Venous plantar plexus: Clinical and surgical implications

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ABSTRACT
In 1888, Lejars described the venous sole that bears his name. It is a venous network arranged on the sole of the foot, which involves the medial and lateral borders. Said author described it indirectly, by transparency, through an injection of resin and black smoke.
In this update, a direct and detailed description of the Lejars venous sole is offered by injection with latex (Butachlor), which clearly identified two planes. The dissections were performed on adult feet and full-term fetuses.
This paper, based on anatomical research, aims to objectively demonstrate the existence of a single venous mesh that is essential for hydraulic function, especially the posterior heel of the foot as a support and walking center. Likewise, the most appropriate surgical incisions are described for the treatment of conditions that compromise this network.
Key words: Plexus; venous; plantar.
Level of evidence: IV

Plexos venosos plantares. Implicancia clínico-quirúrgica

RESUMEN
En 1888, Lejars describió la suela venosa que lleva su nombre. Se trata de un entramado venoso dispuesto en la planta del pie, que involucra los bordes medial y lateral. Dicho autor la describió en forma indirecta, por transparencia, a través de una inyección de resina y negro humo.
En esta actualización, se ofrece una descripción directa y detallada de la suela venosa de Lejars mediante inyección con látex (Butaclor), que permitió identificar claramente dos planos. Las disecciones se efectuaron en pies de adultos y en fetos a término. Este trabajo de investigación anatómica pretende demostrar en forma objetiva la existencia de una malla venosa única que resulta imprescindible para la función hidráulica, sobre todo, del talón posterior del pie como centro de apoyo y marcha. Asimismo, se describen las incisiones quirúrgicas más idóneas para el abordaje de afecciones que comprometen dicho entramado.
Palabras clave: Plexo; venoso; plantar.
Nivel de Evidencia: IV

INTRODUCTION

The paper titled *Thrombosis of the lateral plantar vein*, published in the Postgraduate Orthopedic Instruction section of this journal (*Rev Asoc Argent Ortop Traumatol* 2018; 83(3):214-217) motivated this anatomical description from a surgical point of view, which we believe to be useful for surgeons.

In 1888, Lejars was the first to observe the venous sole with an injection of resin and black smoke. He described, by transparency, the branches, thickness and anastomosis of this sole. It is not absolutely clear from his work if he performed a complete dissection. The sketch on Figure 1 is the only one accompanying his work.

Nowadays, injection and dissection techniques have been improved, which allows us to be more rigorous in the description of this intricate vascular network, unique in the human body.

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How to cite this paper: Santamarta L, Loterzo LG. Venous plantar plexus pump: Clinical and surgical implications. *Rev Asoc Argent Ortop Traumatol* 2019;84(2):155-177. http://dx.doi.org/10.15417/issn.1852-7434.2019.84.2.916

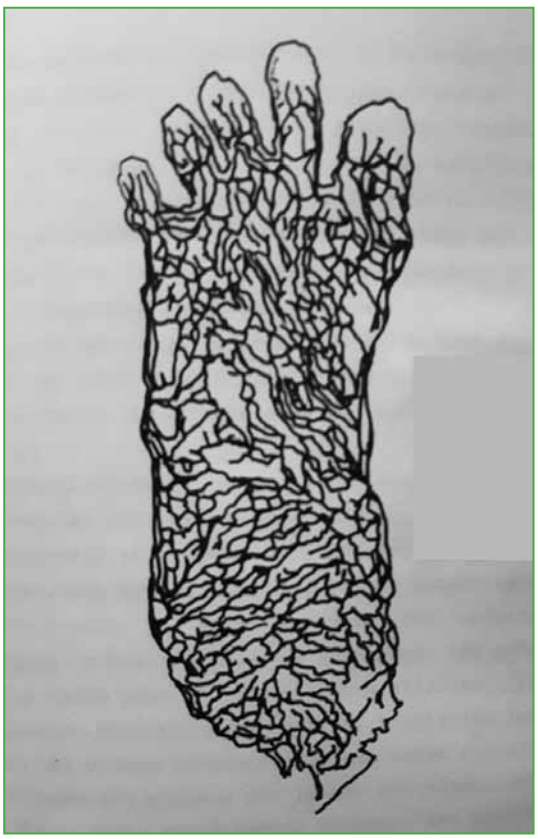

Figure 1. Original Lejars' sketch.

DESCRIPTION OF THE SOLE VENOUS PLEXUSES

We will describe the venous sole through the dissection of fresh sections taken from both adult males and females injected with latex, according to the technique described by Elbio P. Cossi, MD, and adding magnification techniques.

The venous sole is divided into two very clear planes which can be identified easily—but not after hard work:

a) Superficial plexus

b) Deep plexus

a) Superficial plexus

If we perform a panoramic observation of the sole (Figure 2), we could describe narrow and quadrilateral meshes that extend from the interdigital space to the heel, medially to laterally, covering the entire sole of the foot. These meshes become polygonal towards the anterior region. We can also observe a tight interweaving that goes through the depth of the skin and adheres to it in its deepest planes.

The veins of the superficial plexus are of small caliber, approximately from 0.3 to 0.2 mm, but very numerous and arranged in an extremely vascularized network (Figure 3).

Towards the posterior heel of the foot, we can observe a superficial beehive pattern with quadrilateral forms that trace the greater tuberosity of the calcaneus and reach the Achilles tendon in its distal third, surrounding it to form the dorsal venous arch of the foot (Figure 4).

Figure 2. Panoramic image of the plantar venous sole.

Figure 3. Superficial plexus.

In the internal medial region of the sole, numerous branches are seen, arranged in a fan-like manner, from which vertical branches emerge towards the anterior heel, horizontal in the middle region and somewhat oblique towards the posterior heel. These converge towards the back originating the internal marginal vein (for some authors, *internal vein*). These are transparent to the naked eye through the skin. The thickness of this branch is approximately 0.8 to 0.1 mm (Figure 5).

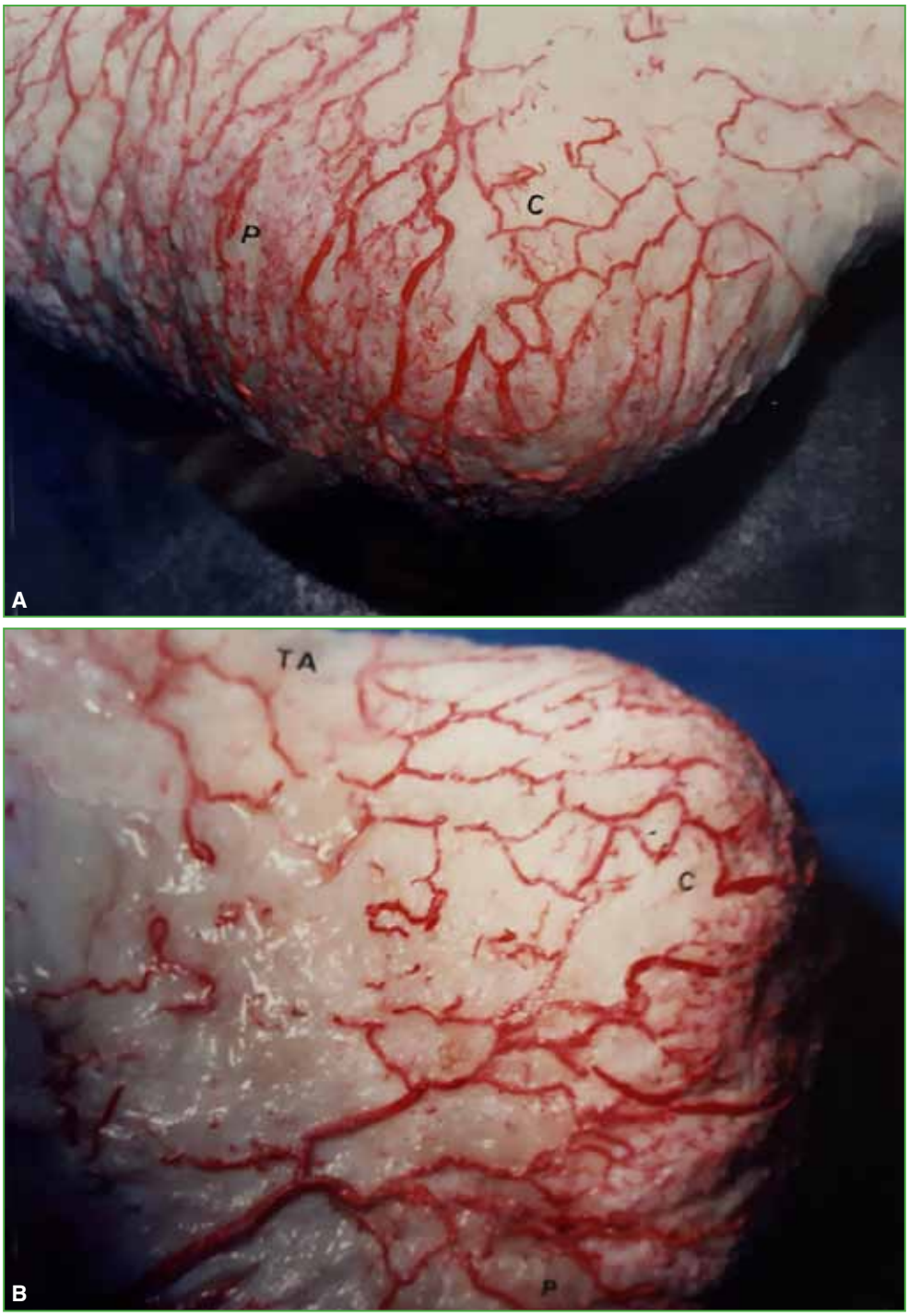

Figure 4. A. Superficial plexus. **B.** Superficial plexus under greater magnification. TA: Achilles tendon, C: calcaneus, P: sole.

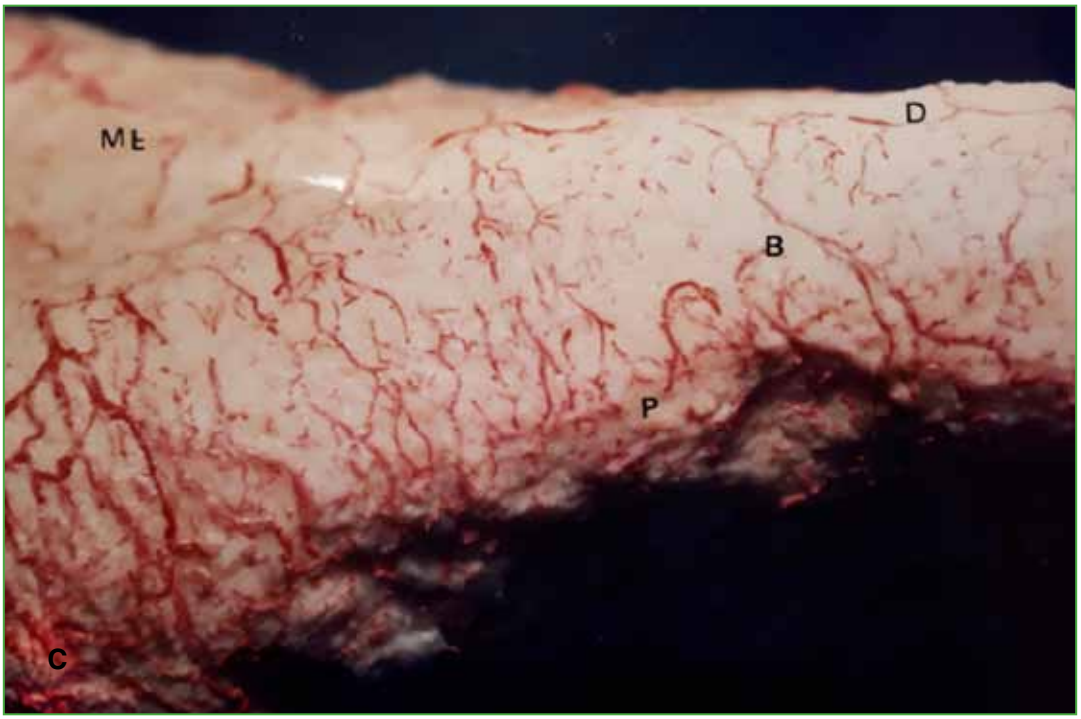

Figure 5. Superficial plexus. ME: external malleolus, B: base of the fifth metatarsal, P: sole, D: dorsum, C: calcaneus.

b) Deep plexus

It is divided into:

1) Posterior heel
2) Medial region
3) Anterior heel
4) Toes (Figure 6)

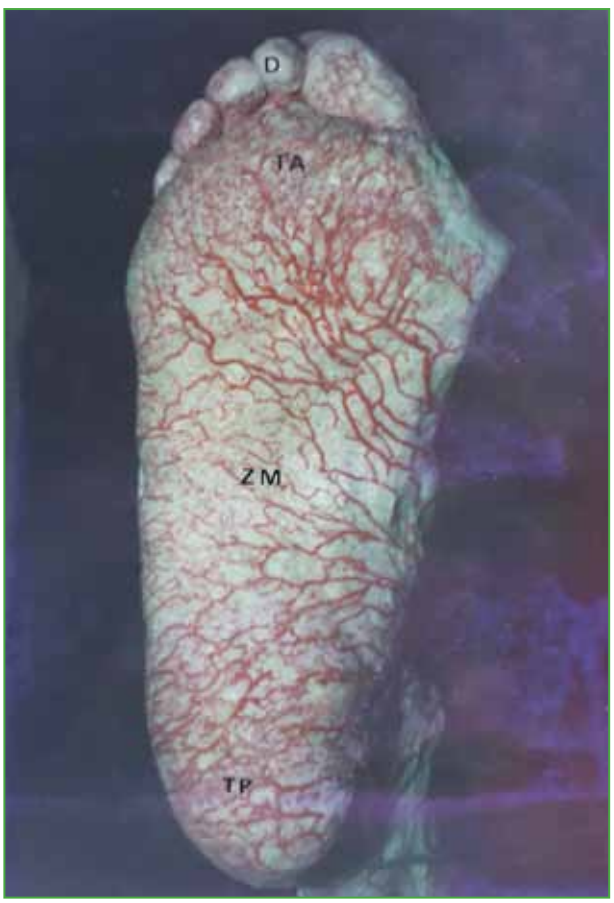

Figure 6. Deep plexus. TP: posterior heel, ZM: medial region, TA: anterior heel, D: toes.

1) Posterior heel

On the heel, veins are thick, well defined, transverse, continuous and constant; they form sinuous paths, and, in many regions, they bulge. Those of smaller caliber intersect with those of greater caliber (Figure 7). They anastomose in the central part of the heel, sometimes by means of thick anastomotic veins (Figure 7) and cover the entire posterior surface of the foot from border to border, and empty into the marginal veins. Towards the Achilles tendon, they end in the dorsal venous arch of the foot, forming an alveolar-like stroma.

Figure 7. A. Deep plexus of the posterior heel. **B.** Image under greater magnification. VT: transverse veins, VCA: central anastomotic vein, E: external, I: internal, C: calcaneus.

Figure 8 shows the calcaneus in detail, with four veins of considerable thickness, which are part of the deep plexus, but which are closer to the Achillean fascia and are located within the subcutaneous cellular tissue.

The calibres found range from 0.5 to 2 mm, and the length from 5.3 to 2.5, 3.5, 1.5, and 1 cm approximately, since it must be considered that the path is not exactly straight, but sinuous, with multiple anastomoses and enlarged venous areas, which are mixed and alternate with the superficial plexus (Figure 9). The average length of the deep dorsal plexus is approximately 8 cm, from the posterior border to the beginning of the medial region.

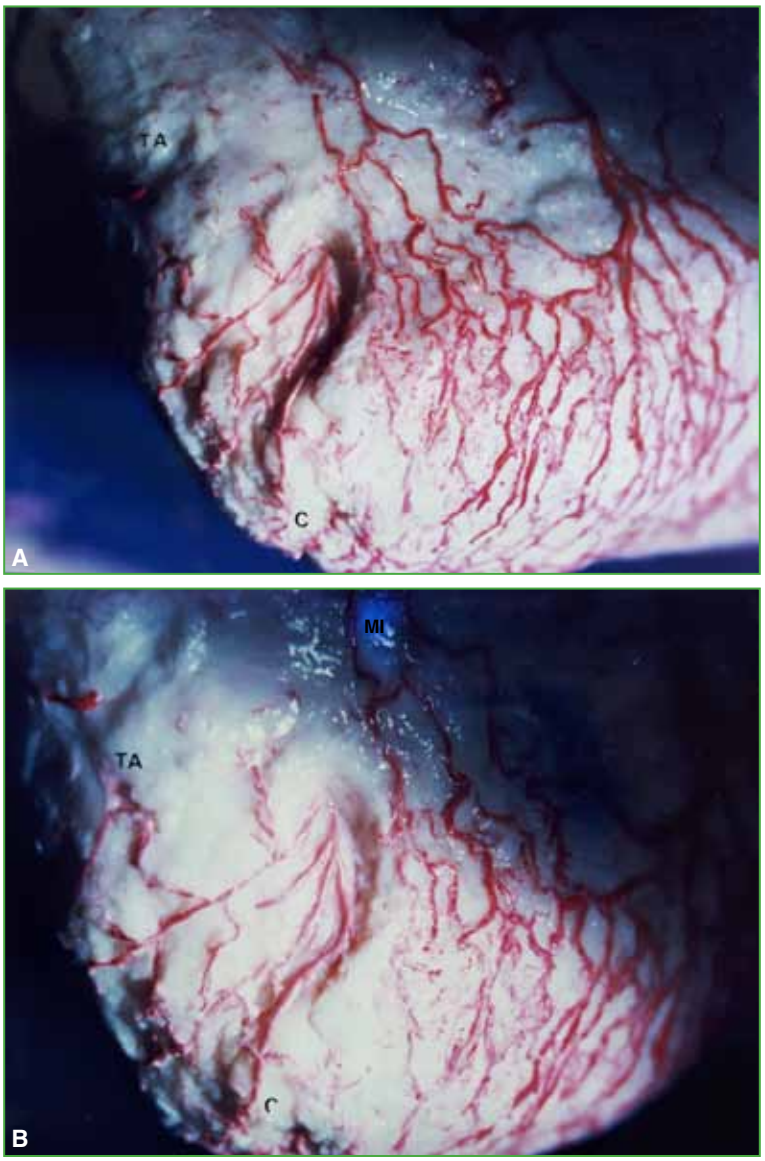

Figure 8. A. Deep plexus of the posterior heel. **B.** Image under greater magnification. TA: Achilles tendon, C: calcaneus, MI: internal malleolus.

Figure 9. **A.** Deep plexus of the posterior heel. **B.** Image under greater magnification. ME: external malleolus, TA: Achilles tendon, C: calcaneus, P: sole, PP: deep plexus, PS: superficial plexus.

2) Medial region

The medial region is limited distally by the five heads of the metatarsals, posteriorly by the beginning of the posterior heel, and internally and externally by both borders (Figure 10).

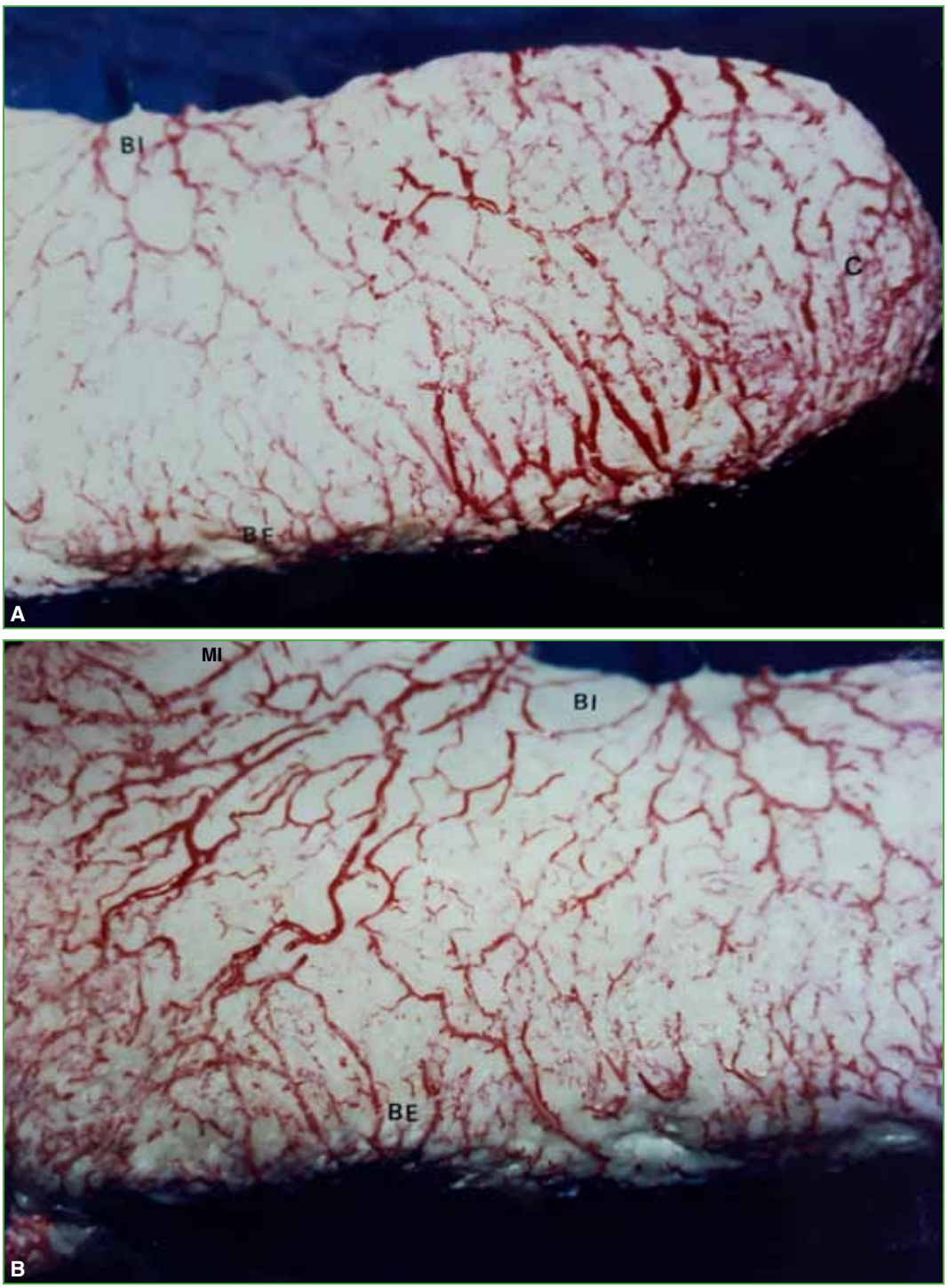

Figure 10. A. Deep plexus of the medial region. **B.** Image under greater magnification. BI: inner border, BE: outer border, C: calcaneus, MI: internal malleolus.

Confluent towards the internal marginal vein, there are six thick trunks varying from 0.1 to 1.5 mm thick (Figure 11).

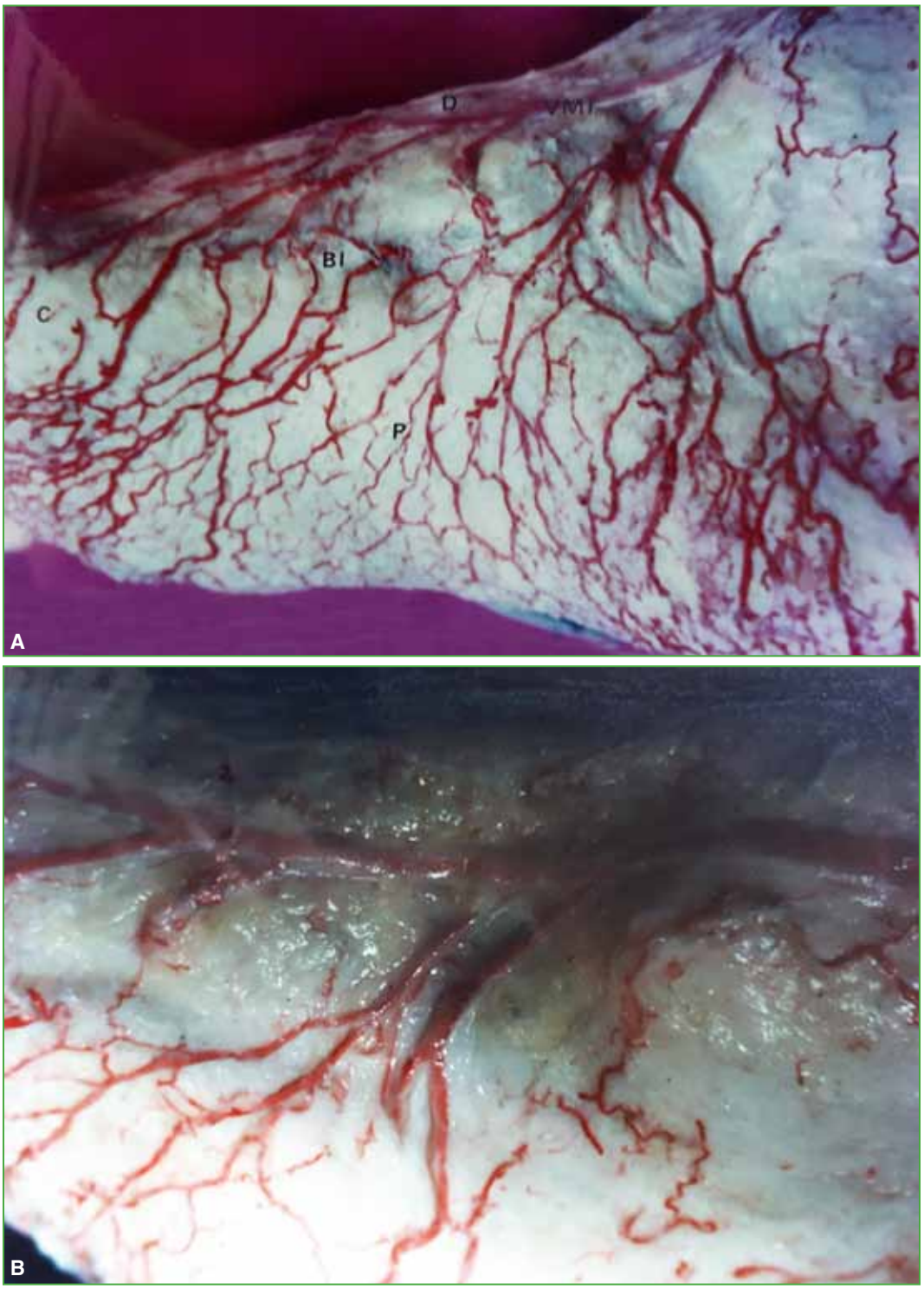

Figure 11. A. Deep plexus of the medial region. **B.** Image under greater magnification. Dorsi-plantar projection. C: head of the first metatarsal, VMI: internal marginal vein, P: sole, D: dorsum, BI: internal border.

The plantar border, highly vascularized both in quantity and thickness, has a transverse direction, in its beginning, along 2.5-3 cm, where its branches begin to bend to enter the anterior heel, continue transversally in the arch of the foot, and adopt a slight obliquity to reach the posterior heel. The branches, which are around 10 to 12, have a thickness of 0.1 to 0.5 mm and a length of 3.5 to 1 cm (smaller and larger, respectively). In the outermost part of the medial region, a beehive pattern of polygonal small veins indivisible from each other is again observed. Within these veins, an almost sinuous vein that crosses the upper or lower region is observed in an almost constant and equal way, distal to the lateral arch, showing posterior concavity, and running from border to border. Its approximate length is 4.5 cm and its thickness is 0.1 mm (Figure 12).

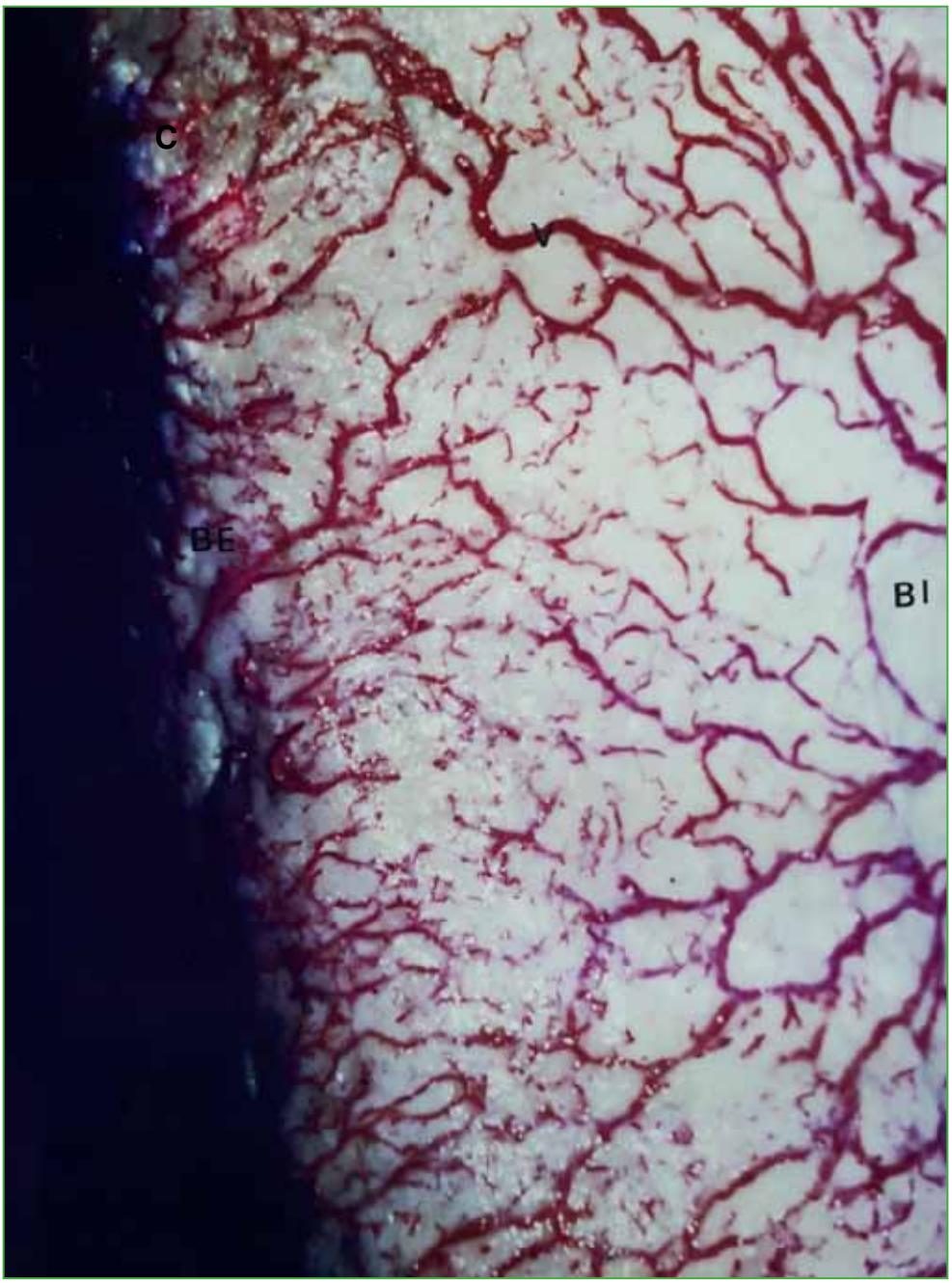

Figure 12. Deep plexus of the medial region. C: head of the fifth metatarsal, BE: external border, BI: internal border, V: vein running from border to border.

3) Anterior heel

In the most anterior region of the sole, we can clearly observe how the two components of the Lejars plexus succeed each other. The superficial plexus covers the most distal region to the interdigital fold (Figure 13), and the deep one, located approximately in the middle of the anterior heel, is composed of seven trunks with a thickness of 0.5 to 0.9 mm (smaller and larger, respectively).

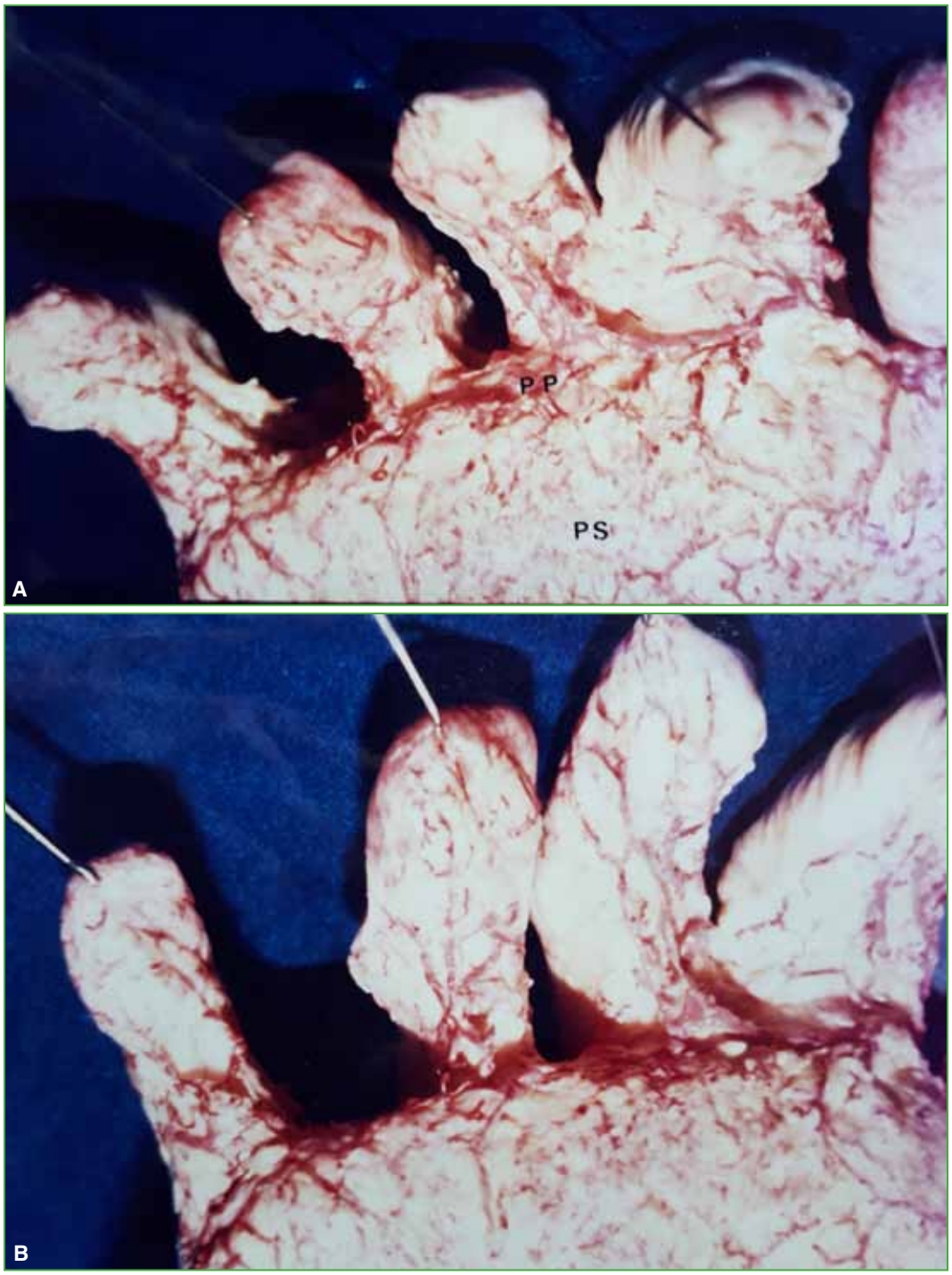

Figure 13. A. Deep plexus of the anterior heel. **B.** Image under greater magnification. Dorsi-plantar projection. PS: superficial plexus, PP: deep plexus.

It should be noted that, although the division into anatomical zones is perfectly delimited and easily visualized, the medial region and the anterior heel form a continuum with respect to the vessels detailed above (Figure 14).

Figure 14. Deep plexus of the anterior heel (under greater magnification). C: head of the first metatarsal, C5: head of the fifth metatarsal, PP: deep plexus, PS: superficial plexus.

4) Fingers

At the end of the anterior heel, origin of the toes, there is a very sinuous vein running from the fifth to the second toe, becoming convex at the base of each toe and concave between each toe, forming a true, vascularized, constant and identical venous sole arch at the base of the toes (Braune's arcade) (Figure 15). This originates interdigital dorsal veins and is originated, in turn, by three thick plantar digital veins, which together form the sign of the star (Figure 15B).

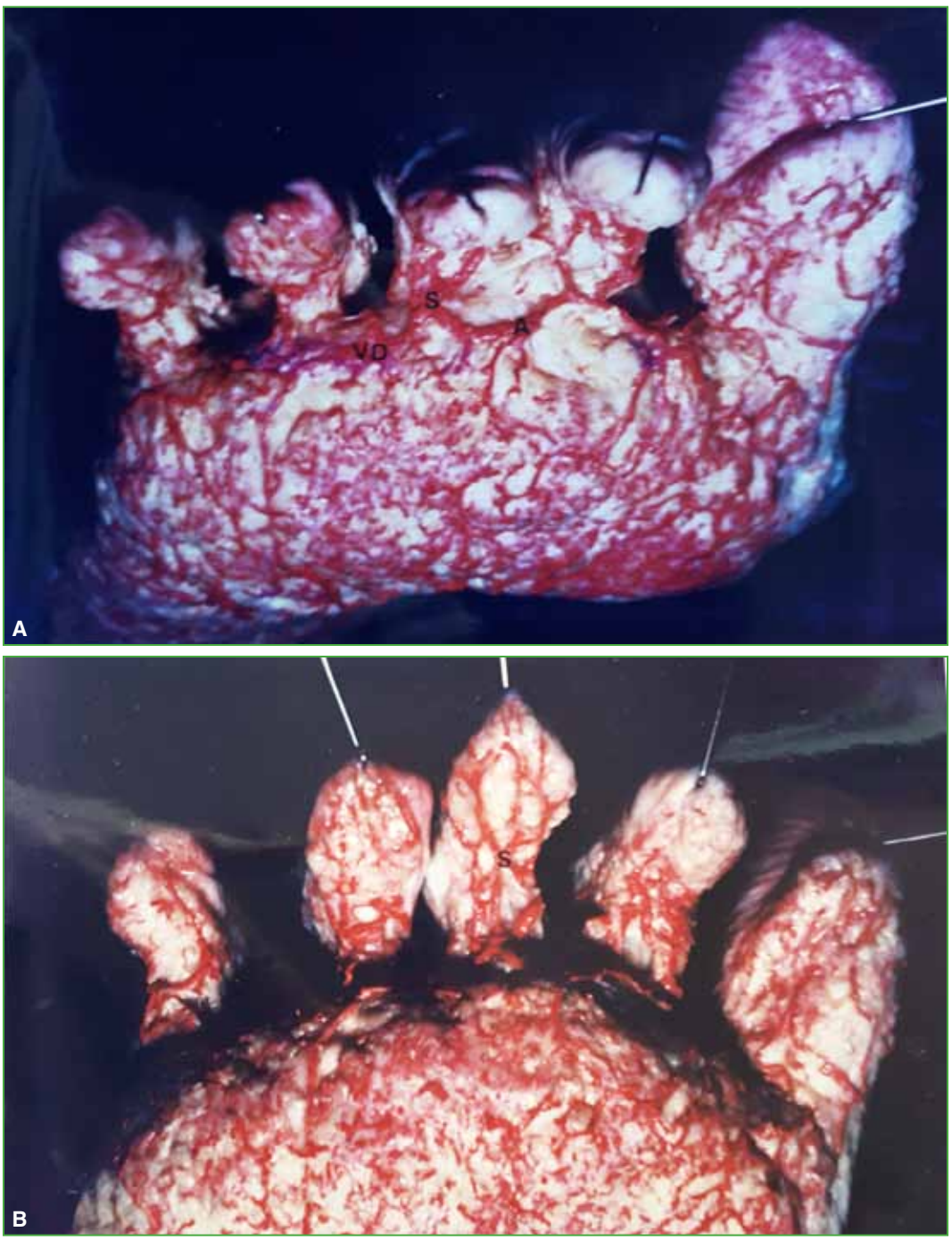

Figure 15. Deep plexus of the toes. **A.** Anterior projection. **B.** Dorsi-plantar projection. A: plantar venous arch of the base of the toes, DV: interdigital dorsal vein, S: sign of the star.

The same goes for the second, third, fourth and fifth toe, but in the Hallux, the plexus becomes poor, and the arch does not reach its origin (Figure 16). The two Hallux plantar veins originate dorsally, in the periungual region (Figure 17), and flow into the internal marginal vein, originating this vein next to the dorsal venous arch. The profuse vascularization shown by the last four toes is strikingly different compared to that of the Hallux.

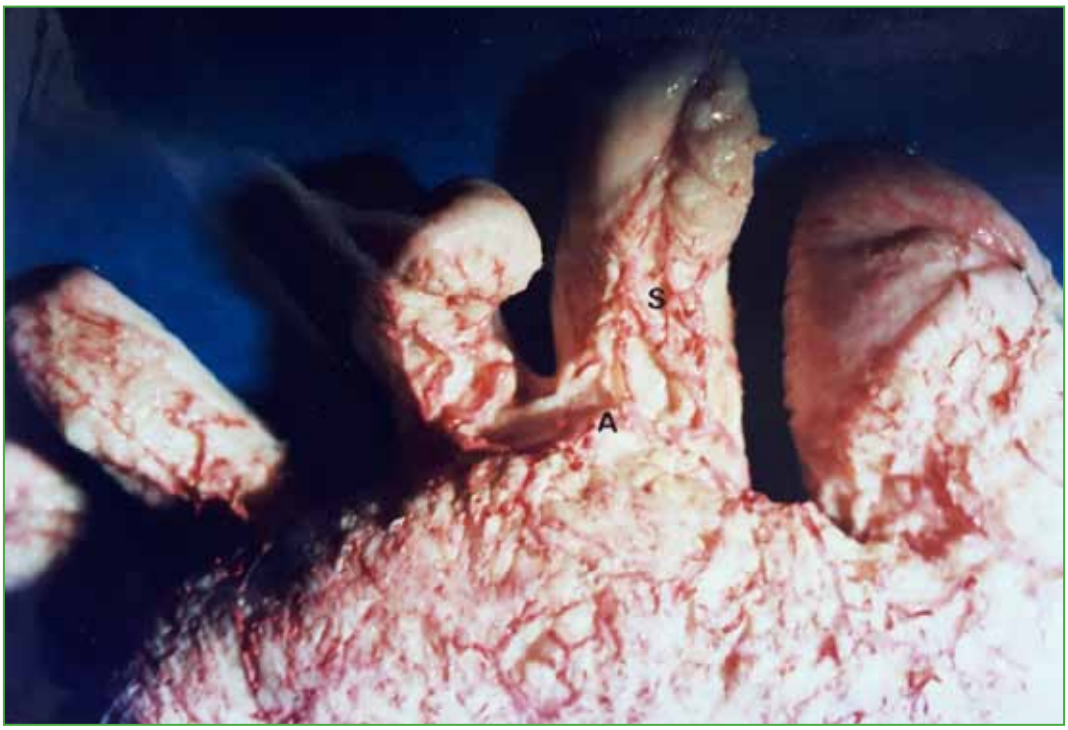

Figure 16. Deep plexus of the toes. S: sign of the star, A: plantar venous arch of the base of the toes.

Figure 17. Deep plexus of the toes. D: first toe (Hallux); U: periungual region.

BORDERS OF THE VENOUS SOLE

We decided to make a brief mention of the borders of the sole, since they differ in their constitution and are not sufficiently prominent in the areas described above.

The internal marginal vein, much more dorsal than lateral or plantar, has much thicker and more extensive origins. Its thickness is approximately 2 mm, and its entire path is more easily observed than that of the external marginal vein (Figure 18). The external marginal vein is much more plantar than the internal one and much less rich regarding the vessels that give rise to it than the latter (Figure 19).

Figure 18. Deep plexus of the borders. VME: external marginal vein, PS: superficial plexus.

Figure 19. Deep plexus of the borders. VMI: internal marginal vein.

Its tributary veins are numerous, but poor in thickness and length. At first sight, they can be confused with the superficial plexus, since they are entangled, rhombus-shaped, and of small length and rugged territory. Their origin, which runs parallel along the fifth metatarsal, is clearly defined (Figure 20) as opposed to its confluence in the external marginal vein (Figure 21).

Figure 20. Deep plexus of the borders. Plantar view. VME: external marginal vein.

Figure 21. Deep plexus of the borders. Lateral view. VME: external marginal vein.

CONCLUSIONS

Applying this anatomical research on the plantar venous sole of Lejars, we made a scheme of incisions respectful of this unique structure, for example, for the drainage of phlegmons and the removal of growths (ganglions, lipomas, etc.) that underlie the subcutaneous cellular tissue, the plantar basal cells and the skin. Therefore, we believe that the best internal approach to the foot is 2 cm from its contact with the floor, more dorsal than plantar (Figure 22). Otherwise, we would section the thickest and most numerous trunks that the plexus has. The best external approach is 1 cm from the contact of the foot with the floor, above the external marginal vein, which is very lateral (Figure 23).

Figure 22. Internal approach of the foot.

Figure 23. External approach of the foot.

Regarding sole incisions, we must respect the medial region and the posterior heel, which is where the plexus is richer in longitudinal and transverse venous branches. As shown in Figure 24, it should be incised above the internal and external marginal veins in order not to damage the thick internal trunks and the thin—but multiple—external branches.

In conclusion, the incisions shown on Figures 22-24 are suggested (always with the same indications), which, respecting the path of the thickest and longest trunks of the plexus, avoid the possibility of damaging the plexus in its critical spots and allow a partially bloodless field.

Figure 24. Plantar approach of the foot.

ANNEX

Venous sole of Lejars in the fetus

In the fetus, it is almost impossible to separate the superficial and deep plexuses, since they are much less vast, have a disordered disposition, and thin and short veins.

The most vascularized and easily observed areas are the posterior heel and the toes (Figure 25), while, in the medial region and the anterior heel, the veins do not have a clear order or direction: they cross and jump out of a subdermal plane to a suprafascial one, deepening after short paths.

Figure 25. Full-term fetus. **A.** Panoramic view. **B.** Image under greater magnification.

In the anterior heel, there is a thick vein that runs from the internal border and the base of the Hallux that, with an oblique direction towards the medial region, is lost towards the deep plane a few centimeters from its beginning (dorsal vein of the Hallux) (Figure 26).

In the posterior heel, we can see how the superficial vessels of the plexus form an anastomosis with the calcaneus branches of the posterior tibialis and how they reach it uninterruptedly. This is the venous bundle that is most clearly observed in the foot of full-term fetuses (Figure 26).

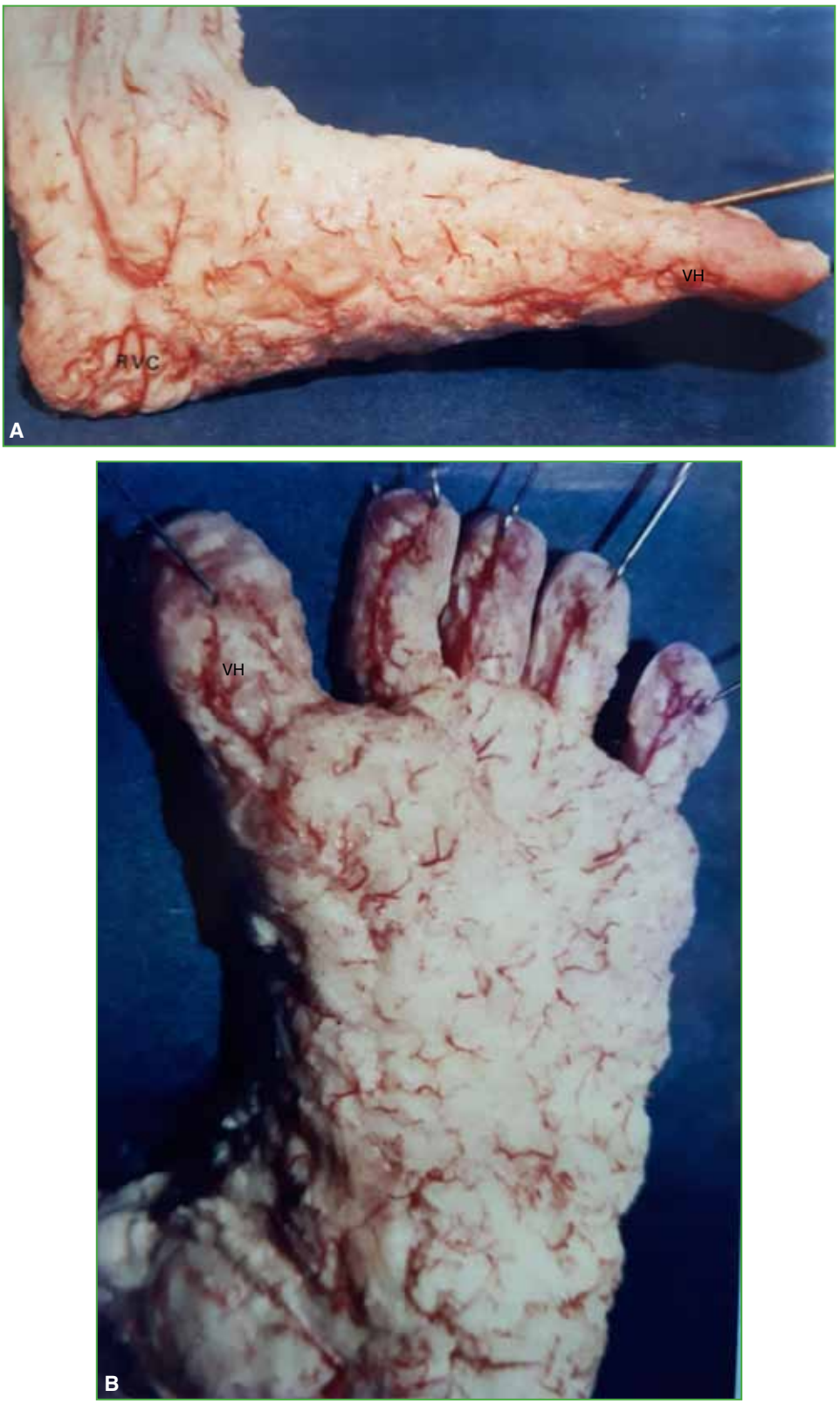

Figure 26. Full-term fetus. **A.** Lateral projection and dorsi-plantar oblique view. **B.** Plantar view. VH: Hallux vein, RVC: calcaneus venous branches.

Five short venous branches, analogous to the deep plexus in the adult's foot, are observed, which can be confused with the rudimentary dorsal venous arch of the foot, located at the same level. The internal marginal vein is not clearly observed; instead, small transverse veins are visualized, which reveals their origin (Figure 27).

At the external border, we can observe, clearly and in the same way as in adults, the origin of the external marginal vein. In proportion, the borders are richer than the sole itself (Figure 28).

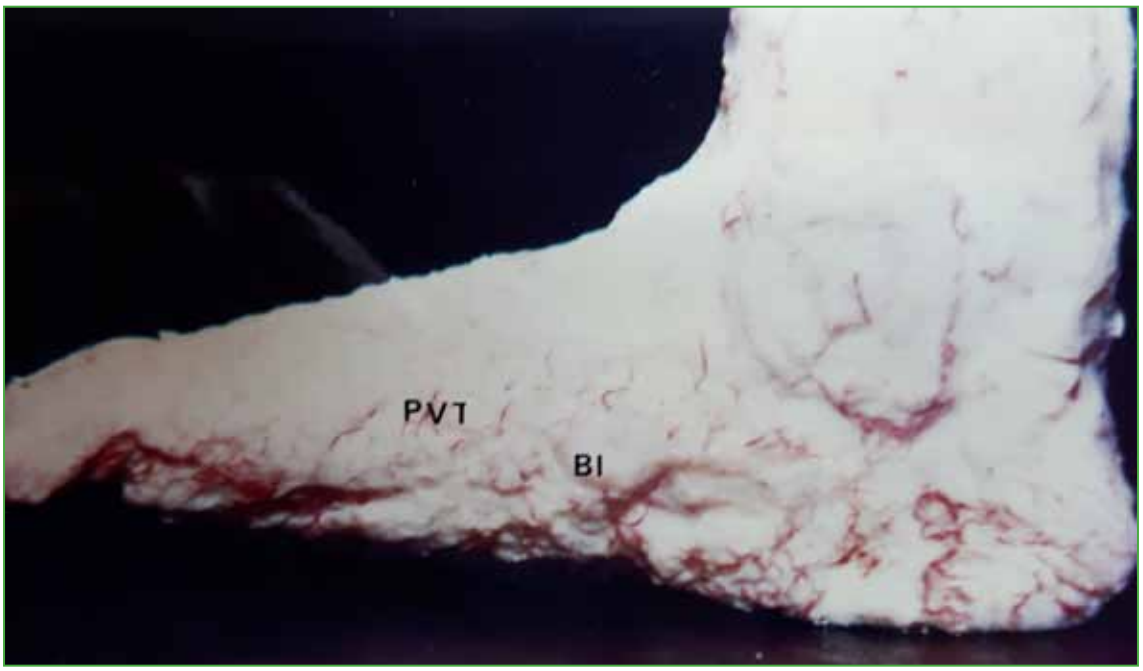

Figure 27. Full-term fetus. BI: internal border, PVT: small transverse windows.

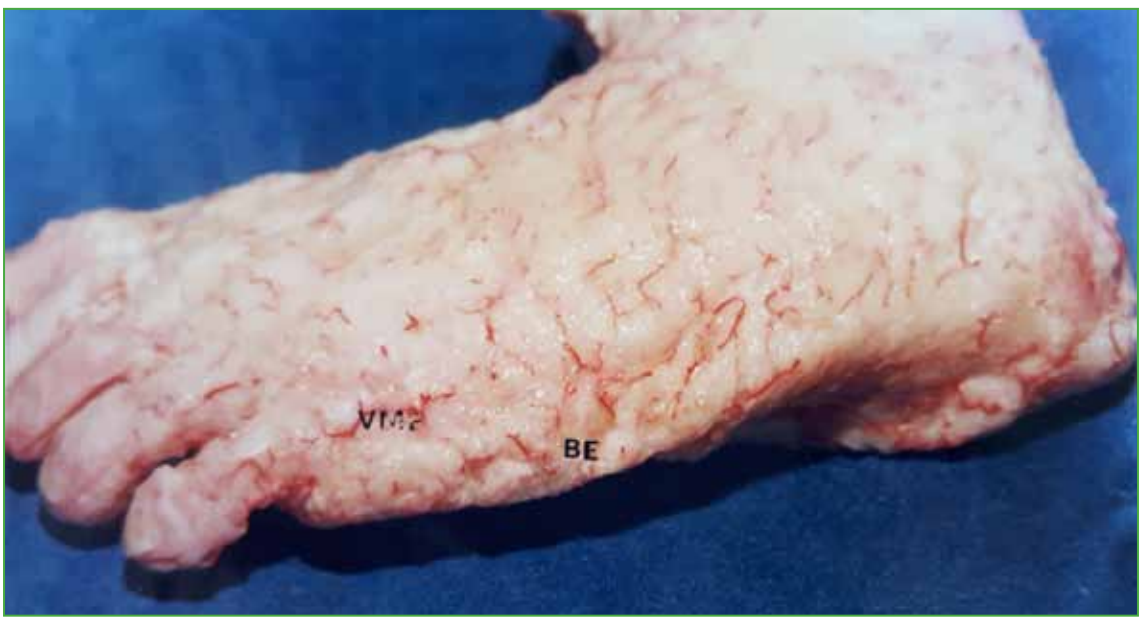

Figure 28. Full-term fetus. BE: external border, VME: external marginal vein.

Up to now and in some preparations, we have observed that the direction of the vessels is slightly transverse in the heel and slightly oblique in the medial region and the anterior heel (Figure 29).

As for the toes, we have observed a considerably thick single vein in each of the last four toes; on the Hallux, we have seen three—a thick internal and two thinner ones—, parallel to each other and oblique inwards. We did not find a venous arch on the base of the toes (Figure 30).

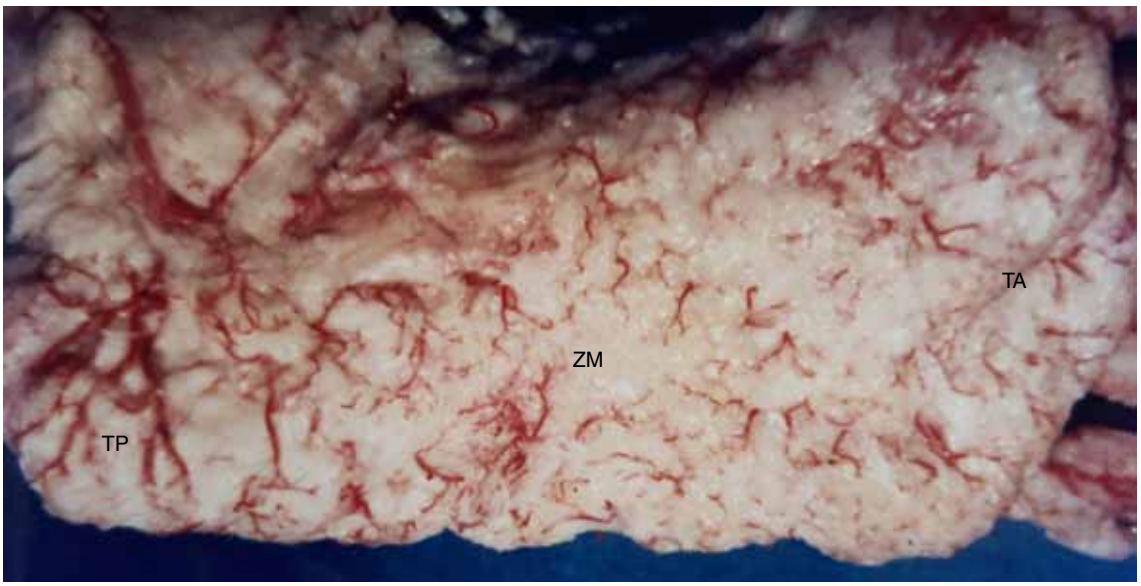

Figure 29. Full-term fetus. TP: posterior heel, ZM: medial region, TA: anterior heel.

Figure 30. Full-term fetus. D: toes, VD: vein of the toe, H: Hallux vein.

Conflict of interests: Authors claim they do not have any conflict of interests.

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