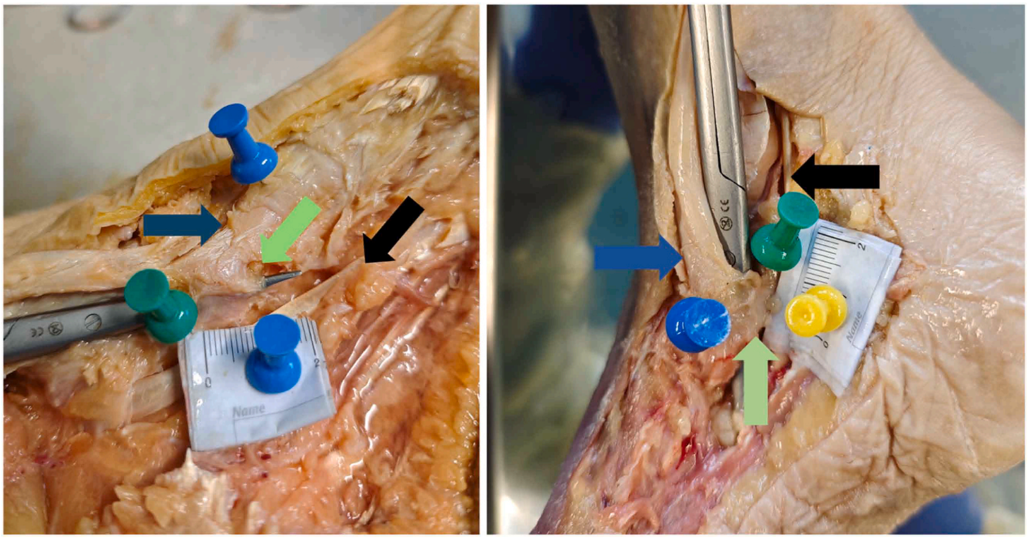

Fig. 1. Anatomical dissection showing the ramus sustentacularis of the tibialis posterior tendon (TPT), which has been elevated using scissors to improve visualization. A measuring tape is placed dorsally to the structure for spatial orientation. The blue arrow indicates the tendon of the tibialis posterior muscle, while the black arrow marks the tendon of the flexor digitorum longus muscle. The green arrow highlights the ramus sustentacular of the TPT.

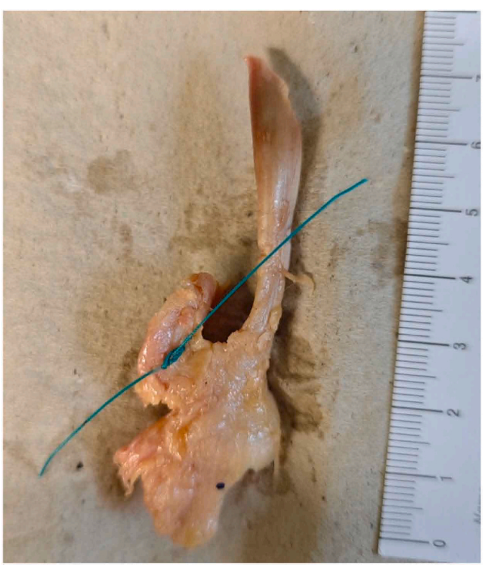

Fig. 2. Anatomical preparation with isolation of the tibialis posterior tendon (TPT) and the ramus sustentacularis. The ramus sustentacularis has been marked with a green thread.

2019; Willegger et al., 2020).

The position of the TPT, posterior to the tibiotalar axis and medial to the subtalar joint, provides mechanical leverage for plantarflexion and inversion. Its primary attachment to the navicular supports the medial longitudinal arch, while supplementary insertions contribute to load distribution and midfoot locking during gait (Willegger et al., 2020; Myerson et al., 2004). Slips to intrinsic muscles, such as the flexor hallucis brevis and abductor hallucis, may reflect evolutionary adaptations for arch stability (Lewis, 1964). The posterior band inserting onto the sustentaculum tali may act as a mechanical fulcrum at its calcaneal anchor, facilitating directional shift and tension redistribution of the TPT and stabilizing the subtalar joint and directly applying varization of the heal (Martin, 1964).

There is considerable variation in the literature regarding the distal insertions of the TPT. Although most anatomical studies agree on the navicular bone as the primary insertion site, descriptions diverge regarding the number, location, and relative prevalence of additional insertions. Among these, the medial and lateral cuneiforms are most frequently reported (Sarrafian, 1993; Bloome et al., 2003; Olewnik, 2019; Park et al., 2021; Uchiyama et al., 2022).

Some authors identified a division into two (Coughlin and Mann, 1999) or three distinct bands (Sarrafian, 1993; Bloome et al., 2003), whereas others reported a consistent main insertion, either with accessory bundles (Musiał, 1963) or with further distal branching into multiple tendon slips (Willegger et al., 2020).

Earlier studies described consistent TPT insertions across the navicular, all cuneiforms, and the 2nd–3rd metatarsal bases in all specimens (Musiał, 1963). Later work identified fewer consistent sites, with accessory slips inserting variably across up to eight tarsal and metatarsal bones (Willegger et al., 2020). Calcaneal insertions occurred in 29.5% and 12.2% of cases, respectively. An attachment of the tibialis posterior (TP) tendon to the sustentaculum tali was first described in 1888 and referred to as a “retinaculum” capable of exerting traction on the calcaneus (von Meyer, 1888).

Sarrafian (1993) provided a detailed description of three anatomically distinct bands. The anterior, being the largest and continuous with the main tendon, inserts broadly on the navicular tuberosity, as well as plantarly on both the cuneonavicular capsule and medial cuneiform. The middle continues as a tarsometatarsal extension, inserting on the middle and lateral cuneiforms, cuboid, bases of the 2nd–5th metatarsals (variably the 5th), the medial limb of the Y-shaped origin of the flexor hallucis brevis, and occasionally the peroneus longus tendon near the first metatarsal base. The posterior is a recurrent band, arising from the main tendon proximal to its navicular insertion, and runs posterolaterally to attach to the anterior surface of the sustentaculum tali, as later reaffirmed by Sarrafian and Kelikian (2011). Bloome et al. (2003) confirmed Sarrafian’s three-band configuration and quantified the insertions, reporting a slip to the abductor hallucis in 45% and a posterior band insertion to the spring ligament in 36% of specimens.

Recent cadaveric studies indicate that the navicular, medial cuneiform, and lateral cuneiform consistently account for the majority of TPT attachments across diverse populations and classification systems. However, considerable variation exists in the number and configuration of additional insertions (Olewnik, 2019; Park et al., 2021; Uchiyama et al., 2022). In a cadaveric study of 80 feet, Olewnik (2019) introduced the first classification of TPT insertions: Type I involved a single attachment to the navicular and medial cuneiform, while Types II–IV corresponded to double, triple, and quadruple insertions, with subtypes

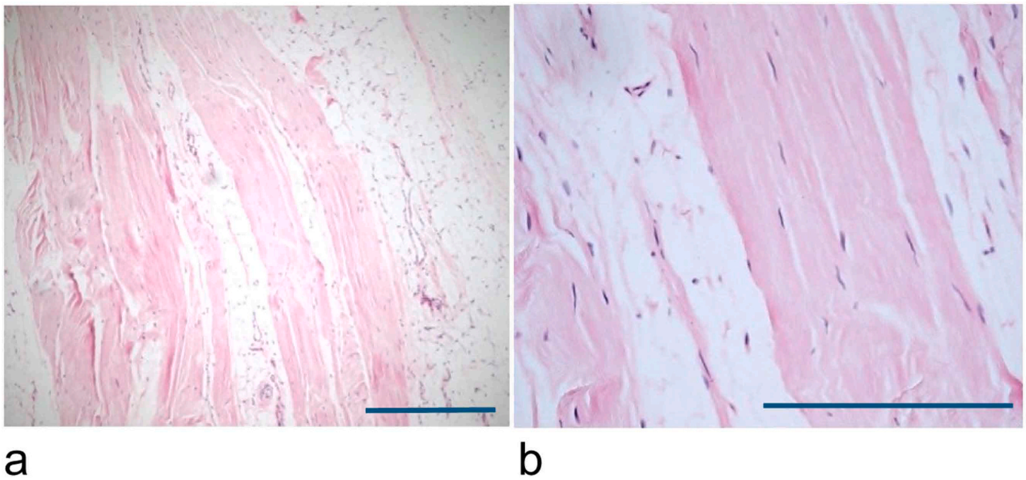

Fig. 3. a-b: Histological longitudinal section of the ramus sustentacularis: Hematoxylin and eosin staining; the images show densely packed, predominantly longitudinally oriented collagen fiber bundles (light to intensely eosinophilic), aligned along the direction of tensile load. Spindle-shaped to elongated nuclei of fibrocytes (dark purple) are interspersed between the fibers and oriented parallelly to the collagen bundles. No inflammatory infiltrates are present. This figure illustrates the typical microarchitectural organization of tendon tissue, confirming that the ramus sustentacularis of the tibialis posterior tendon represents true tendon structure. The scale bars represent 200 μm.

A–C and K describing specific patterns. Park et al. (2021) expanded this framework, adding new subtypes for Type IV (4K-1 through 4K-4) and variations in Type III (3B, 3 C, 3 K), with quadruple insertions being most common among 118 Korean specimens (Park et al., 2021). Uchiyama et al. (2022) examined 100 Japanese feet and classified insertions into seven types with four subtypes (A–D) based on attachment count. In 100% of cases, the TPT inserted onto the navicular, medial cuneiform, and lateral cuneiform, with the latter showing universal involvement, unlike earlier classifications. Together, these sites accounted for 75.1% of the total insertion surface (Uchiyama et al., 2022). These interstudy differences suggest that racial and demographic factors may contribute to the anatomical diversity observed across populations (Olewnik, 2019; Park et al., 2021; Uchiyama et al., 2022). The absence of an explicit description of a ramus sustentacularis may reflect a dissection-related sampling bias: with attention focused distally, a proximal branch could have been mistaken for the flexor digitorum longus tendon sheath and excised to expose the tibialis posterior tendon. This interpretation is speculative and should be considered with caution.

The present study is the first to histologically confirm the ramus sustentacularis of the TPT, establishing it as a true tendinous structure. Although many studies have examined TPT insertions, none have systematically addressed the ramus sustentacularis. While previous research has examined the anterior and middle bands in detail, our investigation was limited to the posterior band. Dissection of 20 formalin-free fixed lower limbs (mean age: 81.7 years) revealed a distinct posterior band in all specimens, supporting Sarrafian's (1993) original observations, and inserting consistently onto the anterior surface of the sustentaculum tali, with a mean width of 13.9 mm. No variation was observed between sexes or sides. Histological analysis in all cases demonstrated densely packed, longitudinally aligned collagen fibers with parallel fibrocyte nuclei and no vascular or inflammatory features. These are hallmarks of mature tendon tissue.

Our findings provide definitive microscopic evidence of the posterior band's anatomical consistency and structural identity. Given its uniform presence, likely role in hindfoot stabilization, and potential surgical relevance, these results warrant an update to classical anatomical descriptions to recognize the sustentacular band as a standard component of the distal insertion of the TPT.

This study has several limitations. The sample size was relatively small, with an unequal sex distribution. Furthermore, the absence of biomechanical testing and dynamic functional assessment restricts interpretation of the posterior band's mechanical role. Future studies should incorporate these aspects to further clarify the clinical relevance of the ramus sustentacularis of the TPT.

CRediT authorship contribution statement

Kajetan Klos: Writing – review & editing, Supervision, Investigation, Formal analysis, Conceptualization. **Ingmar Bothe:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Stefan Landgraeber:** Writing – review & editing, Supervision, Data curation, Conceptualization. **Bilal Al-Qaysi:** Writing – review & editing, Writing – original draft, Visualization, Investigation, Formal analysis. **Preslav Penev:** Writing – review & editing, Supervision, Project administration, Data curation. **Joe Wagener:** Writing – review & editing, Supervision, Investigation, Data curation. **Matthias W. Laschke:** Writing – review & editing, Supervision. **Philipp Winter:** Writing – original draft, Visualization, Software, Methodology, Investigation, Data curation, Conceptualization.

Ethics in publishing statement

This research presents an accurate account of the work performed, all data presented are accurate and methodologies detailed enough to permit others to replicate the work.

This manuscript represents entirely original works and or if work and/or words of others have been used, that this has been appropriately cited or quoted and permission has been obtained where necessary.

This material has not been published in whole or in part elsewhere.

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All authors have been personally and actively involved in substantive work leading to the manuscript and will hold themselves jointly and individually responsible for its content.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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