The Microvasculature of the Nail Bed, Nail Matrix, and Nail Fold of a Normal Human Fingertip

Kenjiro Hasegawa, MD, Barry P. Pereira, ME, Robert W.H. Pho, MD, Singapore

The organization of the microvasculature of the dorsal human fingertip based on a vascular corrosion cast was examined using a stereoscopic microscope. The variations of the superficial capillary network of the 3 specialized areas of skin of the dorsal fingertip (the nail bed, the nail matrix, and the nail fold) are described. In the nail bed numerous capillary loops were observed arising from a deeper regular arrangement of sagittally aligned, parallel rows of vessels. The size and direction of inclination of the capillary loops varied, getting longer and more inclined to the nail bed distally, with the longest capillary loops seen at the hyponychium. There were no capillary loops at the nail matrix region, but there was a single, layered, rectangular plexus of capillaries in the plane of the nail matrix. This extended distally to sagittally stretched coils of vessels that straightened out as the nail matrix enters the nail bed region. At the edge of the proximal nail fold the capillary loops looked like fine bristles and were approximately 3 times shorter than those found on the nail bed and hyponychium. This study provides a baseline for future work in understanding the changes in the microvasculature of the dorsal fingertip due to injury or pathology. (J Hand Surg 2001;26A:283–290. Copyright © 2001 by the American Society for Surgery of the Hand.)

Key words: Microanatomy, vascular corrosion cast, dorsal fingertip, nail bed, nail matrix, stereoscopic microscopy.

Within the dorsum of the fingertip there are a variety of specialized skin tissues with different metabolic needs and functions. The hyponychium, nail bed, nail matrix, and nail fold interface with the nail plate, influencing its growth and remodelling. Our lack of knowledge limits our ability to interpret the deficiency of the nail bed repair and its healing process, which are strongly influenced by the vascularity of the underlying tissue. Blood is predominantly supplied to the dorsum of the fingertip from the dorsal branches originating from the palmar digital arteries, which form 3 arcades on the dorsal surface of the distal phalanx. These arcades have vessels supplying blood to the nail bed, nail matrix, and nail fold. Although the digital arteries have been well described and documented, the organization and distribution of the most superficial layer of the capillary network of the nail bed and nail matrix has not been clearly demonstrated. In the nail bed, some have described the superficial microvascular network as an arrangement of linear rows of capillary loops. Others have reported that there are only sagittally aligned capillaries with no presence of capillary loops.

We present a 3-dimensional description of the superficial capillary network of the hyponychium,
nail bed, nail matrix, and proximal nail fold of the human fingertip. This description is based on a vascular corrosion cast of a fresh intact specimen from a posttrauma avulsion injury in a 30-year-old man. The cast was obtained using a methyl-methacrylate resin (Mercox CL-2R-5; Dai-Nippon Ink Co, Chou-ku, Tokyo, Japan) and was examined using a stereo- microscopic microscope (LEICA MZ6; Leica Microsystems, Singapore). This is a basic anatomic study to be used as a baseline for future studies that will allow comparison between the microvascularity of the nail bed, nail matrix, and nail fold of various other pathologic conditions and fingertip injuries.

**Materials and Methods**

An unsalvageable fresh amputation at the proximal third of the proximal phalanx of the ring finger of a 30-year-old man was made available for this study. The proper palmar digital artery was first cannulated (24 gauge) under an operating light microscope and then irrigated with a saline solution to which heparin had been added. Fifty milliliter of the premixed methyl-methacrylate resin was then carefully injected through the digital artery until the veins were filled. A 20-mL syringe was used, applying hand pressure to inject the mixture. To avoid any damage to the dorsal fingertip, handling of the specimen was always at the proximal end. The specimen was secured to and suspended in a colander with no contact to the sides, allowing the specimen to be transferred from one solution to another with minimal motion and contact. The specimen was first suspended in distilled water for approximately 2 to 3 hours at room temperature to allow complete polymerization of the resin.8,9

To dissolve the soft tissue the specimen was immersed in 20% sodium hydroxide for up to 8 hours a day and then transferred to a large 50-L bath filled with distilled water. A suction pump was used to create a low circulatory disturbance in the water to rinse off any loose tissue. A detergent with surfactant was also added to the water bath to aid in washing away the tissue debris. This cycle was repeated daily.

The specimen always remained secured to the colander. Extreme care was taken when moving the colander and the specimen in and out of the various solutions and baths. At approximately the third week the nail was carefully removed to prevent it from collapsing onto the microvascular cast of the nail bed. After the 12th week we began to alternate between immersing the specimen in the sodium hydroxide solution and in a 10% EDTA-4Na salt solution to slowly decalcify the bone. The cycles were

<table>
<thead>
<tr>
<th>Location</th>
<th>Average Length ($\mu$m)</th>
<th>Mean Diameter</th>
<th>Arterial Limb</th>
<th>Venular Limb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyponychium</td>
<td>600</td>
<td>13</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Nail bed</td>
<td>400–550</td>
<td>13</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Midsection</td>
<td>Unable to measure</td>
<td>14</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Nail matrix</td>
<td>Unable to measure</td>
<td>18</td>
<td>(no loops)</td>
<td></td>
</tr>
<tr>
<td>Nail fold</td>
<td>100–200</td>
<td>10</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. The vascular corrosion cast of the amputated ring finger of the 30-year-old man after all soft tissue and bone had been dissolved (5.5 months after initial injury; magnification $\times 3$). The numbered boxes refer to the corresponding figure: Figure 2, hyponychium; Figure 3, nail bed (lateral edge); Figure 4, nail bed (mid section); Figure 5, nail matrix; and Figure 6, edge of proximal nail fold.
repeated until all the soft tissue and bone were removed. The whole maceration procedure required 5.5 months, leaving the resultant methyl-methacrylate resin cast of the microvasculature of the digit free of any debris (Fig. 1).

A stereoscopic microscope with an attached Nikon F3 camera (Nikon Co; Shinagawa-ku, Tokyo, Japan) was used to observed the capillary networks at the nail bed, nail matrix, and nail fold of this human ring finger specimen while it was suspended in distilled water. The colander allowed us to rotate the specimen to obtain the required orientation for viewing the various regions.

Capillary Size Measurements

The vascular cast was used to measure the diameters and lengths of the capillary loops and plexuses of the hyponychium, nail bed, nail matrix, and the edge of the proximal nail fold. Photographs of the cast were taken through a stereoscopic microscope under ×40 magnification with the specimen immersed in distilled water. The photographs were digitally scanned and magnified and the loop measurements were obtained using Adobe Photoshop 5.0 software (Adobe Systems Co; Shibuy, Tokyo, Japan). The mean size (thickness) of the arterial and venular limbs of the capillary loops, together with the mean length of the loops, were determined using samples of 10 capillaries each from 5 random areas. For the nail matrix, the interconnected plexus of the capillaries was because there were no capillary loops present.

Results

Capillary Size

The more distal capillary loops at the nail bed and hyponychium had 2 limbs typically of unequal sizes (Table 1). The larger limb was assumed to be the venular return and the smaller, the arterial limb. The difference in size between the limbs of the capillary loops was less obvious at the midsection and lateral
edge of the nail bed. No capillary loops were present in the nail matrix, but the size of the capillaries in the rectangular planar plexus was similar to the venular limbs of the capillary loops in the lateral edges and midsection of the nail bed. At the nail fold the capillary loops were smallest and the limbs were equal in size.

The microvasculature arrangement and structures of the superficial capillaries in the dorsal fingertip varied along the length of the fingertip (Fig. 1).

**The Hyponychium.** At the hyponychium, which is just beyond the edge of the nail bed (Fig. 2), long capillary loops with single or multiple twists were noted. The capillary loops were all parallel to each other, densely packed, and reclining horizontal to the plane of the nail bed. The limbs of each loop were of different sizes (diameters); the larger limb was assumed to be the venous return (Table 1).

**Nail Bed.** The distribution of capillary loops appeared to be less dense at the lateral edge of the nail bed region just proximal to the hyponychium. (Fig. 3A) The limbs of the capillary loops (Fig. 3B) were wider apart and thinner, and did not end with a twist; however, the limbs were of relatively equal thickness compared with those at the hyponychium. These loops were also parallel to each other, pointing distally, and reclining relative to the nail bed. At the midregion of the nail bed (Fig. 4A), the capillary loops were arranged along equally spaced, sagittally aligned rows (Fig. 4B). The limbs of the loops were noted to be similar in thickness and were observed to be more intertwined to each other compared with the loops at the lateral edges of the nail bed. The loops at the midsection of the nail bed were noted to rise vertical to the nail bed, forming columnar rows. This changed progressively toward the hyponychium, however, where the loops became longer and reclined more horizontally.

**Nail Matrix.** At the nail matrix (Fig. 5A) the capillary networks did not have capillary loops projecting upward and outward, like those seen in the nail bed. Instead, its microvasculature was an interconnected rectangular plexus that stretched out to long capillary coils running sagittally and parallel to each other. The stretched coil arrangement straightened out as it extended distally (Fig. 5B).

**Nail Fold.** The capillary loops at the edge of the proximal nail fold (Fig. 6) were shorter and thinner and appeared to be like bristles, with its limbs having a loose spiral twist around each other.

**Discussion**

The arrangement, distribution, and size of the superficial capillary network with its capillary loops varied for the hyponychium, nail bed, nail matrix, and proximal nail fold. This study provides new understanding of the dorsal fingertip and its microvasculature from a 3-dimensional perspective. Differences in the skin texture at the hyponychium, nail bed, nail matrix, and nail fold can be observed. Each region has been shown to vary in its dermal microvasculature. Differences in capillary size suggest differences in blood flow and blood pressure. Variations in the length and number of the capillary loops suggest differences in surface areas of the loops, which may contribute to differences in metabolism and heat exchange. A difference in the arrangement, orientation, and architecture of the loops and plexuses could be related to the composition of the underlying tissues present in terms of the types of cells present, the nerve endings and innervation and the collagen, and fascia/fat content. These varied arrangements...
of the capillaries could be related to the kind of support required by the tissue in aiding the growth of the nail plate. Variations to any of these structures will contribute to differences in local growth, regeneration, and repair of the tissues as well as to the growth and repair of the nail plate. Trauma or other pathologies affecting any combination of these underlying soft tissues could result in a variety of nail deformities. Current repair techniques are limited in that they do not take into account this variety of specialized skin with its complex superficial capillary network and the interfaces between these tissues. The data presented can fuel further studies of the basic microanatomy to provide more information that would guide the repair and reconstruction of this complex organ called the fingertip.

This work was performed on a normal fingertip with the aim to first understand the baseline normal microvasculature from a 3-dimensional perspective. This will allow us in the future to conduct comparative studies of the microvasculature of the fingertip for other conditions (e.g., in diabetic cases) and injuries.

This study also confirms the findings of Fleischhauer and Horstmann and Wolfram-Gabel and Sick that capillary loops are present in the nail bed. This is important because 2 other studies did not report the presence of capillary loops at the nail bed, which confuses the issue. Inoue, using a vascular corrosion cast, and Flint, conducting a colored latex injection study, previously reported the microvasculature of the fingertip, but neither reported that capillary loops were present, only the observation of straight, sagittally aligned rows of capillaries in the most superficial layer of the nail bed. Fleischhauer and Horstmann and Wolfram-Gabel and Sick, however, based their work on histologic sections of fingertip injected with gelatinous india ink into the digital vessels and their

Figure 3. (A) The vascular corrosion cast of the lateral edge of the nail bed proximal to the hyponychium. (Magnification ×16.) The arrow indicates the magnified view in panel B, which shows a less-dense distribution of the capillary loops with the limb wider apart. The tips of these loops did not have twists at the end. (Magnification ×40.)
findings may not have been conclusive. The results of our study clearly support their findings of the presence of capillary loops at the nail bed. In perspective, however, neither of the reports was wrong. The sagittal alignment of the microvasculature described by Inoue\(^8\) corresponds with the longitudinally running vessels reported by Flint\(^2\) and the reticular network illustrated schematically by both Fleischhauer and Horstmann\(^5\) and Wolfram-Gabel and Sick.\(^7\) This finding also corresponds to the deeper layer of vessels that extended to the capillary loops observed in our study. Although our method is similar to that used by Inoue,\(^8\) our study differs in that the age of the specimen used was very much younger. This difference could have influenced the results, as Ikeda et al\(^9\) reported that variations in the microvascular patterns could change with age. At the nail matrix a more accurate picture of the microvasculature (Fig. 5) supported the findings of Fleischhauer and Horstmann\(^5\) and Wolfram-Gabel and Sick.\(^7\) Both these earlier reports only mentioned briefly that the germinal matrix had a pseudopapillary network, with vessels arranged in 1 plane being parallel to the matrix.

An interesting observation was the presence of the capillary loops. These were found more at the distal tip of the nail bed region, with a greater abundance (approximately 80% compared with the untwisted capillary loops) at the hyponychium (Fig. 2B,C). The mechanism and function of a twisted capillary loop can only be hypothesized.

**Figure 4.** (A) The vascular corrosion cast of the midsection of the nail bed. (Magnification ×16.) The arrow indicates the magnified view in panel B, which shows the equally spaced rows of capillary loops running parallel to the longitudinal grooves of the nail bed. The limbs of the loops were more intertwined with each other. (Magnification ×40.)

**Figure 6.** (A) The vascular corrosion cast of the edge of the proximal nail fold. (Magnification ×16.) The arrow indicates the magnified view in panel B, which shows the bristle-like capillary loops along the edge of the nail fold. (Magnification ×40.)
Figure 5. (A) The vascular corrosion cast of the nail matrix of the fingertip. (Magnification ×16.) The arrow indicates the magnified view in panel B, which shows the planar rectangular plexuses (p) of interconnected capillaries extending distally to form stretched spring-like coils (c), which straighten out as they extend toward the nail bed (s). (Magnification ×40.)
One hypothesis is that the twisted loops provide a stiffer support to the surrounding soft tissue structures, giving support to the distal tip of the nail plate. The twisted loops also could contribute to a greater role in heat exchange, with great sensitivity to changes in temperature given its larger surface area. The other observation was the stretched coils of capillaries, running sagittally and parallel to each other with an absence of capillary loops (Fig. 5B). This pattern could be related to the growth of the nail plate, stretching out the underlying skin in the nail matrix region and the capillaries. The capillary would then have to accommodate to this greater elasticity, which may account for its spring-like coil design.

References