The myofascial compartments of the foot

A CADAVER STUDY

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Compartment syndrome of the foot requires urgent surgical treatment. Currently, there is still no agreement on the number and location of the myofascial compartments of the foot. The aim of this cadaver study was to provide an anatomical basis for surgical decompression in the event of compartment syndrome. We found that there were three tough vertical fascial septae that extended from the hindfoot to the midfoot on the plantar aspect of the foot. These septae separated the posterior half of the foot into three compartments. The medial compartment containing the abductor hallucis was surrounded medially by skin and subcutaneous fat and laterally by the medial septum. The intermediate compartment, containing the flexor digitorum brevis and the quadratus plantae more deeply, was surrounded by the medial septum medially, the intermediate septum laterally and the main plantar aponeurosis on its plantar aspect. The lateral compartment containing the abductor digiti minimi was surrounded medially by the intermediate septum, laterally by the lateral septum and on its plantar aspect by the lateral band of the main plantar aponeurosis. No distinct myofascial compartments exist in the forefoot.

Based on our findings, in theory, fasciotomy of the hindfoot compartments through a modified medial incision would be sufficient to decompress the foot.

Compartment syndrome of the foot is a serious potential complication of crush injuries, fractures, operations and vascular injuries.[1-3] Approximately 10% of calcaneal fractures develop this complication, and of these 50% develop clawing of the toes and other foot deformities, including stiffness and neurovascular dysfunction.[4] In a retrospective study of patients following treatment for crush injuries of the foot, Myerson et al[5] showed that at an average of 3.3 years following the injury 25% of the patients had a poor outcome. Failure to recognise and treat compartment syndrome at an early stage was given as a contributing cause of long-term disability.

There is no agreement on the number and location of the compartments of the foot.[3] Grodinsky[6] described four fascial clefts and Manoli and Weber,[2] with dye injection, described nine anatomical compartments. Guyton, Shearman and Saltzman[7] called into question the reliability of infusion experiments for identifying compartments. More recently Reach et al,[3,8] using 3-Tesla MRI on healthy volunteers, described ten compartments.

We aimed to provide an anatomical basis for surgical decompression in the event of compartment syndrome.

Materials and Methods

We dissected nine non-paired, fresh-frozen adult human cadaver feet and four formalin-preserved feet. Three of the fresh-frozen feet were transected transversely with a band saw centred over the mid-metatarsals to study the fascia enveloping the interosseous muscles. Dissection of each foot began with removal of all skin and subcutaneous tissue from the ankle to the metatarsophalangeal joints. Removal of the plantar skin and subcutaneous fat exposed the underlying main plantar aponeurosis and its lateral band (Fig. 1). The origins of the plantar aponeurosis and its lateral band were separated from the calcaneum and reflected distally. The underlying muscles of the sole were dissected layer by layer, identifying anatomical compartments and the surrounding fascia along the way. The quadratus plantae muscle was exposed by dissecting the overlying flexor digitorum brevis from its origin and reflecting it distally. The lumbrical muscles and tendons of the flexor digitorum longus were carefully dissected and reflected distally in order to identify the adductor hallucis muscle in the forefoot. Lastly, the plantar interosseous muscles were sought between the metatarsals in 11 of the specimens. Careful dissection of

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Fig. 1

Photograph showing the sole of the right foot.

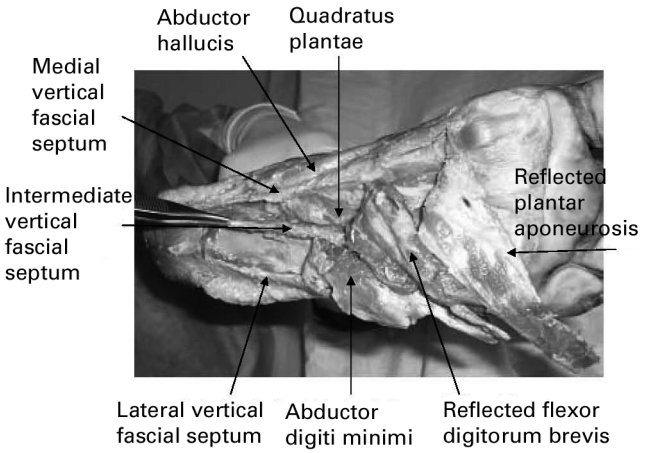

Fig. 2a

these small muscles was carried out to identify any fascia overlying them. The dorsal interosseous muscles were similarly studied. The three transected specimens were also studied to determine the fascial envelopes surrounding the interosseous muscles.

The passage of the posterior tibial neurovascular bundle from behind the medial malleolus into the plantar aspect of the foot was also studied. All findings were documented with still digital photography.

Results

In the hindfoot the medial compartment containing the abductor hallucis was bound on the medial aspect by skin and closely adherent subcutaneous fat and not by any dense fascia. The lateral aspect of this muscle was limited by a dense intermuscular septum, which we have named the medial septum, which separates this compartment from the intermediate compartment (Figs 2 and 3). The medial septum extended from the medial border of the main plantar aponeurosis and was attached dorsally to the calcaneus, navicular and medial cuneiform. The posterior tibial neurovascular bundle entered from the medial into the intermediate compartment through a hiatus near the origin of the septa from the calcaneum. The intermediate compartment containing the flexor digitorum brevis and the quadratus plantae was bounded medially by the medial septum and laterally by the lateral intermuscular septum, which we have named the intermediate septum (Figs 2 and 3). The intermediate septum arose from the lateral edge of the main plantar aponeurosis and the medial edge of its lateral band and extended dorsally to insert into the calcaneum and the cuboid. This septum was incompletely developed in four of the 13 specimens. The intermediate compartment was limited on the plantar aspect by the main plantar aponeurosis. The quadratus plantae was located more deeply and was separated from the flexor digitorum brevis by a thin filmy and often incomplete septum that ran transversely (Fig. 4). The lateral compartment containing the abductor digiti minimi was bound on the medial aspect by the intermediate septum and laterally by the lateral septum (Figs 2 and 3). The lateral septum was a dorsal extension of the lateral border of the lateral band of the plantar aponeurosis and inserted into the calcaneum and the fifth metatarsal. On the plantar side the lateral compartment was limited by the lateral band of the plantar aponeurosis. In summary, a total of three tough vertical fascial septae were noted to extend from the hindfoot to the midfoot.

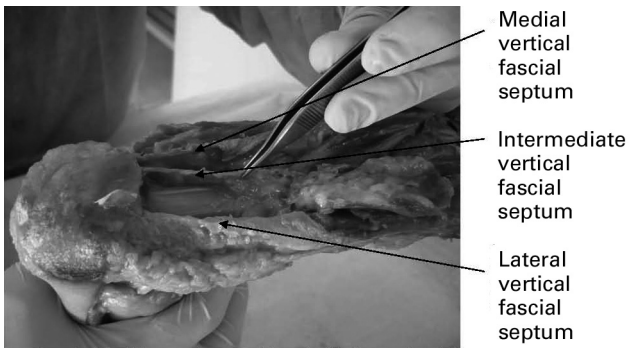

Fig. 2b

Photograph showing a) the muscles and fascial septae of the sole of the left foot and b) the three tough vertical fascial septae that extend from the hindfoot to the midfoot.

In the forefoot, the adductor hallucis was found to lie deep to the flexor digitorum longus tendons and the lumbricals. No dense fascial envelope was found surrounding it in any of the 13 specimens. With regards to the interosseous muscles, no fascia was found overlying the plantar interosseous muscles on the plantar aspect. However, a layer of fascia was found overlying the dorsal interosseous muscles.

The posterior tibial neurovascular bundle traversed the medial compartment and penetrated the medial septum approximately 4 cm from the posterior limit of the calcaneum.

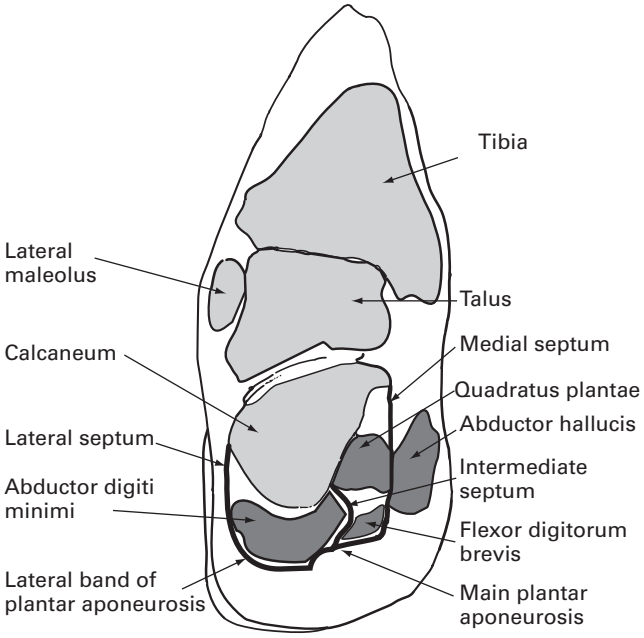

Fig. 3a

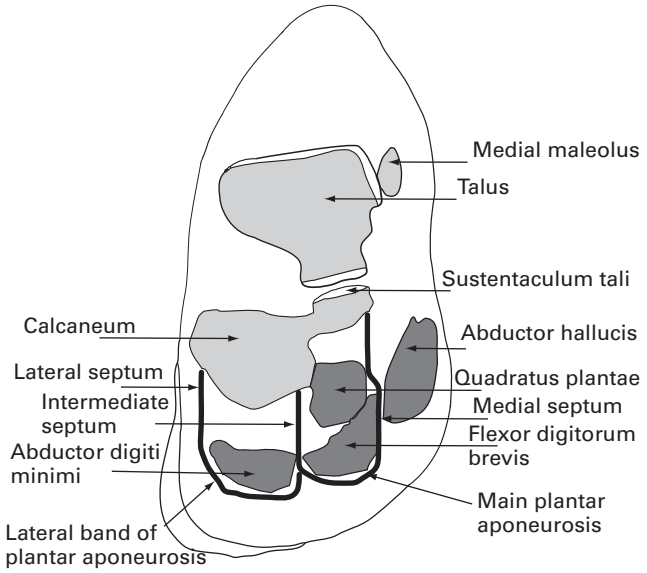

Fig. 3b

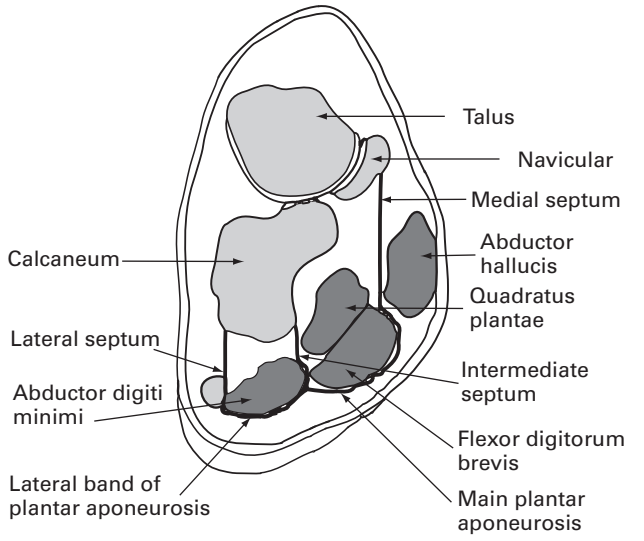

Fig. 3c

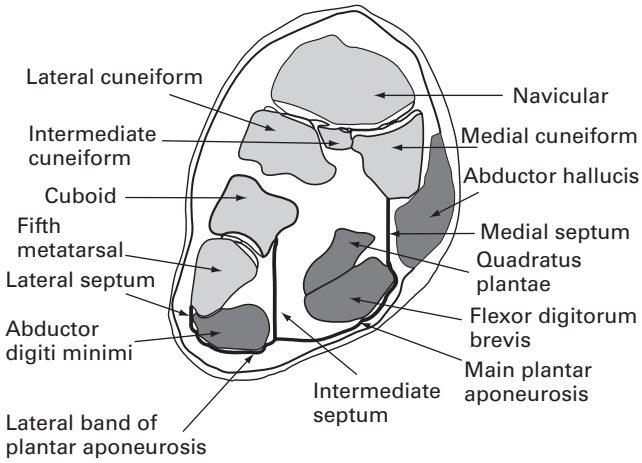

Fig. 3d

Diagrams showing transverse sections of a) and b) the hindfoot, and c) and d) the midfoot.

Discussion

A detailed understanding of the anatomy of the myofascial compartments of the foot allows effective needle placement to measure compartment pressures and even more importantly, facilitates the choice of incisions for their safe and adequate decompression. We believe that direct anatomical dissection is probably more reliable than indirect techniques using dye infusion or even MRI. A densely adherent subcutaneous fatty layer was mistaken for a dense fascial envelope by indirect techniques of investigation.[2,9]

We identified three compartments that extended from the hindfoot to the midfoot; the medial, intermediate, and lateral. Unlike the other two, the medial compartment containing the abductor hallucis was only covered by skin and subcutaneous fat on its medial aspect. This study contradicts previous reports[1,2] that showed fascia enveloping the abduc-

Fig. 4

Photograph showing a thin filmy fascia overlying the quadratus plantae.

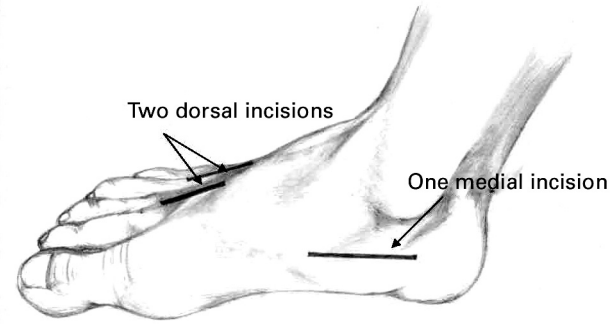

Fig. 5a

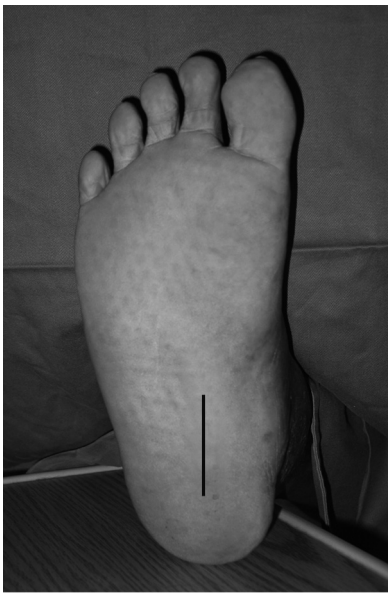

Fig. 5b

a) Diagram showing the standard incisions for fasciotomy of the foot, b) photograph showing our recommended incision over the instep.

tor hallucis muscle medially. In the intermediate compartment, a thin filmy layer separated the deeply lying quadratus plantae from the superficial flexor digitorum brevis. This makes it likely that the quadratus plantae would not need to be released separately in patients with compartment syndrome. Guyton et al[7] also showed that pressures far below 30 mm of mercury easily breached this fascial layer. Again contrary to a previous report[9] no Y-shaped fascial septum surrounded the adductor hallucis. Finally, no fascia enveloped the plantar interosseous muscles which is also contrary to a previous report,[1] although fascia was seen over the dorsum of the dorsal interosseous muscles.

In the course of our dissections, we identified five structures in the plantar aspect of the foot that may play a major role in the development of compartment syndrome in the hindfoot and/or midfoot. They are: the plantar aponeurosis, the lateral band of the plantar aponeurosis, the medial vertical fascial septum, the intermediate vertical fascial septum and the lateral vertical fascial septum. All these structures are highlighted because of their tough consistency and we believe that they will need to be incised, if the associated compartments are to be adequately decompressed.

With a better understanding of the anatomy of the foot, we can now be more precise in identifying the compartments vulnerable to the development of increased pressure and limiting surgical decompression to the affected compartments only. Currently, the approaches for compartment decompression generally include two dorsal incisions for access to the forefoot compartments, and one medial incision for decompression of the hindfoot.[1,2,10]

We question the need for the two dorsal incisions in the absence of fascia completely encasing the interosseous muscles except perhaps to stabilise associated metatarsal fractures. This approach has also been used to decompress the adductor hallucis which is not encased in any fascia that needs to be released.

The compartments that need to be decompressed are the intermediate and lateral. The previously described medial hindfoot incision[1,2] was aimed at decompressing the abductor hallucis first. The surgeon then proceeds laterally to decompress the intermediate and lateral compartments through the same incision. We question the usefulness of this medial incision. In our study there was no fascia over the abductor hallucis medially and thus this incision is not required. Further dissection through this incision places the posterior tibial neurovascular bundle at risk. Further advancement to reach the lateral compartment only increases the damage to the muscles in these compartments. A direct lateral incision to release the lateral compartment

has been proposed.[11] However, this approach may compromise subsequent surgical exposure to stabilise an associated calcaneal fracture. Our anatomical study revealed that only two hindfoot compartments are completely encased in fascia that need to be released.

We suggest that the two dorsal and one medial standard incision routinely described may not be the most effective means of decompressing the foot in the event of compartment syndrome. We propose that an incision on the non-weight-bearing instep of the foot over the main plantar aponeurosis commencing 5 cm from the posterior edge of the heel and extending 5 cm distally is used (Fig. 5). The plantar aponeurosis should be exposed and incised. Through this incision the medial septum and if present the intermediate septum should also be incised. The more dorsally-located posterior tibial neurovascular bundle is safe with this approach.

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