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Original Article

Flexor hallucis longus. A cadaveric study of its distal insertion

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Abstract

Objective: Describe flexor hallucis longus (FHL) distal insertion.

Methods: Ten cadaver feet were dissected to evaluate FHL distal insertion, the width of insertion, and the distance between insertion borders and medial-lateral phalangeal borders.

Results: All specimens showed a lateral tendon fascicle inserted more lateral and distal than the main insertion. The mean lateral and medial insertion distance to the phalangeal border was 3 mm and 5.2 mm. The FHL long axis was 12.36% laterally deviated at the metatarsophalangeal (MTP) joint and 14.07% at the interphalangeal (IP) joint.

Conclusion: The FHL has a closer insertion to the lateral phalanx border, and its long-axis midpoint is laterally located in relation to the IP and MTP joint. The detailed knowledge of the FHL true anatomy. The discovery of a lateral deviated axis, a lateral fascicle, and a lateral footprint.

Level of Evidence V; Cadaveric Study.

Keywords: Hallux valgus; Cadaver; Foot.

Introduction

Hallux valgus (HV) deformity prevalence in the general population reaches 23% in adults and 35.7% in older adults[1,2]. Even though its high prevalence, its etiology has not been completely elucidated[3]. The first ray is an inherently unstable structure, which relies on a fine balance between its static and dynamic stabilizers to maintain its alignment[4]. Regarding dynamic stabilizers, the abductor hallucis longus strongly resists the valgus of the proximal phalanx, but it becomes dysfunctional as its medial and plantar attachment rotates inferiorly, showing histological and electromyographic changes probably due to the hallux deformity[5]. The adductor hallucis is attached to the plantar surface laterally, so it tends to pull the phalanx into pronation and tether its base[6]. Normal variations in the attachment of the abductor hallucis have been described but without any association with HV[7]. The adductor tendon might also have a role in HV, but it has not been proven. There is no evidence of shortening[8] or overactivity of this muscle in HV, although botulinum toxin injection has successfully treated it[9].

Multiple risk factors have been associated with HV, including muscle imbalance[5]. During HV progression, with the bowstring of the flexor hallucis longus (FHL), it is reasonable to think that the change at the moment arm of this structure can help HV evolution[10]. The anatomy and function of this muscle have been described, but there is still some missing information, especially regarding its distal insertion. The FHL arises from the inferior posterior surface of the fibula and lower part of the interosseous membrane and inserts into the plantar surface of the distal phalanx of the hallux. It primarily functions as a hallux flexor but also contributes to ankle supination and is a very weak ankle plantar flexor. Anatomical

Study performed at the Clínica Universidad de Los Andes, Santiago, Chile.

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studies involving the FHL have focused on the relationship between the FHL and flexor digitorum longus[11], but, to our knowledge, there is no literature describing the detailed anatomy of the FHL distal footprint and its relationship with hallux osseous anatomy. Therefore, the purpose of this study is to go back to the anatomy basics and describe the details of the FHL distal insertion, as it is still unknown. In addition, analyze the spatial relationship of the FHL distal portion with the hallux osseous anatomy by assessing the FHL footprint in the distal phalanx and the position of FHL traction in both interphalangeal (IP) and metatarsophalangeal (MTP) joints. Our hypothesis is that the distal footprint in cadavers without hallux valgus deformity is in the osseous midline.

Methods

This investigation was approved by our ethical committee (CEC201968). Ten adult fresh frozen cadaveric feet amputated below the knee were used. Specimens were stored at -25 degrees Celsius and thawed at room temperature for 24 hours before testing. None of the dissected feet demonstrated evidence of previous foot or ankle surgeries or deformities.

One foot and ankle surgeon dissected the feet through a plantar approach. The skin was removed, progressing through muscular and fascial layers, exposing the FHL tendon and bony structures, leaving in situ ligamentous attachments (Figure 1). Two foot and ankle surgeons identified the distal footprint at the most distal point in the distal phalanx; the morphology was analyzed after 2D on-screen digitalization of the macroscopic images. All the measurements were done with a digital ruler. The width of the tendon insertion was measured on the widest portion from medial to lateral. The distance between the insertion borders of the FHL and medial-lateral phalangeal borders was also measured on the widest portion. The force vector of the FHL was simplified as a line centered on the midline longitudinal axis (Figure 2). The spatial relationship of the FHL with IP and MTP joints was measured by the position of the FHL long axis width midpoint in relation to the phalanges and metatarsal width 1 cm proximal to each joint, IP, and MTP (Figure 2) for standardization.

Results

In all the specimens examined in this study, the FHL distal footprint was easily recognized. Its mean insertion width on the distal phalanx was 12.1 mm (range 10 to 15) standard deviation (SD ± 1.5). All specimens showed a lateral tendon fascicle inserted more lateral and distal than the main tendon

Figure 1. Exposure of the flexor hallucis longus, phalanges, and plantar ligamentous through a plantar approach.

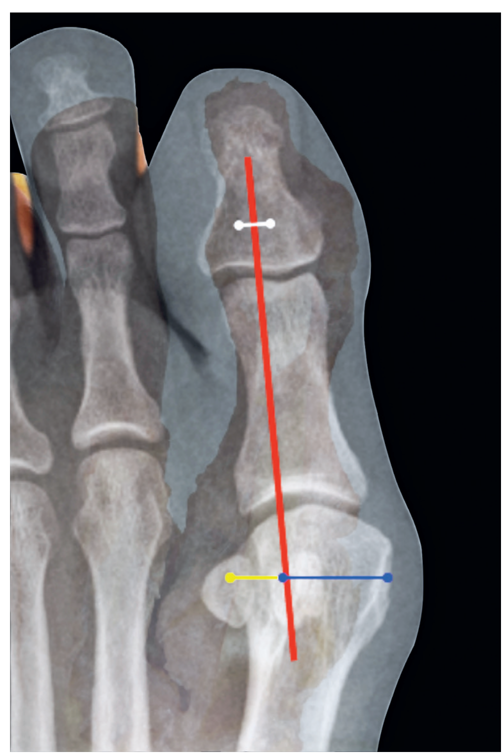

Figure 2. The force vector of the flexor hallucis longus (FHL) was simplified as a line centered on the longitudinal axis (vertical line). The spatial relationship of the FHL with interphalangeal and metatarsophalangeal joints was measured at 1 cm from the joint (horizontal lines).

insertion. The mean distance of insertion to the lateral border was 3 mm (range 3 to 4) (SD ± 0.7), while the mean distance of insertion to the medial border was 5.2 mm (range 4 to 7) (SD ± 1.1), showing a more lateral insertion on the distal phalanx (Figure 3). The FHL long axis line, 1 cm proximal to the IP joint, with a mean of 7 mm (range 6 to 9) (SD ± 1.05) away from the lateral border and 9.3 mm (range 9 to 10) (SD ± 1.2) from the medial border, showing a mean of 14.07% laterally deviation from the long osseous axis (Figure 4). The FHL long axis line, 1 cm proximal to the MTP joint, had a mean of 11.8 mm (range 10 to 13) (SD ± 0.92) away from the lateral border and 15.2 mm (range 15 to 17) (SD ± 1.6) from the medial border, showing a mean of 12.36% laterally deviation from the long osseous axis (Figure 5).

Discussion

In the HV pathogenesis, the extensor hallucis longus (EHL) tendon appears to bowstring laterally, increasing the valgus displacement and occasionally acting as a dorsiflexor of the proximal phalanx[8]. The FHL, like the EHL tendon, is known to participate by accentuating the deformity when it has already been developed due to the bowstring effect it generates on the hallux when it is in the valgus position[8]. The further the FHL is from the first metatarsal head, the weaker the moment arm of the flexor and the greater valgus of the hallux and varus of the first metatarsal head become[12]. The moment arm of the flexors moves from an inferior to a lateral direction

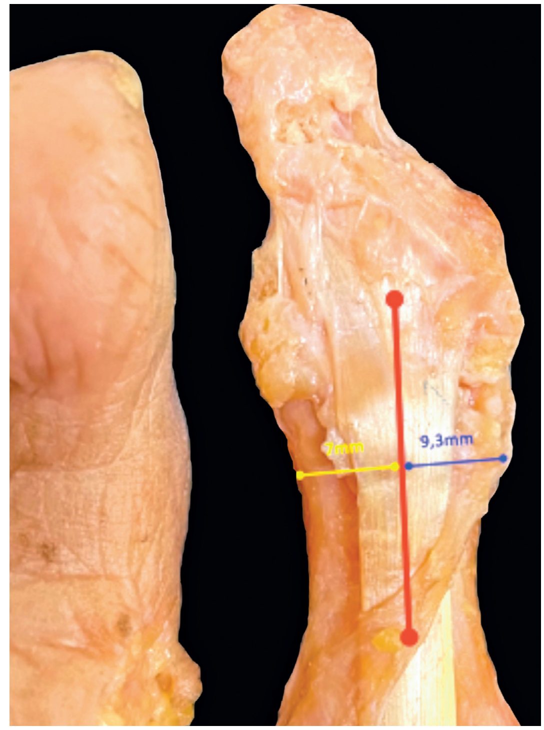

Figure 4. Flexor hallucis longus axis line showed a 14.07% lateral deviation on the interphalangeal joint. It was located 7 mm from the lateral border and 9.3 mm from the medial border.

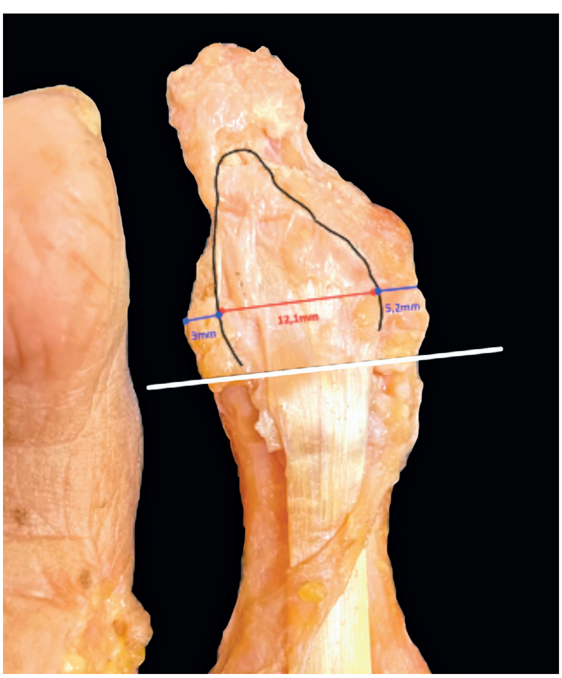

Figure 3. Boundary of the flexor hallucis longus footprint. The insertion width was 12.1 mm closer to the lateral border (3 mm) than the medial border (5.2 mm).

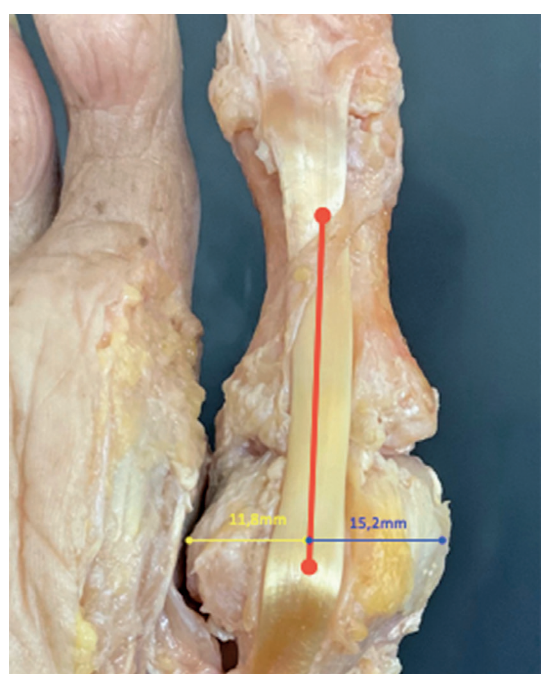

Figure 5. Flexor hallucis longus axis line showed a 12.36% lateral deviation on the metatarsophalangeal joint. It was located 11.8 mm from the lateral border and 15.2 mm from the medial border.

as the great toe pronates or moves into valgus[13]. To the authors' knowledge, this is the first study that analyzes FHL distal footprint and its axis of action related to hallux osseous anatomy. It was found a laterally deviated longitudinal axis of the tendon related to the osseous longitudinal axis that theoretically could create a laterally deviated force vector direction, which could act as a primary deforming force in some patients rather than a progressing one. Furthermore, the finding of a lateral insertion from the midline on the distal phalanx, and the discovery of this lateral FHL fascicle, present in all our specimens, could accentuate the action of a laterally deviated FHL force vector, adding more risk factors to patients that are predisposed to develop HV. Unfortunately, none of these specimens had HV deformity. It would be interesting to analyze the FHL distal insertion in cadavers with HV as a future line of research.

Conclusion

There is no current literature describing the distal anatomy of the FHL tendon. It was found that the FHL main axis slightly laterally deviates from the midline in relation to the osseous longitudinal axis. In addition, the FHL insertion footprint is also laterally deviated from the midline at the distal phalanx and has a distal fascicle inserted more distal and lateral than the FHL main footprint. All these three conditions create a laterally deviated force vector over the hallux that, in some patients, could be involved in the pathogenesis of HV.

Authors' contributions: Each author contributed individually and significantly to the development of this article: FCR *(https://orcid.org/0000-0002-3524-0624). Performed the dissections, data collection and approved the final version; COM *(https://orcid.org/0000-0003-2574-9010) and, GCU *(https://orcid.org/0000-0002-1993-6250) and, MPP *(https://orcid.org/0000-0002-2820-5337) Conceived and planned the activities that led to the study, approved the final version; XA *(https://orcid.org/0000-0002-0908-9908) Formatting of the article, bibliographic review, approved the final version; AIB *(https://orcid.org/0000-0003-4898-4259) Performed the dissections, data collection and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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