Original articles

The deep plantar arch in humans constitution and topography

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Received November 15, 2000 / Accepted in final form March 08, 2001

Key words: Anatomy - Foot - Arteries - Deep plantar arch

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Abstract

Abstract The integrity of the various structures within the feet depends on their blood supply. Lesions of the feet often require revascularization, which if successful avoids the need for amputation. To provide greater anatomical detail to aid vascular surgery and imaging, the anatomy and constitution of the deep plantar arch was studied in 50 adult cadaveric feet. The arteries of the foot were injected with red neoprene latex and dissected under magnification. The deep plantar arch, present in all feet, was the result of anastomosis between the deep plantar artery and the deep branch of the lateral plantar artery. The deep plantar artery was predominant in 72% of specimens (Type I arches) and the lateral plantar artery in 22% (Type II), with the contribution being equal in 6% (Type III). The medial plantar artery contributed to the medial segment of the deep plantar arch by its deep branch in 12% of specimens. The distance between the deep plantar arch and each interdigital commissure was generally constant, averaging 29% of total foot length. The deep plantar arch was located in the middle third of the foot in all specimens, being in the distal part of this third in 90%. The deep plantar arch is, therefore formed mainly by the deep plantar artery, a branch of the dorsal artery of foot its location can be estimated if foot length is known.

The foot plays an important role in recreational, sporting and occupational activities, with the integrity of its component parts depending on its blood supply. Consequently, a thorough knowledge of the topography and relations of its arteries is necessary for advances in its arterial reconstruction [19]. Such reconstructions often avoid amputations in cases of arterial trauma resulting from industrial and automobile accidents, as well as in patients with diabetes and severe ischaemia of the lower limbs [9, 10, 14].

Surgical arterial bypass for feet generally makes use of pre and/or intraoperative arteriography for evaluating the arterial network, as well as for checking the success of the bypass [20]. The central arterial component of the foot is the deep plantar arch, formed by the anastomosis between the deep plantar a. (a terminal branch of the dorsal a. of the foot) and the deep branch of the lateral plantar a. Both arteries contribute in different ways to the formation of the arch [11, 13, 25].

Therefore, the characteristics of the deep plantar arch were studied to determine its formation and topography, both of which are of interest in vascular surgery and imaging of the feet.

Material and methods

This study was conducted using 50 feet (25 right, 25 left) from 25 embalmed Brazilian adult cadavers (22 male 3 female aged 32 to 70 years) at the Universidade Federal de São Paulo and Universidade Federal de Santa Catarina, Brazil. The arteries of the foot were injected with latex neoprene (Artifix L14) stained red through the anterior tibial a. in the distal third of the leg. With the aid of magnification the dorsal, superficial and deep plantar regions of the foot were dissected.

The external diameters of the deep plantar a., prior to it passing toward the plantar region at the posterior extremity of the first interosseous space, and the deep branch of the lateral plantar a. were measured using a digital caliper (Starrett™). Also measured were 1- the length of the foot along its axial line 2- the distance between the deep plantar arch and each interdigital commissure and 3- the distance between the arch and the *pternion* (the most posterior point from the heel) (Fig. 1a-c). To determine the topographical location of the deep plantar arch, the length of the foot was divided in thirds (anterior, middle, posterior), with each third further subdivided into proximal, middle and distal parts (Fig. 2).

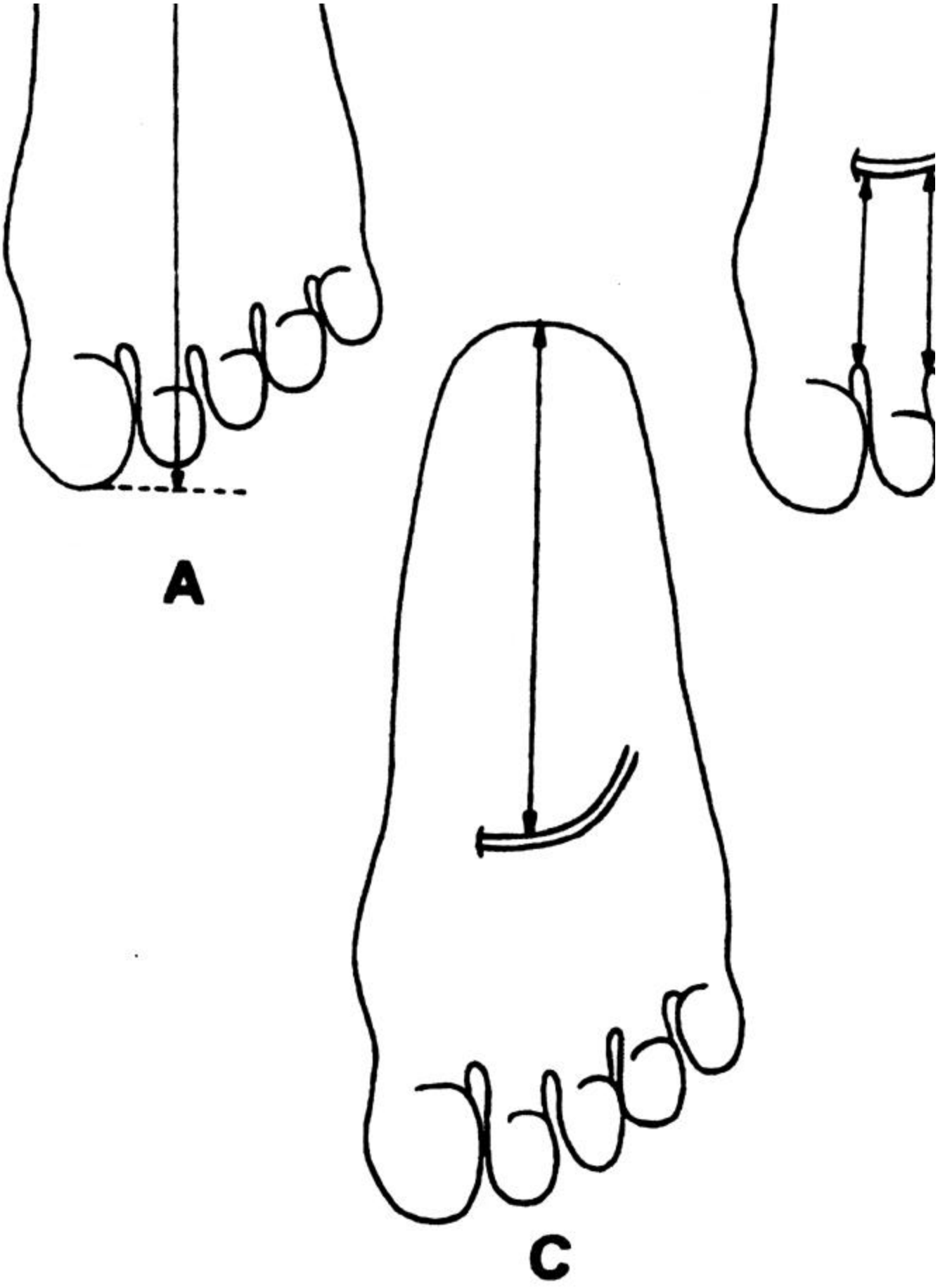
A
C

Fig. 1a-c Schematic representation of measurements made in the plantar region. **a**, Length of the foot in axial line **b**, distance from the deep plantar arch to each interdigital commissure **c**, distance from the deep plantar arch to the *pternion*

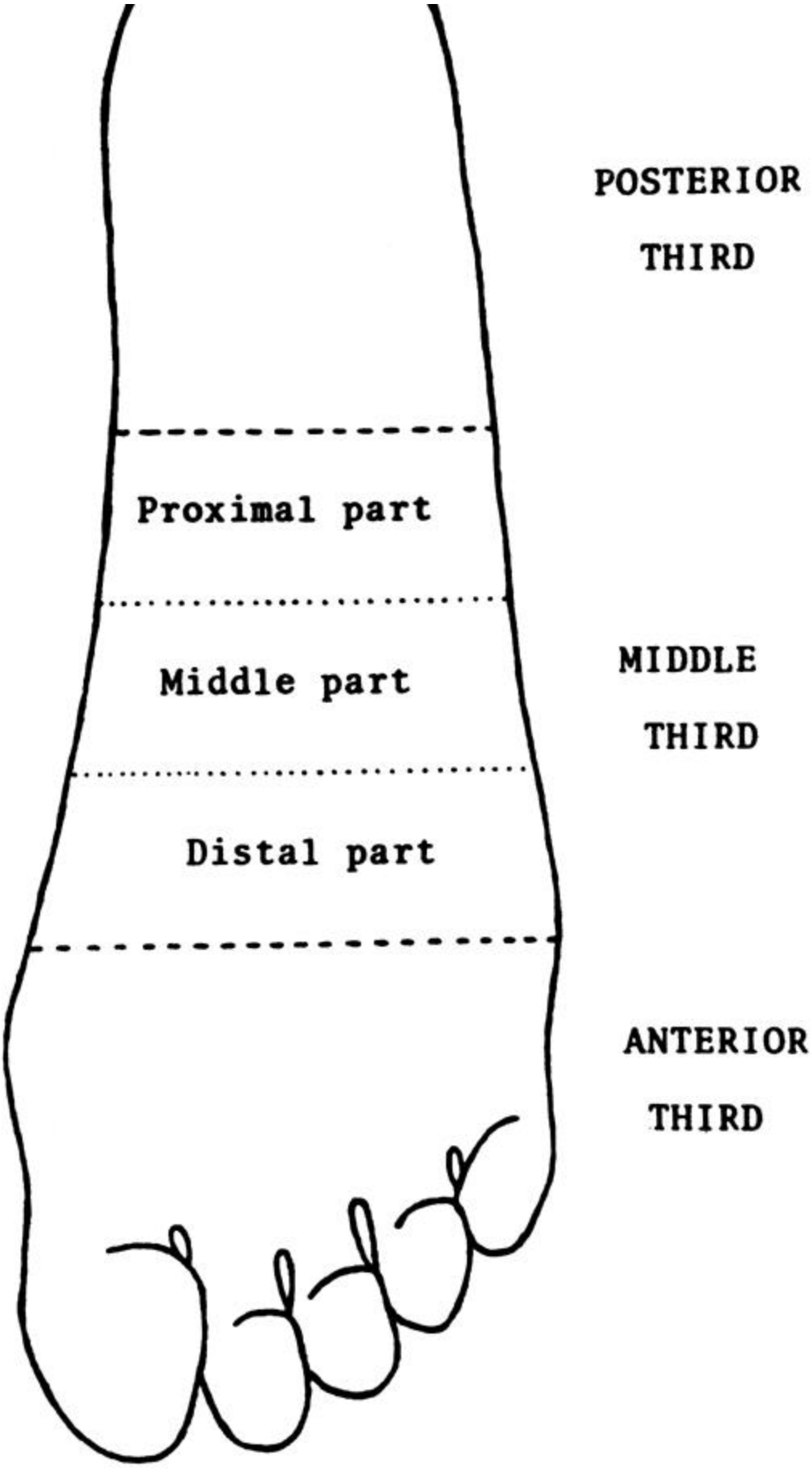
POSTERIOR
THIRD
Proximal part
Middle part
MIDDLE
THIRD
Distal part
ANTERIOR
THIRD

Fig. 2 Subdivision of the plantar region in thirds and its correspondent parts

Results

The deep plantar arch was present in all specimens and was formed by an anastomosis between the deep plantar a., a branch of the dorsal a. of foot, and the deep branch of the lateral plantar a. In 49 specimens (98%) the deep plantar a. was single and entered the plantar region through the posterior extremity of the first interosseous space. In the remaining specimen (2%) the dorsal a. of the foot gave two deep plantar aa., which passed through the first and second interosseous spaces respectively both participated in the formation of the deep plantar arch. The deep plantar arch was classified into one of three types depending on the contribution of each a.. For this purpose the diameter of the deep plantar a. was compared with that of the deep branch of the lateral plantar a. to determine which was predominant or whether there was an equal contribution.

The following types were identified

- Type I the contribution from the deep plantar a. predominated (Figs. 3-4)

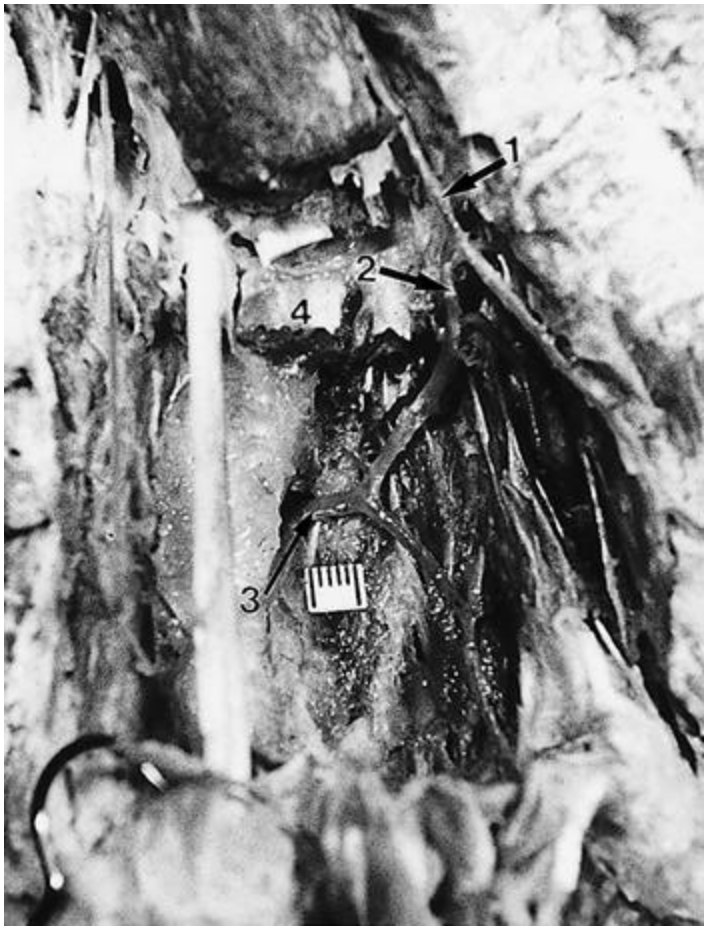

Fig. 3 Type I deep plantar arch. The lateral plantar a. (*1*) and its deep branch (*2*). The medial part of the arch (*3*) is larger than its lateral part. *4*, adductor hallucis m.

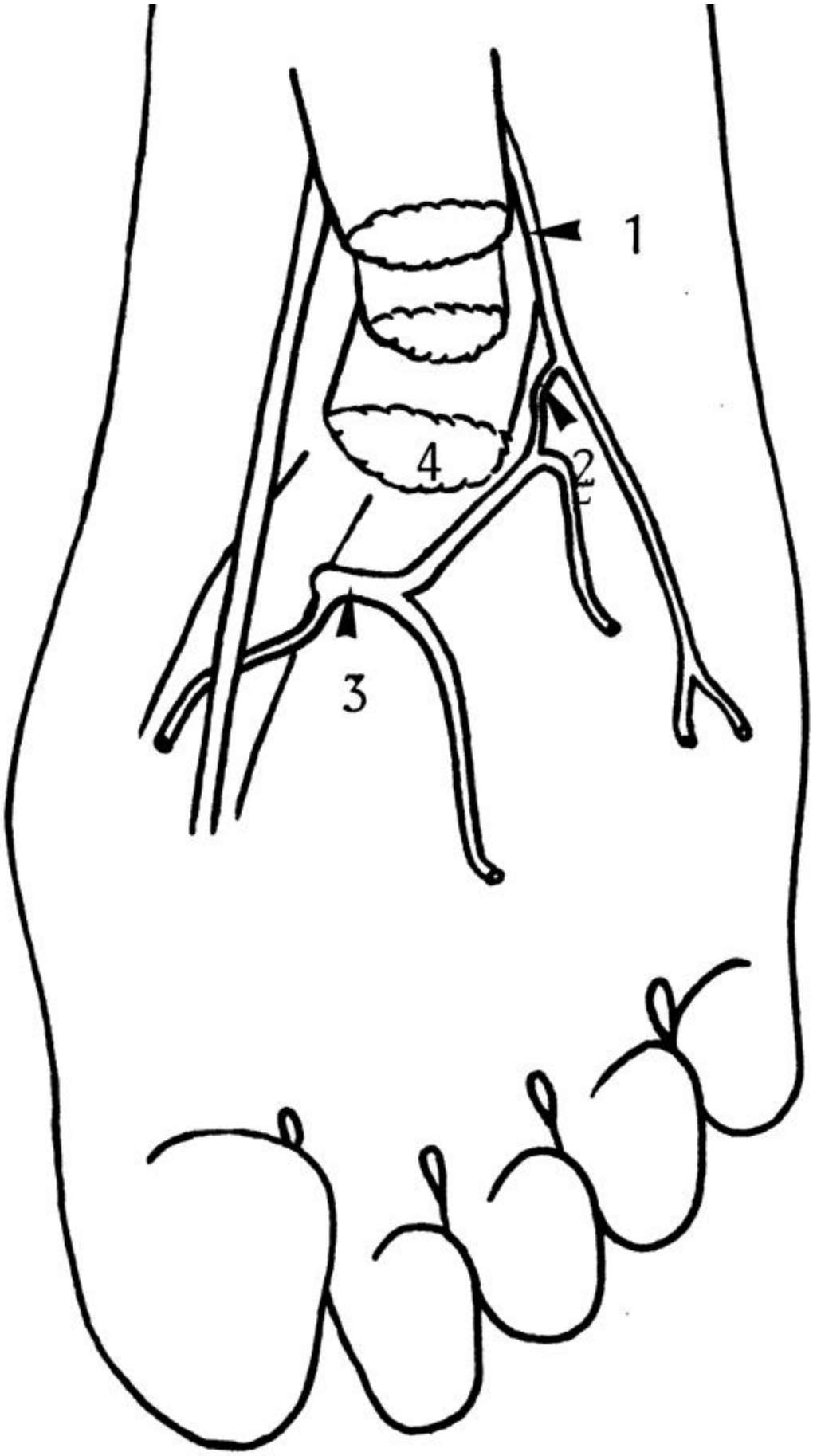
1
2
3
4

Fig. 4 Schematic view of Fig. 3

- Type II the contribution from the deep branch of the lateral plantar a. predominated (Figs. 5-6)

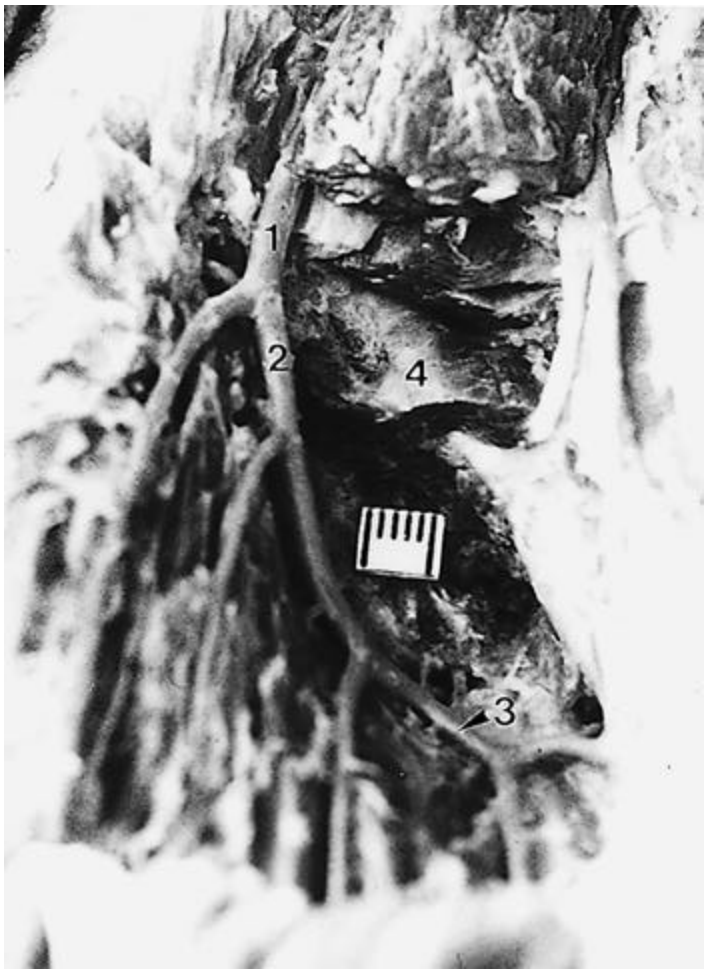

Fig. 5 Type II deep plantar arch. The lateral plantar a. (*1*) and its deep branch (*2*). The medial part of the arch (*3*) is more slender than its lateral part. *4*, adductor hallucis m.

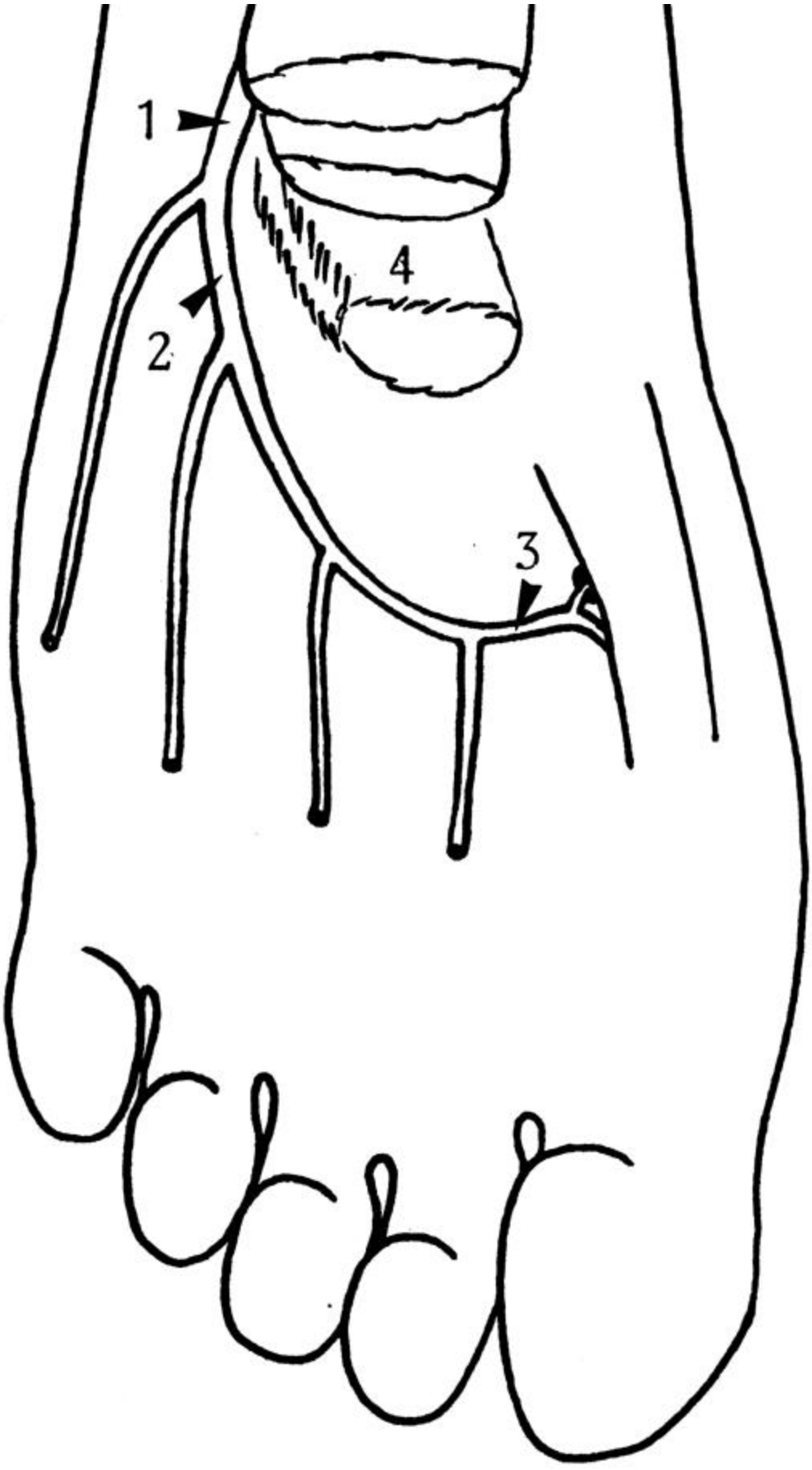
1
2
3
4

Fig. 6 Schematic view of Fig. 5

- Type III both arteries contributed equally

The frequencies observed for each type, as well as the number of bilateral occurrences, are given in Tables 1 and 2. The ? 2 statistical test for agreements between the sides showed that Types I and III arches tended to occur bilaterally.

	R		L		Total	
	n	%	n	%	n	%
Type I	18	36.0	18	36.0	36	**72.0**
Type II	5	10.0	6	12.0	11	**22.0**
Type III	2	4.0	1	2.0	3	**6.0**
Total	25	50.0	25	50.0	50	100.

Table 1. Classification of the deep plantar arch on the right and left sides

	Right		
Left	Type I	Type II	Type III
Type I	15	2	1
Type II	3	3	0
Type III	0	0	1
Total	18	5	2

Table 2. Bilaterality of each deep plantar arch type

The medial plantar a. generally terminated by dividing into deep and superficial branches. The deep branch joined the deep plantar arch in six specimens (12%), two on the right side and four on the left (Figs. 7-8); it was bilateral in only one specimen. The communication, two specimens in each case, was at the level of the first interosseous space, at the level of the second metatarsal and at the level of the second interosseous space.

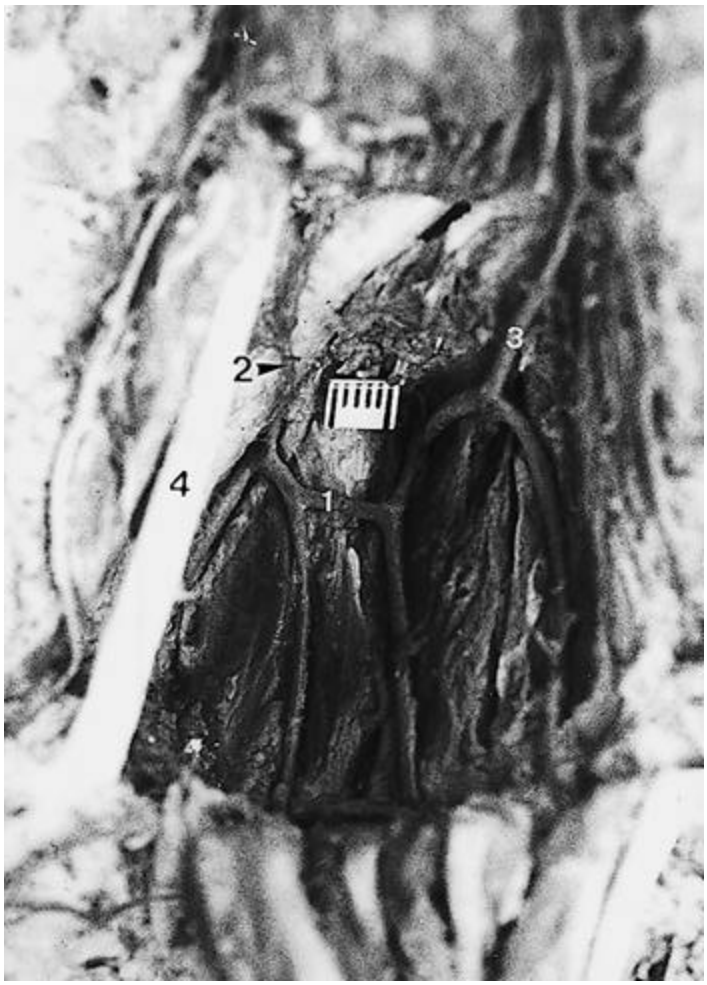

Fig. 7 Deep plantar arch (*1*). *2*, deep branch of the medial plantar a. *3*, deep branch of the lateral plantar a. *4*, flexor hallucis longus tendon

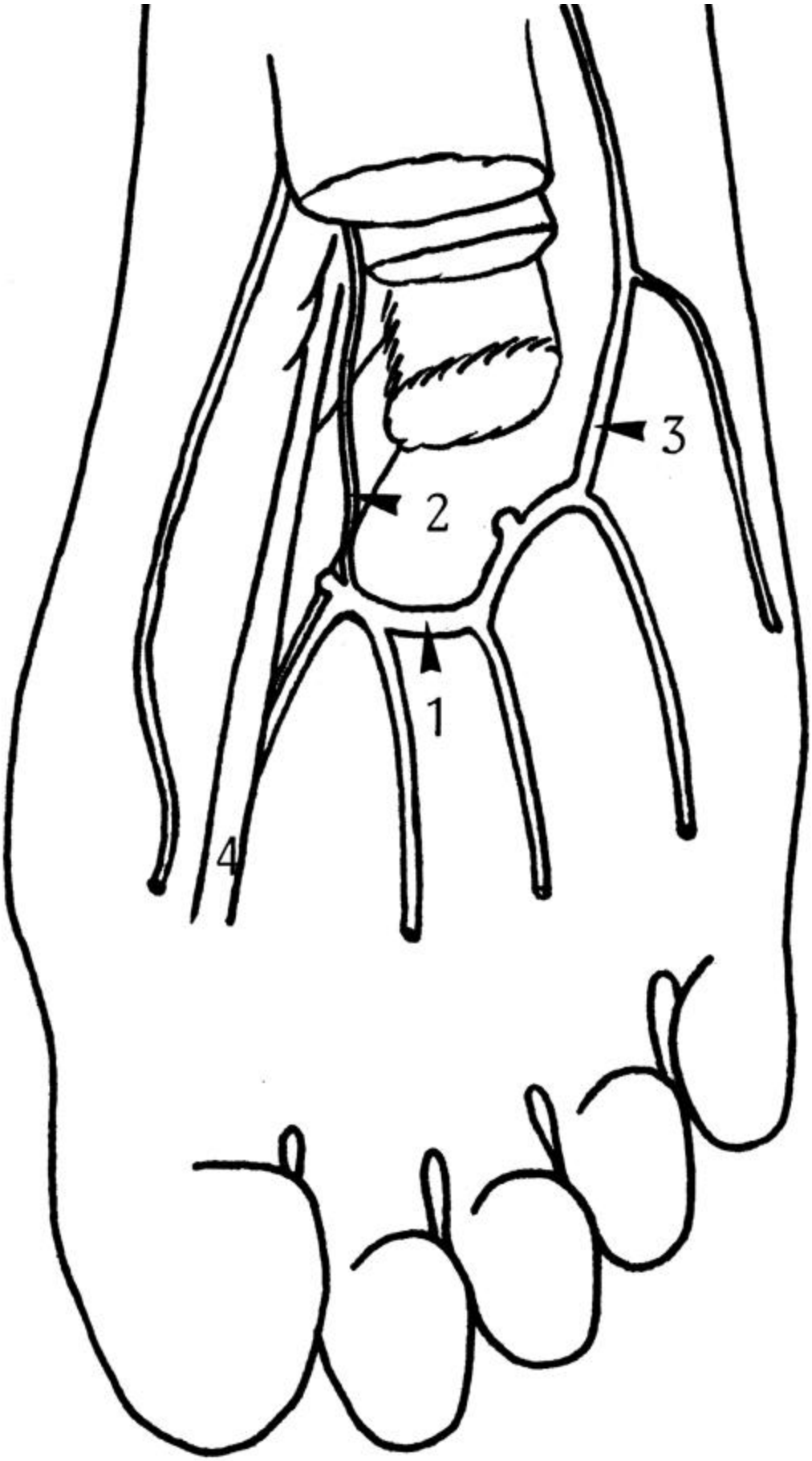
3
2
1
4

Fig. 8 Schematic view of Fig. 7

To determine the topographical location of the deep plantar arch, the distances between the arch and each interdigital commissure was measured. Using the Spearman statistical test it was confirmed that the four "plantar arch - commissure" distances were positively correlated with the length of the foot. The following formula was applied

Distance between plantar arch - commissure x 100

Length of the foot

The mean distances between the plantar arch and commissure were equivalent as percentages

- Plantar arch - 1st commissure = 28.73% foot length

- Plantar arch - 2nd commissure = 29.13% foot length

- Plantar arch - 3rd commissure = 28.1% foot length

- Plantar arch - 4th commissure = 28.65% foot length

All plantar arches were located in the middle third of the foot, where it was located as follows in 90% (45 feet) it was in the distal part, with a bilateral incidence in 21 individuals (84%) in 8% (4 feet) it was at the junction of the middle and distal parts and in 2% (1 foot) it was in the middle part.

Discussion

One of the contributors to the deep plantar arch is the deep plantar a., which in 98% of specimens reached the plantar region by crossing the first interosseous space as previously described [6, 11, 12, 17, 18, 20, 24]. However, smaller incidences have also been reported, e.g. 90% [5] and 80% [21]. There is no report in the literature of the presence of two deep plantar arteries, passing through the first and second interosseous spaces respectively, both participating in the formation of the arch. There are, however, reports describing a single deep plantar a. passing through the second interosseous space [1, 2, 3, 8, 11, 15]; such an arrangement is common in Simians but rare in humans.

The other a. participating in the formation of the arch through its deep branch is the lateral plantar a. this contribution was constant. This artery has been used as a flow receptor vessel in revascularization of the foot in six patients with diabetes, five of which did not require subsequent amputation [9].

The deep plantar arch was present in all specimens in our series, being formed by an anastomosis between the deep plantar and lateral plantar aa. variations in this arterial formation have been reported. The arch has been described as being formed exclusively by the deep plantar a. in 40%, exclusively by the lateral plantar a. in 4% and by both in 55.8% [7] the arch was present and complete in 85.9% [2] and 90% [5, 26]. An open arch, i.e. not presenting as the described anastomosis, has been reported in only one out of 130 cases [1].

The contribution of the deep plantar and lateral plantar aa. to the formation of the deep plantar arch is characteristic. The present findings reveal the predominance of the deep plantar a. in 72% of the specimens (Type I), of the lateral plantar a. in 22% (Type II) and no predominance in 6% (Type III). However, other investigators have reported different values the predominance of the dorsal a. of the foot (through the deep plantar a.) was found in 82% [11], 80.9% [25], 48% [13] and 47.5% [18] of specimens. These same authors found the predominance of the lateral plantar a. in only 10%, 15.2%, 17% and 12.5% of cases, respectively. Similar findings have been reported in fetuses and neonates, in which the diameter of the dorsal a. of the foot was often larger than that of other foot arteries [17]. Thus, the description according to most classical French authors of the lateral plantar a. as being the major contributor to the plantar arch cannot be accepted, since this pattern has been found in only one third of 50 neonatal feet [6].

In spite of the differences in occurrence between this study and others [11, 13, 18, 25], the a. that predominantly contributes to the formation of the plantar arch is the dorsal a. of foot via its terminal branch, the deep plantar a. Therefore, the arch is formed mainly by the dorsal a. of foot and not by the lateral plantar a., as previously stated [22, 23].

Both the dorsal a. of foot and the lateral plantar a. have been used to revascularize the foot in patients with severe ischaemia of the limbs with good results, thereby avoiding the need to amputate [4, 10, 14]. However, due to the characteristics of the

deep plantar arch formation, it is proposed that either the dorsal a. of foot or the deep plantar a. should be considered as a first option as the receptor vessel in such reconstructive surgery, as previously proposed [21]. The lateral plantar a. would then be a second option.

It was observed that Type II arches were more frequent than Type III, however others have found Type II in 10% and III in 8% of specimens [11]. Nevertheless, the contrary has also been reported Type III in 35% [13] and 40% [18], and Type II in 17% and 12.5%, respectively.

Analysis of the number of bilateral cases of each type shows that Types I and III have a tendency to be symmetrical, confirming a previous report [13].

In the present series the medial plantar a. joined the deep plantar arch in only 12% of specimens, confirming that this anastomosis may sometimes occur [23]. Others, however report this pattern to occur more frequently (57.5%) [18], in a further report percentage values were not given [16]. Such an arrangement occurred at the level of the first interosseous space, at the level of the second metatarsal bone and the level of the second interosseous space, i.e. in the medial segment of the arch [24].

With respect to the topographical location of the deep plantar arch, it was found that the distance between it and each of the commissures was, on average, equivalent to 29% of total foot length. Reference to this has not been found in the literature.

Further analysis of the topography of the arch revealed that all arches were located in the middle third of the foot, agreeing with previous observations relating it to the base of metatarsals or to the proximal extremity of the interosseous mm. [8, 12, 24]. The present findings, probably more accurate than those reported previously, show that in most feet (90%) the arch is located in the distal part of the middle third with a high bilateral incidence.

Bearing these observations in mind it should becomes easier for the vascular surgeon to estimate the location of the deep plantar arch if the individual's foot length is known.

Collectively, the findings reported here emphasize the importance of a sound anatomical understanding of the arterial system of the foot in relation to the various procedures that are carried out on it. These include the interpretation of arteriograms, as well as the surgical procedures for revascularization of the foot with the aim of avoiding premature amputation.

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Surg Radiol Anat 23: 253-258
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