VASCULAR ANATOMY OF THE THUMB AND ITS CLINICAL IMPLICATIONS

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The thumb is the distinguishing character of the human hand. Humans have significantly larger first ray in comparison to other primates which permits better opposition and allows better utilization of the other fingers in different types of grip and pinch finger strength. The opposable thumb has made it possible to apply the superior intellect of human brain. As suggested by the Stone Age tools, opposition of the thumb initiated the humans' attempt to modify the environment to its benefit. The thumb contributes to 40% of hand function[1] and is critical for gripping actions and fine prehension. Hence, appropriate management of thumb trauma as well as reconstruction of thumb is of prime importance for functional rehabilitation of the patient. Hence, a hand surgeon should be well versed in vascular anatomy of the thumb which varies from that of the fingers.

However, dedicated anatomical studies on thumb vascularity have reported varying vascular anatomy and have used inconsistent nomenclature for arteries.[2-10] A consistent terminology for vascular structures of thumb is of paramount importance for appropriate

description. Determination of dominant vascular channels in different anatomical regions is important for prioritizing the surgical approaches. Early studies[11-12] on thumb vascularity were based on cadaveric dissection and were prone to errors. More recent studies have utilized injection of intravascular agents such as Methyl Methacrylate-India Ink[13] combination or blue latex injection[14] which preserve the vascular architecture to a greater extent. This has led to subtle changes in concepts. The venous architecture of thumb has been studied to even lesser extent with our literature search being able to find only one dedicated study.[14]

The arterial architecture of thumb can be understood by separating the vascular anatomy as the Principal Arteries of thumb and the digital circulation.

PRINCIPAL ARTERIES: ANATOMY

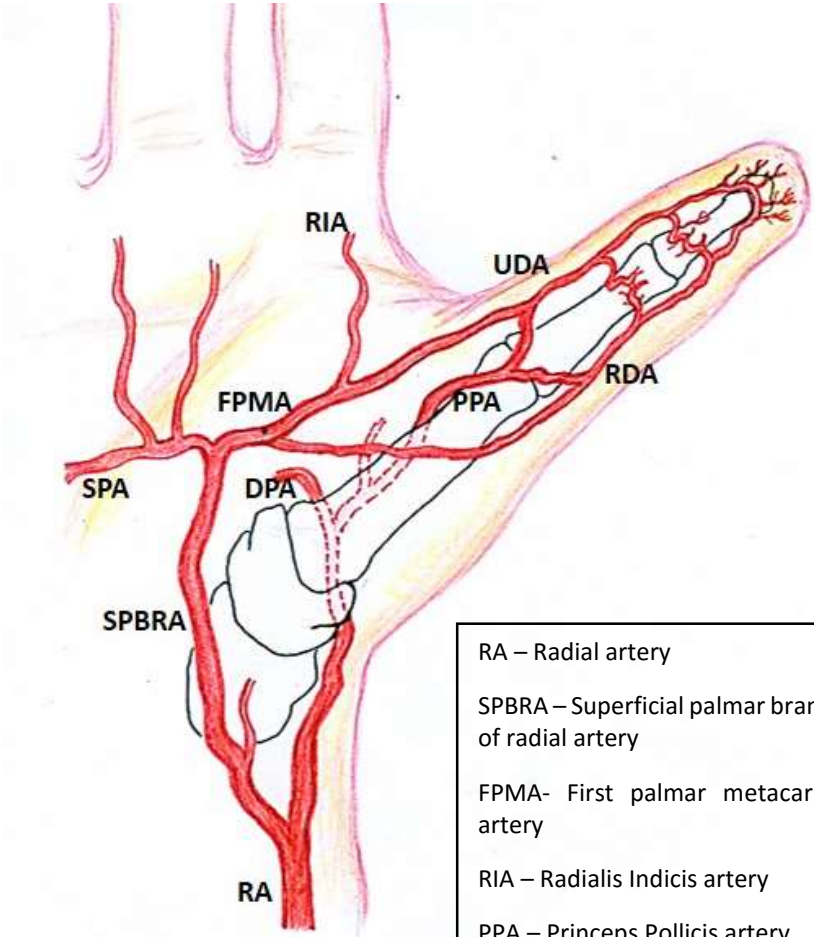
Principal Arteries are the arteries showing least anatomical variation between the cadavers and act as source for digital circulation.

The major arterial supply of thumb is from the branches of the Radial artery with some contribution from Ulnar Artery (Figure 1, 2) through the two main arteries:

1. Princeps Pollicis artery (PPA), a branch of the dorsal radial artery, which constitutes the major blood supply of the thumb through the ulnar and radial digital arteries on the volar aspect and the

ulnar digital artery on the dorsal aspect of the thumb. PPA contributes to both the dorsal and palmar circulation of the thumb. It originates as one of the terminal branches of the radial artery at the bony apex of first web space where it passes deep to first dorsal interosseous muscle to enter the palmar space. It courses along the first metacarpal shaft. At the level of neck of first metacarpal, it gives Dorsal Ulnar Artery branch and turns sharply to lie on the palmar aspect of head of first metacarpal. Then, it bifurcates into radial and ulnar digital branches of the palmar circulation (73.3%) or it may continue as one of the digital arteries (majorly ulnar digital artery). In 20% of specimens, PPA may bifurcate on the dorsal aspect.

2. First Palmar Metacarpal artery (FPMA) arising commonly from Superficial Palmar arch which is formed by anastomosis between Superficial Palmar Branch of Radial artery (SPBRA) and the ulnar artery. Throughout its course, it is palmar to the thenar muscles. Shortly after its origin, it gives Radialis Indicis branch (RIA) and almost immediately bifurcates into radial and ulnar branches which anastomose with the respective radial and ulnar digital branches from PPA to form the respective Radial and Ulnar Digital Arteries.



RA – Radial artery

SPBRA – Superficial palmar branch of radial artery

FPMA- First palmar metacarpal artery

RIA – Radialis Indicis artery

PPA – Princeps Pollicis artery

UDA – Ulnar digital artery

RDA – Radial digital artery

SPA – Superficial palmar arch

DPA- Deep palmar arch

Figure 1: **The palmar arterial system of the thumb showing major principal arteries of thumb.**

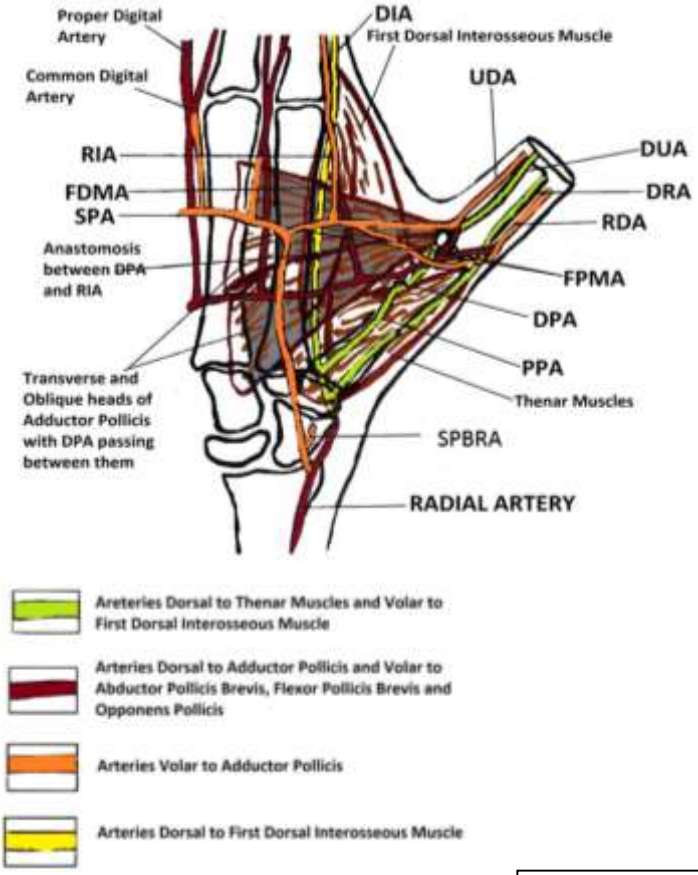


Figure 2 **– Showing complex anatomy of arterial anatomy of thumb in multiple planes.**

The colour of the arteries is depicted with reference to the muscle layers in which they are found in order to help the surgeon to understand at what level of surgical dissection they would encounter the arteries.

DIA – Dorsal Interossei artery

FDMA – First Dorsal metacarpal artery

DUA- Dorsal Ulnar artery

DRA – Dorsal radial artery

PRINCIPAL ARTERIES: CONTROVERSIES

Defining the PPA: There exists an inconsistency in the nomenclature of FPMA and PPA, where some old studies[15] describe FPMA as PPA. Based on this nomenclature, the study by Ames et al.[6] in 1993 suggested that "Princeps Pollicis Artery" has only minor role in the vascularity of thumb bringing the name itself into question. The term should be attributed to the branch of radial artery penetrating into the palmar space at the level of the base of first metacarpal as it was found to have a thicker diameter and more consistent anatomy in a recent study[13] conducted on 30 cadavers using improved technique for preservation of vascular architecture. In this study, the mentioned PPA was present in all cadavers. The mentioned PPA gave rise to dorsal ulnar digital artery in 76.6% cases and was the source of both radial and ulnar digital arteries of palmar circulation in 73.3% cases and the dominant palmar digital artery in rest; justifying the name "Princeps Pollicis Artery".

Origin of FPMA: This artery has also been given other names, including the First Commissural Artery and the Intermetacarpal Artery[16-17]. It is widely reported to originate from the superficial palmar arch. Certain literature including a recent systematic review[18] describes the origin of FPMA from deep palmar arch. This confusion arises due to anastomosis

between the deep palmar arch and Radialis Indicis Artery (RIA) (Figure 3) distal to the distal border of Adductor Pollicis (in a manner similar to the formation of common Digital arteries in second, third and fourth web spaces). This gives a false impression of FPMA originating from deep palmar arch. However, majority of the studies[5-8, 19] including the studies by Ramirez et al[13] describe a vessel from the superficial palmar arch that bifurcates to anastomose with the radial and ulnar palmar digital branches of the PPA.

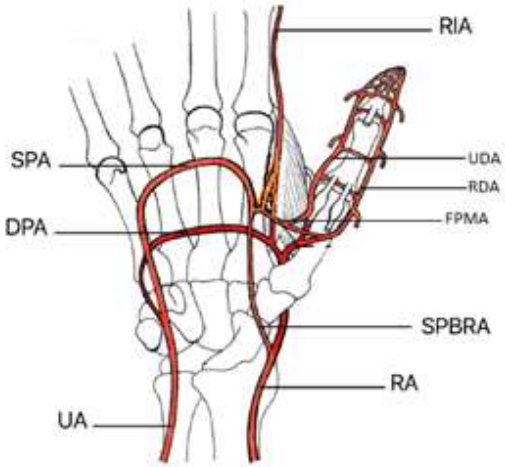


Figure 3 **- FPMA originating from the Superficial Palmar Arch, giving Radialis Indicis Artery which receives communicating branch from Deep Palmar Arch.**

The anatomical variations[20] of SPA aggravate the confusion regarding origin of FPMA. The pattern represented in Figure 1 is present in less than half of the population.

In about one-third of specimens, SPA is completely constituted by Ulnar Artery (Figure 4) with FPMA being the continuation of ulnar artery. In such cases, the FPMA receives a branch from DPA which may give a false

impression of its origin from DPA (the anastomosing branch from DPA inadvertently being labelled as FPMA). However, when the origin of contributing branches to palmar digital branches of thumb is considered, this confusion is cleared.

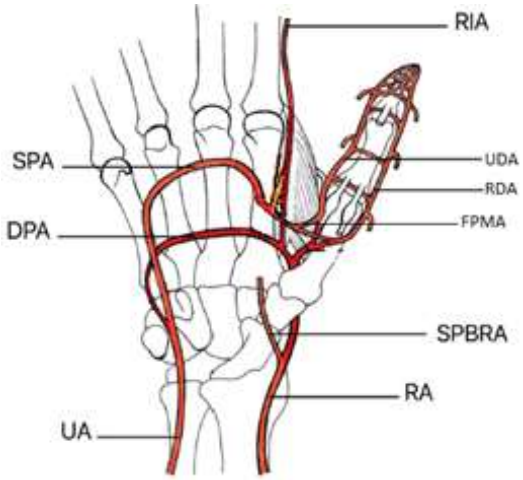


Figure 4 **- Incomplete Superficial Palmar Arch, in which FPMA is the continuation of Ulnar artery (SPA).**

In remaining 15% of cases, SPA is incomplete with Ulnar artery terminating into Common Digital Artery of second web space (Figure 5). In such cases, the FPMA is the continuation of superficial palmar branch of radial artery.

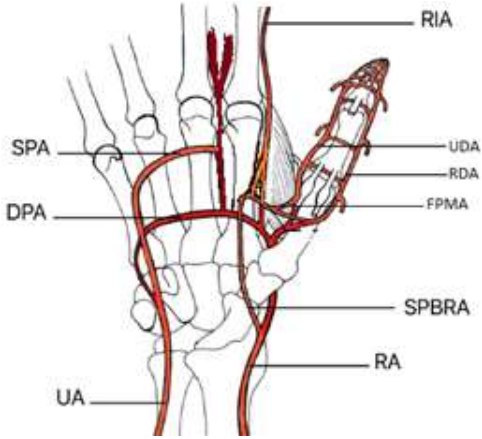


Figure 5 **- Incomplete Superficial Palmar Arch, in which FPMA is exclusively coming from Superficial Palmar Branch of Radial Artery (SPBRA).**

DIGITAL CIRCULATION: ANATOMY

Palmar Circulation:

Ulnar Digital Artery (UDA)

UDA (in five-sixth of the specimens) originates from the confluence of branches of PPA and FPMA (Figure 1 and 2). In 10% of specimens, it originates from the confluence of FPMA branch and an aberrant branch from radial artery, and in the remaining it arises directly from FPMA. The average diameter of the digital artery is 1.1 mm (range, 0.7 to 1.9mm) at the middle third of the proximal phalanx. UDA was found to be consistently present according to various cadaver studies.

Radial Digital Artery (RDA): RDA has the most inconsistent anatomy. RDA most frequently (54% of specimens) originates as a confluence of branches of PPA and FPMA (Figure 1 and 2). In rest of the cases, variable contribution from Superficial Branch of Radial Artery is present (varying

from a minor contribution to being the only component). However, PPA is the major feeding vessel in 87% of cases. The average diameter of the radial digital artery is 0.81 mm (range, 0.4 to 1.8 mm).

Both UDA and RDA follow paths parallel to the tendon sheath of the flexor pollicis longus. In the entirety of this path they are lateral to the digital nerves. The digital arteries terminate to form an arcade at the level of the distal phalanx.

Palmar Anastomosis: There are four levels of anastomoses (Figure 6) on the palmar aspect of the thumb located at the metacarpophalangeal joint, the middle third of the proximal phalanx, the interphalangeal joint, and the arcade formed in the thumb pulp. The anastomosis in the pulp is in an inverted-V form under the fat pads distal to the flexor pollicis longus insertion in the distal phalanx.

There are anastomoses between the dorsal and palmar systems, most frequently on the ulnar side of the finger located at the level of the MCP joint, the middle third of the proximal phalanx, and the distal phalanx.

Small branches arise from the most distal anastomosis and enter the vincula of the flexor pollicis longus tendon, nourishing it at interphalangeal joint.

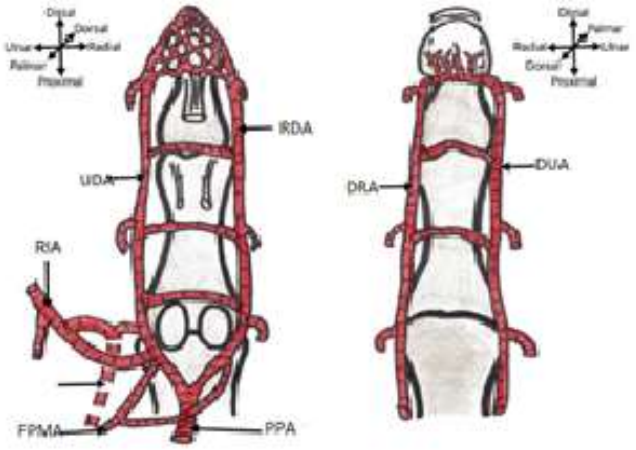


Figure 6 **- Palmar and Dorsal anastomosis at different level.**

Dorsal Circulation:

Dorsal Radial Artery (DRA): DRA originates directly from radial artery (in two-thirds of specimens[13]) at the level of trapezio-metacarpal joint and runs parallel to the extensor pollicis longus tendon (Figure 7 and 8). This artery continues distally up to the distal phalanx, where it forms an arcade with the dorsal ulnar artery. In about one-fourth of the specimens, DRA is present only at the level of distal third of proximal phalanx, being absent proximally and distally. In such cases, the DRA originates as a branch of radial digital artery in the palmar circulation. When complete DRA is present, the average diameter is 0.4 mm (0.1-0.9mm).

Figure 7 **- Dorsal Radial digital artery (DRA) originating directly from the Dorsal Radial artery. Dorsal Ulnar digital artery (DUA) originating from the Princeps Pollicis Artery (PPA) usually seen in 75% cases.**

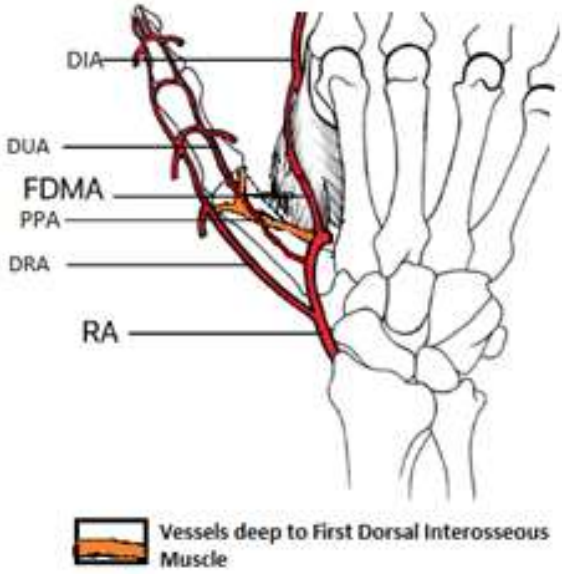


Figure 8 **- Dorsal Ulnar digital Artery (DUA) originating directly from the Dorsal Radial Artery.**

Dorsal Ulnar Artery (DUA): DUA arises as a direct branch of PPA (in three-fourth of specimens) at the level of MCP joint (Figure 7), in the rest it arises directly from radial artery (Figure 8). The DUA continues over the ulnar border of the proximal and distal phalanges parallel to the extensor tendon and terminates in an arcade proximal to the eponychium. The average diameter of DUA at the middle third of the proximal phalanx is 0.61 mm (range, 0.2 to 1.2 mm).

Dorsal Anastomosis: Three levels of anastomosis (Figure 6) are observed between the DRA and DUA. They are at the level of the middle third of proximal phalanx, the interphalangeal joint and the distal phalanx. At the level of distal phalanx, an inverted U-shaped arcade (between 0.3 and 0.7mm vessel diameters) is formed proximal to the eponychium and nail germinal matrix. In cases where the dorsal radial artery is not present, the arcade is formed between the palmar radial digital artery and the dorsal ulnar artery.

DIGITAL CIRCULATION DOMINANCE: Owing to the larger diameter of palmar vessels and inconsistency in the presence of DRA, a palmar dominance in vascularity is present with superimposed ulnar dominance.

CLINICAL SIGNIFICANCE ASSOCIATED WITH VASCULAR ANATOMY OF THE THUMB

Revascularization and Reconstruction of Thumb:

Brunelli and Gilbert[7] divided the thumb into three vascular segments based on the dominance of vessels in different regions as follows (Figure 9):

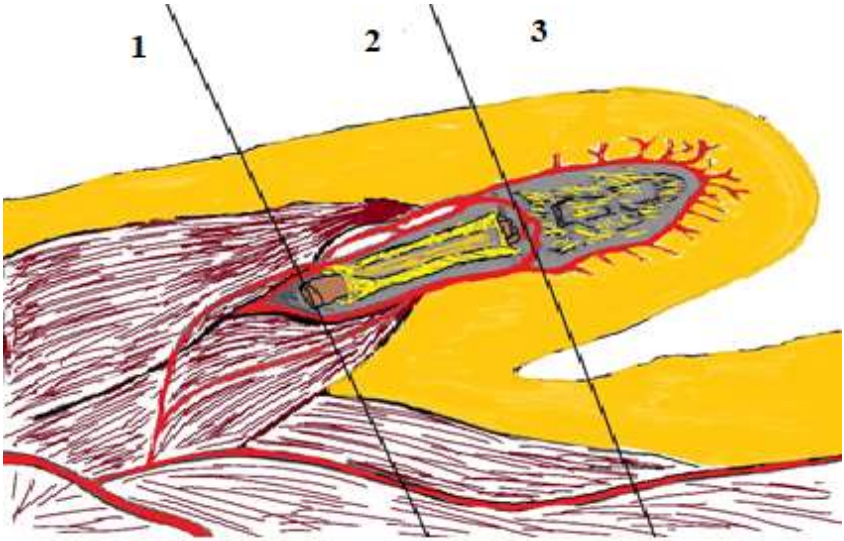


Figure 9 - **Vascular segments of thumb. Musculature in segment 1 results in deep location of arteries of surgical importance in this zone necessitating exploration from dorsal aspect.**

First Segment: It is located between the thenar crease and MCP joint flexion crease. The arteries are located deep especially in palmar aspect.

Hence, exploration and anastomosis are advised to be done from dorsal aspect (first webspace) due to easier approach and dominance of PPA in this region.

Second Segment: It is located between the MCP crease and IP crease. Exploration from palmar aspect along the flexor tendons is advised. Since, the UDA is thicker and consistent exploration and repair of the vessel from the dorso-ulnar aspect of the thumb is recommended. However, in case of inability to locate the UDA, exploration from dorsal aspect for DUA is advised owing to inconsistency in the anatomy of RDA.

Third Segment: It is the pulp segment beyond IP crease. The presence of arcade increases the chances of survival of a lacerated skin flap and hence dedicated exploration for vessels is not necessary in this region.

Difficulty in getting adequate length during Reverse Flow Island Flap: Due to formation of arcade beyond MCP flexion crease and shorter length of thumb in comparison to other digits, gain in the pedicle length of reverse flow island flaps is limited to 6.5 cm in comparison to 10 cm for other fingers.[7]

Autonomous Dorsal Circulation: The presence of independent dorsal arterial circulation in the thumb, as opposed to other digits, has facilitated the ability to raise skin flaps on the volar aspect of thumb based on both the volar digital vessels. The examples of which include Moberg's flap (1-1.5 cm length gain; Figure 10) and its modification by

O'Brien (2 cm length gain; Figure 11) and Elliott (Figure 12). Here in order to advance the volar flap, the skin on the volar aspect is completely separated up to MCP flexion crease without any risk of viability of the dorsal skin.

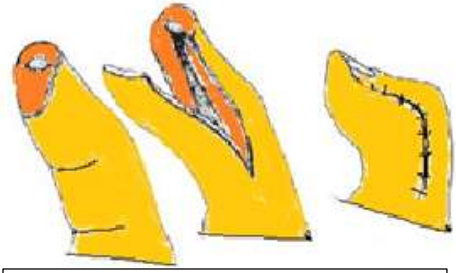


Figure 10: **Moberg's Flap**

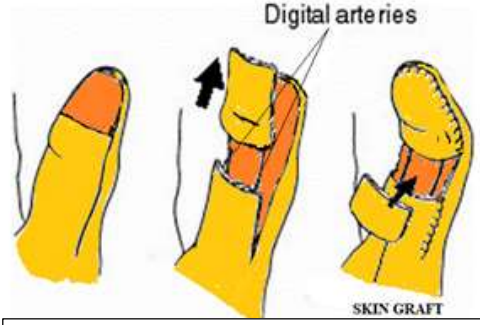


Figure 11: **O'Brien's modification of Moberg's Flap**

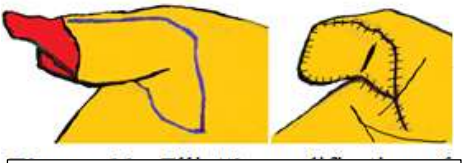


Figure 12: **Elliott's modification of Moberg's Flap**

Figure 10, 11, 12 **– Showing volar flaps and its various modifications elevated on both digital vessels.**

The independent vascularity on the dorsal aspect can also be used to raise reversed flow pedicle flap from the dorsal aspect to cover the defect over volar aspect like Brunelli's reversed dorsoulnar flap (Figure 13) and Moschella's reversed dorsoradial Flap (Figure 14).

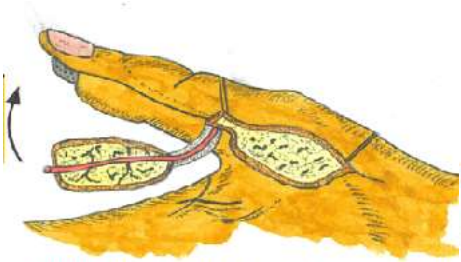


Figure 13: **Brunelli's Reversed Dorsoulnar Flap**

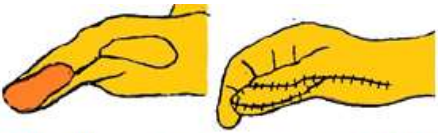


Figure 14: **Moschella's Revered Dorsoradial Flap.**

VENOUS ANATOMY

Dorsal veins: The dorsal system begins with small veins at the distal aspect of the nail sulcus and the eponychial fold which coalesce into four to eight large vessels at the level of the IP joint. At the level of the MCP joint, only two or three veins are present with diameter of 1 to 1.5 mm (Figure 15).

Palmar veins: The Palmar system is not as well developed as the dorsal system and thus not of much surgical importance. Distal to the IP joint, one or two veins of more than 0.5 mm in diameter are present deep within the pulp, beneath a superficial plexus of much smaller vessels connected by numerous small transverse anastomoses. Proximal to the IP joint, these veins start a dorsal course along the radial and ulnar sides of the thumb to communicate with the dorsal system. A transverse vessel at the level of the IP joint is frequently present.

Ulnar veins: The veins on the ulnar side of the thumb are oblique vessels coursing from the palmar aspect proximally to the dorsum. The pattern of these long oblique vessels is inconsistent, with the exception of a vein that is always present in the first web space. This webspace vein ranges between 1 mm and 2 mm in diameter. Its location is variable in the dorsal-palmar plane; but it consistently courses into the webspace, accepting communications from both palmar and dorsal surfaces of the thumb. This vein is very important during replantation and may require anastomosis with vein from the adjacent dorsal web space for establishing outflow.

Radial veins: As on the ulnar side, the radial veins of the thumb have oblique communicating vessels between the palmar and dorsal systems. In almost all thumbs, a very prominent oblique vein originates from the palmar system at the level of the IP joint and proceeds proximally to join the dorsal system.

Figure 15: Dorsal venous anatomy of the thumb

Cross-sectional anatomy: The dorsal veins are present at all levels in thumb whereas large calibre palmar veins may be absent proximal to IP joint level. Hence, venous system shows dorsal dominance suggesting need for exploration on dorsal aspect for establishing venous outflow.

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