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An Additional Tool for Precise Location of the Chiasma Plantare: A Morphometric Study on Fresh Frozen Cadavers

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Abstract

In this study, the distances between the chiasma plantare and two bony landmarks (summit of the medial malleolus and tuberosity of the navicular bone) were measured. In addition, the angle between these structures was measured.
Twenty fresh frozen feet were dissected. The chiasma was exposed. The adjacent neurovascular structures were retracted. The medial malleolus and tuberosity of the navicular bone were identified. The FHL and FDL tendons were dissected. This area was photographed, and measurements were taken using a digital caliber. The data were statistically analyzed, and the mean values and standard deviations were calculated.
The chiasma plantare was found to be at 5.41 ± 0.22 (average 5.09 – 5.76) cm distal to the medial malleolus, and 2.47 ± 0.25 (average 2.13 – 2.81) cm below tuberosity of the navicular bone. The angle between them measured 23.04 ± 6.62 (average 18.66 – 38.65) degrees.
It was concluded that measuring the angle between the medial malleolus, chiasma plantare, and tuberosity of the navicular bone may add beneficial information about the precise location of the chiasma.

Keywords: Chiasma plantare; master knot of Henry; precise location of the chiasma; tendon of flexor digitorum longus; tendon of flexor hallucis longus.

Introduction

The chiasma plantare or “Master Knot of Henry” was first defined as the site where the tendon of flexor digitorum longus (FDL) crosses superficial to the tendon of flexor hallucis longus (FHL) [1, 6].

FDL and FHL tendons transfer have been reported by many authors. FDL tendon transfer has been used for the surgical treatment of chronic posterior tibial tendon dysfunction (PTTD) [3, 8, 18]. Similarly, FHL tendon transfer has been used for the surgical treatment of chronic lesions of Achilles tendon [4, 19, 22-24].

Different surgical techniques for harvesting these two tendons have been described. A common approach is through an incision along the medial border of the foot[1, 10,12,15]. Harvesting of the tendons through an approach to chiasma plantare is technically challenging because of the variable interconnections between the FHL and FDL, and the direct proximity of the chiasma to the medial plantar neurovascular bundles [11]. Injury of the medial plantar nerve is a serious complication that leads to chronic postoperative pain with poor clinical outcome. Injury of distal branches of posterior tibial artery and nerve has also been reported[1, 7].

Despite chiasma plantare has been widely used as a surgical landmark during the tendon graft harvesting [1, 12, 16, 21], it is still a subject of controversy [10].

Therefore, understanding of anatomical variations and interconnections at the chiasma plantare will help to guide the surgical decision and decrease the potential morbidity. Different studies were done to demonstrate the anatomical relationship between the chiasma plantare and the tendon length available for surgical harvesting, but these studies had very limited number of cases and were applied to Caucasian and Asian populations [10]. As this anatomical relationship may show variations in different ethnic or racial preferences, further studies are essential to understand the location of the chiasma plantare. So, it became the aim of this study to add a valuable tool for precise location of the chiasma by measuring the distances between it and two bony landmarks (summit of the medial malleolus and tuberosity of the navicular bone), and the angle between them.

Materials and Methods

Twenty feet from ten adult fresh frozen cadavers were dissected in the Anatomy Department, Ain Shams University College of Medicine; Egypt. There were no signs of previous surgery around the foot or ankle, or relevant deformities.

To expose the chiasma plantare, the skin, superficial fascia, and plantar aponeurosis were removed. Then flexor digitorum brevis (FDB), abductor hallucis (AH), and flexor hallucis brevis (FHB) muscles were cut from their proximal attachments and retracted distally. The adjacent neurovascular structures (medial planter nerve and vessels) were also retracted. The medial malleolus and tuberosity of the navicular bone were identified on the medial foot. The FHL and FDL tendons were dissected. Taking the chiasma plantare as boundary, both tendons were defined proximally and distally. The distances between the chiasma and both summit of the medial malleolus and tuberosity of the navicular bone were measured using a digital caliber. The angle between the medial malleolus, the chiasma, and tuberosity of the navicular bone was measured using a protractor. All measurements were taken by the same researcher while each foot was lying on lateral side. The samples were photographed by digital camera (Samsung – ST200) **(Fig. 1A)**.

The data were statistically analyzed. The mean values and standard deviations (SD) were calculated using the SPSS statistical program version 20 (IBM Corporation, New York, USA).

Ethical consideration:

The protocol of the study was carried out in accordance with the guidelines approved by the Committee of Research Ethics.

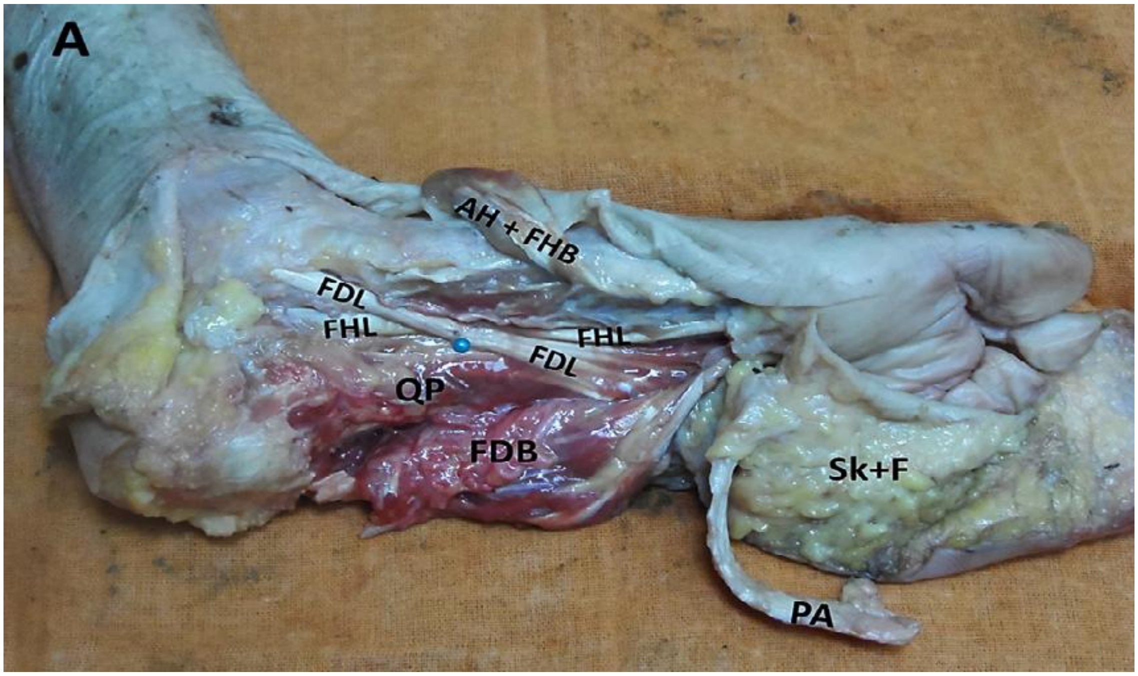

Figure 1A:A photograph of left dissected foot showing the chiasma plantare marked by blue pin. Skin and fascia (Sk+F), plantar aponeurosis (PA), flexor hallucis brevis (FHB), abductor hallucis (AH), and flexor digitorum brevis (FDB) are cut and reflected. Notice the flexor digitorum longus tendon (FDL) crossing superficial to flexor hallucis longus tendon (FHL). (QP) = quadratus plantae muscle.

Results

No significant difference was found between right and left sides as regards morphometric measurements of all variables. The mean measurements and (SD) were summarized in **Table 1**.

Table 1: Distances between the chiasma and bony landmarks:

The landmark	Summit of the medial malleolus	Tuberosity of the navicular bone	The angle between the chiasma and the 2 landmarks
The distance mean ± SD (range)	5.41 ± 0.22 (5.09 – 5.76)[a]	2.47 ± 0.25 (2.13 – 2.81)[a]	23.04 ± 6.62 (18.66 – 38.65)[b]

a) Cm.
b) Degrees.

The mean length of feet was 21.5 ± 1.38; (mean ± SD); (average 19.3 – 23.1) cm.

The chiasma plantare was identified at 5.41 ± 0.22 (average 5.09 – 5.76) cm distal to the summit of the medial malleolus **(Figs. 1B and 2)**, and 2.47 ± 0.25 (average 2.13 – 2.81) cm below tuberosity of the navicular bone **(Figs. 3 and 4).**

The angle between the medial malleolus, the chiasma, and tuberosity of the navicular bone measured 23.04 ± 6.62 (average 18.66 – 38.65) degrees.

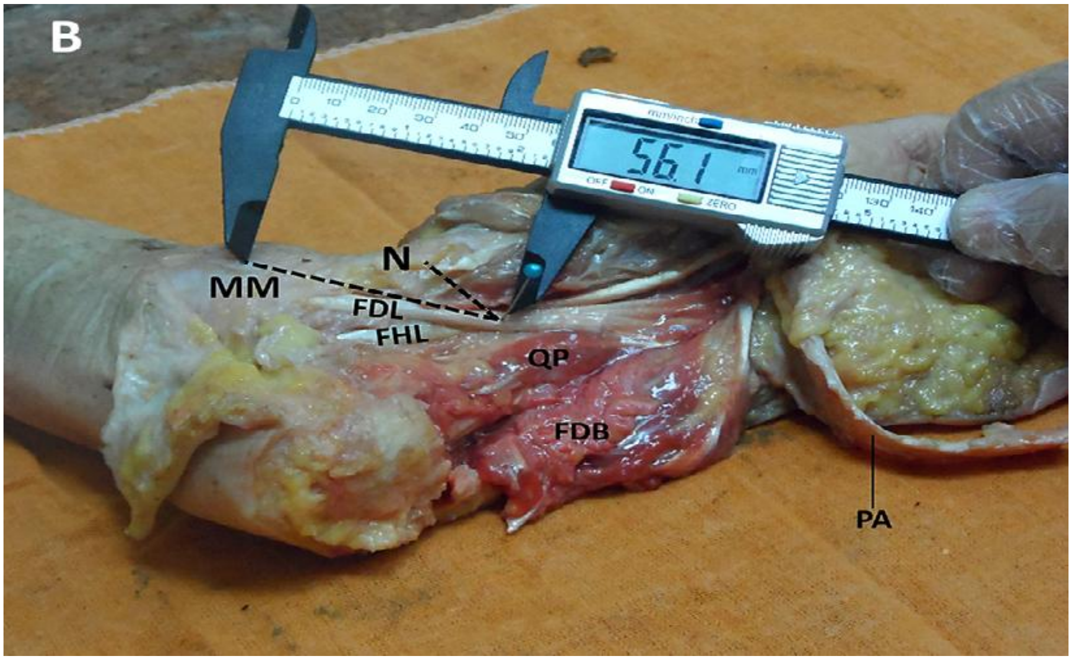

Figure 1B: The distances between the chiasma and both medial malleolus (MM) and navicular bone (N) are marked by black dotted lines. Notice the reading of the digital caliber recording 56.1 mm (5.61 cm) between the chiasma and the summit of the medial malleolus. (FDL) = flexor digitorum longus tendon, (FHL) = flexor hallucis longus tendon, (QP) = quadratus plantae, (FDB) = flexor digitorum brevis, (PA) = plantar aponeurosis.

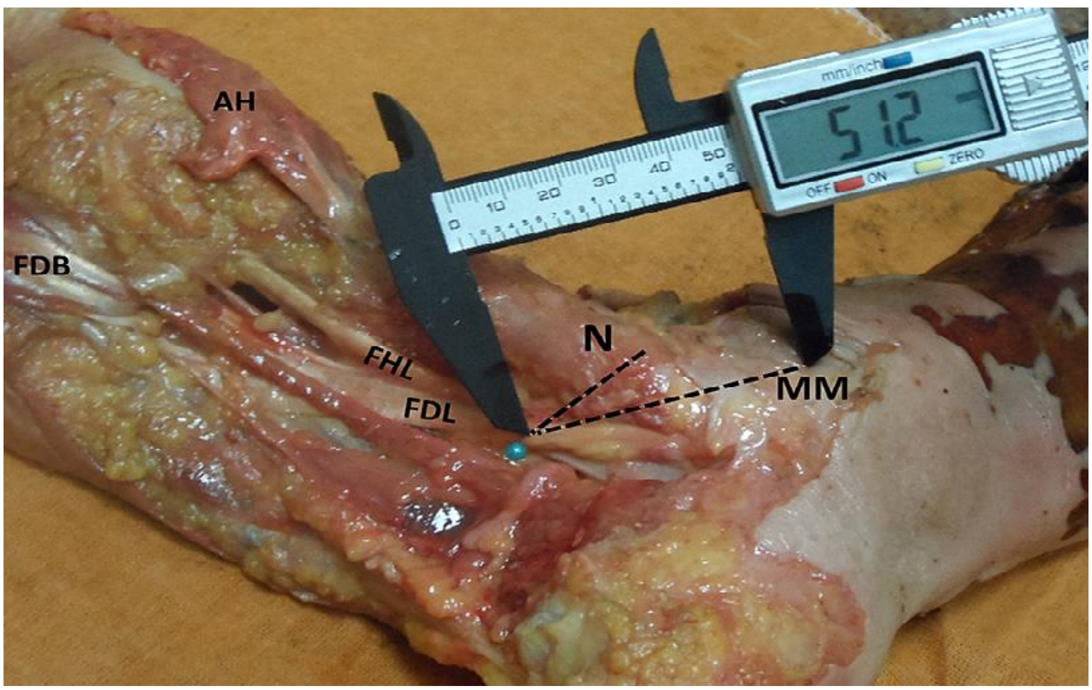

Figure 2: A photograph of right dissected foot showing the chiasma plantare marked by blue pin. The distances between the chiasma and both medial malleolus (MM) and navicular bone (N) are marked by black dotted lines. Notice the reading of the digital caliber recording 51.2 mm (5.12 cm) between the chiasma and the summit of the medial malleolus. (FDL) = flexor digitorum longus tendon, (FHL) = flexor hallucis longus tendon, (FDB) = flexor digitorum brevis muscle (cut and reflected), (AH) = abductor hallucis (cut and reflected).

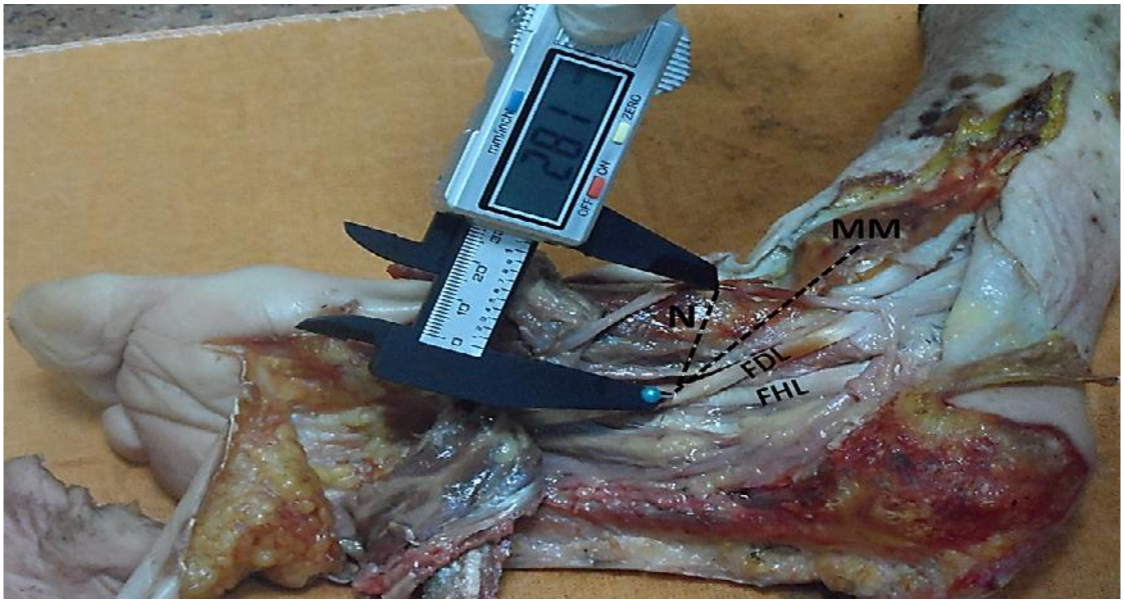

Figure 3: A photograph of right dissected foot showing the chiasma plantare marked by blue pin. The distances between the chiasma and both medial malleolus (MM) and navicular bone (N) are marked by black dotted lines. Notice the reading of the digital caliber recording 28.1 mm (2.18 cm) between the chiasma and the tuberosity of the navicular bone. (FDL) = flexor digitorum longus tendon, (FHL) = flexor hallucis longus tendon.

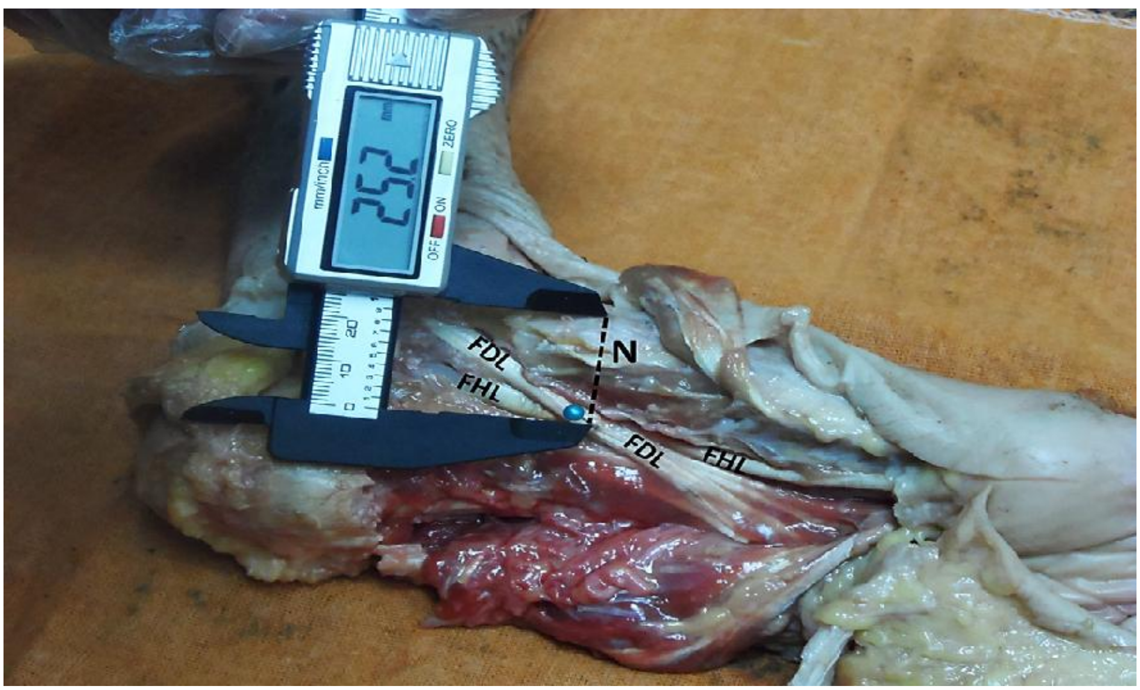

Figure 4: A photograph of left dissected foot showing the chiasma plantare marked by blue pin. The distance between the chiasma and navicular bone (N) is marked by black dotted line. Notice the reading of the digital caliber recording 25.2 mm (2.52 cm). (FDL) = flexor digitorum longus tendon, (FHL) = flexor hallucis longus tendon.

Discussion

The anatomical relationship between the tendons of FHL and FDL has been described in different ways in both anatomical and surgical literature. Both tendons are routinely used in reconstructive surgeries for posterior tibial tendon insufficiency [8, 18] and Achilles tendon tendinopathy [2, 5, 22].

Many authors have reported that the usage of FHL tendon grafts has more successful outcomes than FDL tendon grafts, especially in Achilles tendon repair procedures [2, 4].Regarding the surgical treatment of posterior tibial tendon dysfunction, **Spratley *et al*.** [20] has proposed the usage of FHL tendon grafts instead of FDL tendon grafts.

Different surgical techniques are used for harvesting the FHL tendon including single incision, double incision, and minimally invasive techniques. The graft tendon length varies according to the chosen surgical technique [10, 14, 21]. However, toe deformities and nerve injuries have been reported after FHL tendon transfers, especially while harvesting the tendon distal to the chiasma plantare[7].

Therefore, the exact knowledge about the location of the chiasma plantare and the tendinous variations in this region is important for the tendon harvest and assessing the expected function loss after grafting.

Regarding the anatomical variations of cross-attachments between FHL and FDL tendons, many authors have investigated, classified, and demonstrated different cross-attachments including cross-attachments from FDL to FHL, from FHL to FDL, connections in both directions, and also no connections between both tendons [9, 11, 13, 17, 22].

These studies had a very limited number of cases and were limited to Caucasian population. **Mao *et al*.**[10] have introduced a more comprehensive classification on Asian population using sixty four legs from thirty two formaldehyde preserved cadavers. They have reported the existence of connections between FDL and FHL tendons in all specimens. The majority of these connections were directed from FHL to FDL, while the incidence of cross-attachments in both directions was rare. The authors stated that differences between their study and previous studies may be partially due to ethnic and racial backgrounds of the dissected specimens. More recently, **Orhan *et al*.**[14] have defined two new types of connections between FHL and FDL (two slips from FHL to FDL and one slip from FDL to FHL; and two slips from FDL to FHL and one slip from FHL to FDL).

Regarding the location of the chiasma plantare, it plays an important role in harvesting tendon graft, especially in harvesting FDL tendon graft with medial approach and FHL tendon graft with double incision technique [1, 16, 21].

Data about exact location of chiasma plantare was limited with the study of **Mao *et al*.**[10]**.** They defined the location of the chiasma in relation to the interphalangeal (IP) joint of big toe and the tuberosity of navicular bone. They have reported that the chiasma was located at 10.89 ± 1.08 (range 9.22 - 13.04) cm proximal to the IP joint and 2.21 ± 0.34 (range 1.59 - 3.04) cm under the navicular tuberosity. Contrast to this study, **Orhan *et al*.**[14] have found the chiasma plantare to be more proximal to the (IP) joint of big toe; at 12.61 ± 1.11 (range 10.33 - 14.09) cm, and deeper to the navicular tuberosity; at 1.75 ± 0.39 (range 1.11 - 2.44) cm. They added another bony landmark, the medial malleolus and located the chiasma at 5.93 ± 0.74 (range 4.72 - 7.35) cm distal to it.

In our study, the chiasma was found to be 2.47 ± 0.25 (range 2.13 – 2.81) cm under the navicular tuberosity; in more agreement with **Mao *et al*.**[10], and 5.41 ± 0.22 (range 5.09 – 5.76) cm distal to the medial malleolus; about 0.5 cm closer as compared with **Orhan *et al*.**[14]. These variations may be due to racial backgrounds of the dissected specimens, but also the nature of dissected specimens should be taken into consideration. Contrast to both **Mao *et al*.**[10] and **Orhan *et al*.**[14], the dissected specimens in our study were fresh frozen and not formaldehyde preserved.

In addition, the angle between the medial malleolus, the chiasma plantare, and navicular tuberosity was measured in this study as a new variable that may help in exact detection of the site of the chiasma. It measured 23.04 ± 6.62 (range 18.66 – 38.65) degrees.

Limitations of the study:

Although the results of this study have been informative about the location of the chiasma plantare, it has certain limitations.

We have used only twenty feet from ten fresh frozen cadavers which may be considered a limited number of cases.

To our knowledge, this study is the first trial to measure the angle between the medial malleolus, the chiasma plantare, and the navicular tuberosity in fresh frozen specimens.

Conclusion

In the light of our findings, we conclude that the exact location of the chiasma plantare is variable according to racial backgrounds and nature of the examined specimens. Putting into consideration the angle measured in this study may add beneficial information about the precise location of the chiasma. We strongly recommend performing further studies to measure this angle and analyze its variations.

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Authors' contributions:

AF: study design, data collection, dissection, measurements, data analysis, manuscript writing, and manuscript editing. GT: study design, dissection, photographing, and manuscript editing. EH: study design, data collection, dissection, and manuscript editing.

Conflict of interest:

The authors declare that they have no conflict of interest, commercial associations, or intent of financial gain regarding this research.

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