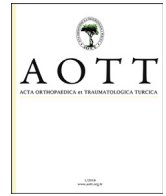


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## Anatomy of Master Knot of Henry: A morphometric study on cadavers

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## ABSTRACT

**Objective:** The objective of this study was to evaluate the features of flexor hallucis longus (FHL), flexor digitorum longus (FDL) and flexor digitorum accessorius (FDA) muscles with relevance to the tendon grafts and to reveal the location of Master Knot of Henry (MKH).

**Methods:** Twenty feet from ten formalin fixed cadavers were dissected, which were in the inventory of Anatomy Department of Medicine Faculty, Mersin University. The location of MKH was identified. Interconnections of FHL and FDL were categorized. According to incision techniques, lengths of FHL and FDL tendon grafts were measured. Attachment sites of FDA were assessed.

**Results:** MKH was  $12.61 \pm 1.11$  cm proximal to first interphalangeal joint,  $1.75 \pm 0.39$  cm below to navicular tuberosity and  $5.93 \pm 0.74$  cm distal to medial malleolus. The connections of FHL and FDL were classified in 7 types. Tendon graft lengths of FDL according to medial and plantar approaches were  $6.14 \pm 0.60$  cm and  $9.37 \pm 0.77$  cm, respectively. Tendon graft lengths of FHL according to single, double and minimal invasive incision techniques were  $5.75 \pm 0.63$  cm,  $7.03 \pm 0.86$  cm and  $20.22 \pm 1.32$  cm, respectively. FDA was found to be inserting to FHL slips in all cases and it inserted to various surfaces of FDL.

**Conclusion:** The exact location of MKH and slips was determined. Two new connections not recorded in literature were found. It was observed that the main attachment site of FDA was the FHL slips. The surgical awareness of connections between the FHL, FDL and FDA, which participated in the formation of long flexor tendons of toes, could be important for reducing possible loss of function after tendon transfers postoperatively.

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## Introduction

The term, "Master Knot by Henry, or equivalently used Henry's Knot" was first identified as referring to the intersection territory, where the tendon of flexor digitorum longus (FDL) crosses over the tendon of flexor hallucis longus (FHL).<sup>1,2</sup> Despite Master Knot of Henry (MKH) has been widely used as a surgical landmark during the tendon graft harvesting,<sup>2–5</sup> awareness of exact anatomical settlement of this important area remains controversial.<sup>6</sup> From this perspective, there is an intense need for further studies understanding the precise location of the MKH.

Tendon grafts of FHL and FDL are commonly used in reconstructive foot and ankle surgery.<sup>3,7–13</sup> Despite the literature offers the descriptions of several techniques for harvesting these tendon grafts,<sup>2–6,14–16</sup> there is a limited data based on the tendon graft lengths.<sup>6</sup> Connections between FHL and FDL tendons is utmost important for harvesting tendon grafts.<sup>8</sup> Knowledge of the interconnections is crucial for surgeons to minimize the functional loss during post-op period and understand the underlying cause of functional loss of toes.<sup>8</sup> However, anatomical outcomes of these studies considering the interconnections harbor inconsistencies.<sup>6,8,17–21</sup> In this regard, further studies on different

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populations can be of great help to clarify the anatomical inconsistency of these interconnections. Within the context of tendon grafting, another significant anatomical focus should be on the flexor digitorum accessorius (FDA) which acts directly on the flexor function of the toes considering its direct attachment to the tendons of FHL and FDL.<sup>22–24</sup> Overall, a deeper view of the attachment of FDA both with FDL and FHL tendons is needed to a better understanding of the functional and anatomical properties of long flexor tendons of toes.

In summary, the main objectives of this study were to (1) determine the location of MKH, (2) measure the length of tendon grafts based on certain surgical techniques, (3) investigate the connections between the FHL and FDL and (4) define the attachment patterns of FDA.

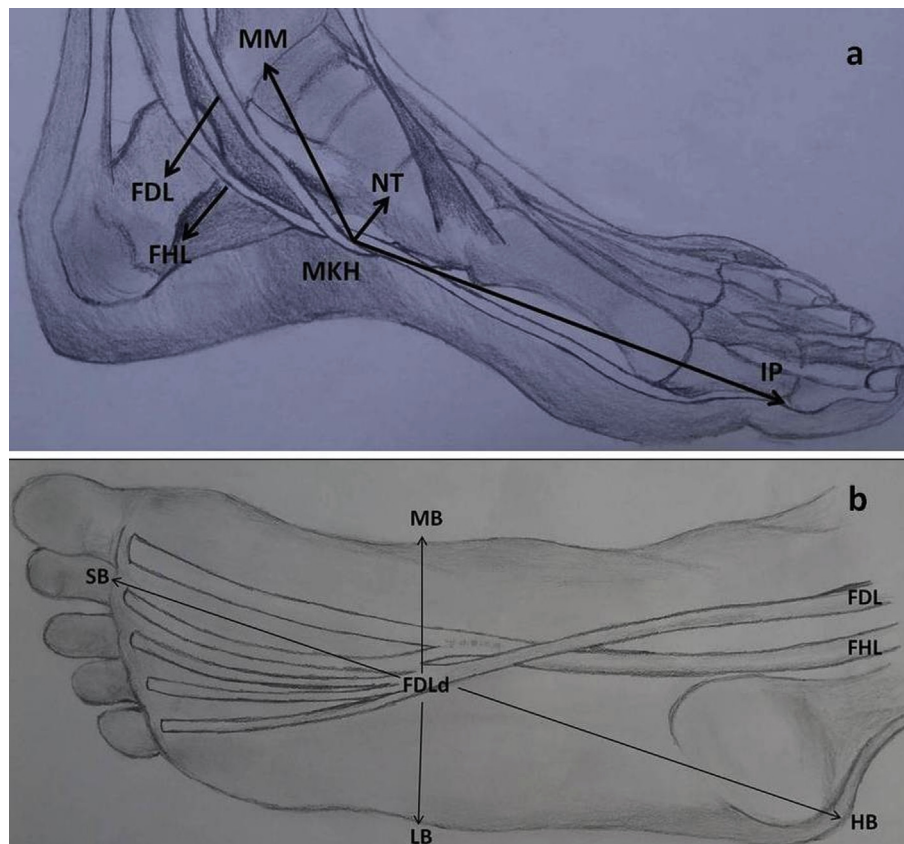
### Material and methods

The authors declare that they perform the study in accordance with the provisions of the Declaration of Helsinki 1995 (as revised in Edinburgh 2000). Twenty feet of 10 (2 females, 8 male) formalin-fixed adult cadavers in Turkish population were dissected (aged between 45 and 104 years, average  $66.9 \pm 18.9$ ), which were in the inventory of Anatomy Department of Medicine Faculty, Mersin University. There were no signs of previous surgery or any other deformity around the ankle and foot. To expose the connections in the area of MKH, anatomic structures (skin, superficial fascia, plantar aponeurosis, flexor digitorum brevis and

abductor hallucis muscles) were removed and neurovascular bundles (posterior tibial artery, tibial nerve, medial and lateral plantar arteries and nerves) were retracted laterally. As follows, the concordant with their courses the mentioned tendons were dissected from musculotendinous junctions proximally towards the distal end of toes.

MKH was considered as the point where FDL crossed the FHL (Fig. 1). The distance of proximal and distal points of slips and MKH to medial malleolus, navicular tuberosity and first interphalangeal joint were recorded (Fig. 1a). FHL and FDL tendons were cut into two as proximal and distal parts at the MKH. Length, width and thickness of the proximal and distal parts of FHL and FDL plus the slips were measured. Relations of proximal and distal points of slips with MKH and FDL tendon division were evaluated.

Taking into account the study of Mao et al.,<sup>6</sup> tendon graft lengths of FHL harvested by single, double and minimal invasive incision techniques were measured (Fig. 2a). On the other hand, according to the parameters of Panchbhavi et al.,<sup>15,16</sup> the location of FDL tendon division and FDL tendon graft lengths harvested by plantar approach (Figs. 1b and 2b) were determined. Also, to find incision length and FDL tendon graft lengths in medial approach, the landmarks of Park et al.<sup>4</sup> were used (Fig. 2b). Distance from tip of second toe to back of heel was measured. Considering the previous studies,<sup>6,8,17,21</sup> connections between FHL and FDL (Fig. 3) and the contribution of FHL slips to long flexor tendons of toes (Fig. 4) were classified. Connections of FDA with FHL and FDL were identified and innervation pattern of FDA was evaluated.



**Fig. 1.** The illustrations: 1a shows the distance of MKH to medial malleolus (MM), navicular tuberosity (NT) and first interphalangeal joint (IP). 1b shows the distance of FDL tendon division (FDLd) to lateral border of the foot (LB), medial border of the foot (MB), base of the second toe (SB) and back of the heel (HB).

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