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Hand

Cutaneous Perforators and Their Clinical Implications on Intrinsic Hand Flaps: A Systematic Review

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Background: Most hand flaps are local intrinsic flaps because hand perforators are small and fragile. The purpose of this review was to gather anatomical data on cutaneous perforators of the hand and their implications on intrinsic hand flaps.
Methods: An electronic search was performed through PubMed, Scopus, ScienceDirect, ProQuest, and CINAHL in April 2021. The search terms included "hand," "palm," "manus," "cutaneous artery," "angiosome," and "perforasome." Studies were filtered according to the PRISMA flow chart, and critically appraised using the Quality Appraisal for Cadaveric Studies (QUAC) and Appraisal Tool for Cross-sectional Studies (AXIS).
Results: A total of 33 studies were included, of which 20 were pure anatomical studies, 10 combined anatomical and clinical studies, and three imaging-based clinical studies. A total of 643 hands and 406 fingers were included. The dorsal aspect of the hand, the dorsal digits, hypothenar, midpalm, thenar, and dorsal wrist consistently have adequate, closely distributed perforators of small diameters and short pedicle lengths. A series of clinical studies proved the success of elevating local perforator flaps on each of these areas.
Conclusions: The hand contained densely interlinked cutaneous perforators of varying sizes and pedicle lengths. Although some areas of the hand are still unexplored, knowledge on cutaneous perforators of the hand allows the creation of a variety of possibilities for intrinsic hand flap designs. *(Plast Reconstr Surg Glob Open 2022;10:e4154; doi: 10.1097/GOX.0000000000004154; Published online 22 April 2022.)*

INTRODUCTION

Since the 1980s, the works of Manchot, Salmon, Cormack, and others have opened the world's knowledge on arteries of the skin.[1–3] During the same period, Taylor and Palmer proposed a new concept of three-dimensional vascular territories that supply blocks of tissues of the skin, called angiosomes.[4] In 1989, Koshima and Soeda shared that a large skin flap could survive without muscle, based on a single perforator artery to the skin.[5] Two decades later, Saint-Cyr introduced the concept of perforasomes, a three- and four-dimensional arterial vascular territory of a single perforator.[6] These evolutionary findings have been a breakthrough for designing flaps in plastic surgery.

Before the emergence of the perforator concept, conventional skin flaps have been used by surgeons to cover defects for decades. These flaps are based on arteries located between or within the muscles or fascia,[7] supplying not only the skin, but also other tissues in the area. In hand surgery, sacrificing these arteries will risk tissue ischemia on the distal part of the hand. Given this limitation, there is a rigid formula for designing flap dimension and location.[4] On the contrary, perforator flaps base their blood supply from arteries in the subdermal or subcutaneous plexus. They enable more flexibility in harvesting donor areas. Any flap can be raised as a perforator skin

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flap, as long as there is sufficient knowledge on the anatomy of the cutaneous arteries and perforators.[7]

When designing perforator flaps, accurate knowledge on the number of perforators, location, diameter, pedicle length, and reliability is important for successful transfer. Some researchers have investigated the anatomical variations of these cutaneous perforators. However, data are scattered and incomplete. The purpose of this review was to gather anatomical data on cutaneous perforators in the hand and its clinical implication on intrinsic flaps of the hand. It is expected that with more knowledge, perforator-based flaps can be used more often, which give great benefit compared with conventional flaps in hand surgery.

Takeaways

Question: What is the anatomy of the cutaneous perforators of the hand and its clinical implications on intrinsic hand flaps?

Findings: Numerous perforators are found throughout the hand, presented in summary and figures. Although information was scattered, we found studies on the position, diameter, and length of these perforators on almost all parts of the hand, which elucidated the abundance of vessels throughout the hand.

Meaning: With adequate anatomical knowledge, these perforators could be utilized as local or free intrinsic hand flaps.

MATERIALS AND METHODS

An electronic search through PubMed, Scopus, ScienceDirect, ProQuest, and CINAHL was conducted in April 2021 by the two authors. Search terms include “hand” OR “palm” OR “manus” AND “cutaneous artery” OR “angiosome” OR “perforasome.” Search filter was done according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) recommendation (**See figure, Supplemental Digital Content 1,** which displays the PRISMA flow diagram of this study. **http://links.lww.com/PRSGO/C9**.) To maximize the search scope to clinical and imaging-based studies, the terms “anatomy” and “cadaver” were not used.

The two authors assessed and filtered title and abstract, removed duplicates, screened full texts, and found 34 eligible studies. Thirty-three studies that incorporated cadaver dissections were appraised using the Quality Appraisal for Cadaveric Studies (QUAC) tool. One cross-sectional study was appraised by the Appraisal Tool for Cross-sectional Studies (AXIS) tool. One study was considered ineligible, leaving 33 studies suitable to be included in this review.

This review included all studies with human hand subjects, either cadavers or live subjects, with detailed anatomical analysis on cutaneous perforators of the hand. The hand represents the area from the wrist to the fingertips. There was no limitation of publication year. Due to translation limitations, this review excluded studies that are unavailable in the English language. Types of studies included are anatomical, clinical, and observational studies. Data regarding the anatomical position, density, number of perforators, diameter, length of pedicle, and incorporated flap surgeries were extracted and analyzed. These data will give an estimated depiction on the reliability of intrinsic hand flaps.

RESULTS

From 33 studies as shown in Table 1, 20 studies are purely anatomical studies (A),[8–27] 10 studies are mixed anatomical and clinical studies (B),[28–37] and three studies are imaging-based clinical studies (C).[38–40] Most anatomical studies visualize the cutaneous perforators (CP) by dissection, but some used x-ray imaging and casting. There were a total of 643 hand and 406 finger specimens: 601 of the hands were cadavers, and the remaining 42 were live subjects.

Digits

Only one study analyzed perforators of the princeps pollicis artery (PPA) on the palmar side of the thumb.[38] An average of two perforators was found, 70% (11/16) of which were at the distal half of the first metacarpal bone, with a diameter of 1.2 ± 0.4 mm wide and pedicle length of 8.9 ± 4.8 mm. A flap from this perforator can cover up to 80%–100% of a thumb defect. Eight studies (Fig. 1) found perforators on the dorsum of the second–fifth digits. In the dorsum of the proximal phalanx, the number of CPs varies from two to four,[20,22,23,28,29] whereas the middle had two CPs. Interestingly, one study in stillbirth cadaver revealed five perforators.[24] No detailed studies on the distal phalanx and volar digits were found. Most flaps were raised from the dorsal skin of the proximal phalanx, to cover distal defects (Table 3). Braga-Silva[41] and Valenti et al[29] based their skin flaps with rotation point on the proximal interphalangeal joint (PIPJ). Endo et al[28] proposed skin flaps from the dorsolateral side of finger base to cover the distal pulp, with an oblique pedicle path. Larger flaps based on the anastomosis of proper palmar digital artery (PPDA) and dorsal metacarpal artery (DMA) could be raised to cover larger distal defects.

Hand Dorsum

Almost all studies found the first and second DMA to be consistent, and the third and fourth to be less consistent. Omokawa et al[14] reported a 100% incidence of the first–fourth DMAs, and 95% of the fifth DMA. Anastomoses between DMAs with palmar arteries were consistently found in the first–third DMAs, 65% and 40% in the fourth and fifth DMA, respectively.[14] Most authors found perforators from both the DMA and palmar communicating branches on the distal and the proximal side of the hand.[10,27,32,39]

Table 2 shows the varying number of cutaneous perforators found between studies. Some studies[22,23,30] only mentioned the number of perforators near the metacarpophalangeal joint. As seen in Figure 2, more perforators were found on the distal part of the dorsal hand, with each of the proximal, middle, and distal third areas of the hand pierced by at least one perforator.[14,32]

Table 1. Anatomical Study Profile

No.	Authors	Type of Study	No. Hands	No. Fingers	Hand R	Hand L	Subject Data M	Subject Data F	Subject Data Age	Area	Arteries
1	Omokawa et al[8]	A	30							Thenar	SPBRA
2	Al-Dhamin et al[38]	C	8							Thumb	PPA
3	Strauch and Moura[9]	A		141						Digits	PPDA
4	Endo et al[28]	B	19	71							PPDA
5	Braga-Silva et al[20]	A	36	144			16	2	47–76 (58)		PPDA
6	Wolf-Mandroux et al[21]	A	8	26	4	4					PPDA
7	Yang and Morris[22]	A	16				6	2	Av. 69	Digits & dorsal hand	PPDA, DMA
8	Beldame et al[23]	A	7	24	4	3			71–82		PPDA, DMA
9	Valenti et al[29]	B	15								PPDA, DMA
10	Khanfour et al[24]	A	12								PPDA, DMA
11	Quaba et al[30]	B	18							Dorsal hand	DMA
12	Sherif[25]	A	21		13	8	13	1	30–68		First DMCA, RA
13	Omokawa et al[14]	A	20								First–fifth DMA
14	Yoon et al[27]	A	15		10	5					Fourth DMA
15	Yoon et al[10]	A	20		11	9					Fourth inter-MC space
16	Raigosa et al[39]	C	17		8	9					Fourth inter-MC space
17	Liu et al[31]	B	15								Second DMA
18	Nanno et al[40]	C	42						24–56 (37)		Second DMA
19	Liu et al[11]	A	24								Second DMA
20	Facchin et al[32]	B	20		14	6					Second–fourth DMA
21	Oppikofer et al[12]	A	12		7	5					DCBUA
22	Hu et al[33]	B	30		16	14				First web	First DMA, RPDAIF, UPDAT
23	Omokawa et al[13]	A	30		15	15	15	10	44–48	Palm	DPArch, UA, DBAIA
24	Omokawa et al[26]	A	20							Dorsal wrist	Dorsal wrist CP
25	Hu et al[33]	B	30		16	14					
26	Omokawa et al[15]	A	32		15	17	17	15	54–84	Hypothenar	Hypothenar CP
27	Hwang et al[16]	A	18								Hypothenar CP
28	Uchida et al[35]	B	10								Hypothenar CP
29	Toia et al[17]	A	14				8	6			Hypothenar CP
30	Hao et al[36]	B	30				16	14	30–76 (55)		Hypothenar CP
31	Han et al[18]	A	26				8	5	70–99 (82)		Hypothenar CP
32	Pak et al[37]	B	8				2	2			Hypothenar CP
33	Postan and Poitevin[19]	A	20								Hypothenar CP

*A, anatomical study; B, anatomical + clinical study; C, imaging-based study; DBAIA, dorsal branch of anterior interosseous artery; DCBUA, dorsal carpal branch of ulnar artery; DPA, deep palmar artery; DPArch, deep palmar arch; F, feminine; inter-MC, intermetacarpal; L, left; M, masculine; PUAP, palmar ulnar artery perforator; R, right; RA, radial artery.

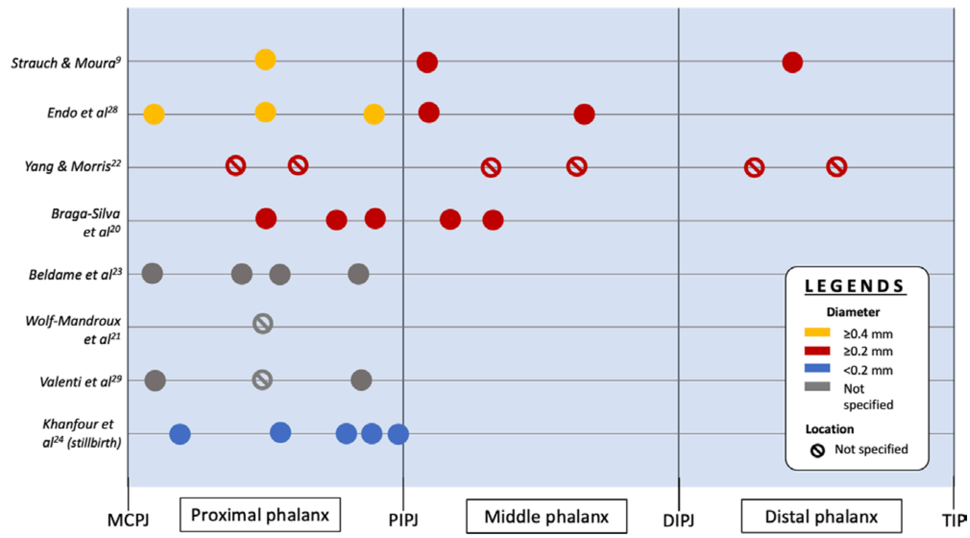

Fig. 1. Perforator location in each phalanx of the second–fifth dorsum digits. DIPJ, distal interphalangeal joint; MCPJ, metacarpophalangeal joint; TIP, fingertips. These perforators arise from PPDA, proper palmar digital artery, with diameters less than 1 mm.

According to a study that discusses all the spaces, the cutaneous perforators of the dorsal hand were equally distributed among the intermetacarpal spaces, with 48% of the perforators found proximal and 52% distal to the juncturae tendinum.[32] In contrast, three studies[10,23,27] found no perforators on the middle third of the hand, proximal from the juncturae tendinum. The average diameter of the perforators ranges from 0.1 to 0.6 mm, without significant difference between the distal and proximal side.[32] All studies that incorporate clinical application only raised flaps on the distal side; although some mentioned that the proximal area is also available for flap elevation.[30–32]

Two studies found that the first DMA divides into three branches (the ulnar, intermediate, and radial branch), but none pinpoints their locations.[25,33] Sherif[25] found one more cutaneous perforator from the artery that supplied the superficial branch of the radial nerve. According to Hu et al,[33] these perforators constantly anastomose with ulnar, intermediate, and radial branches of the dorsal perforators of the palmar artery, the radial palmar digital artery of the index finger (RPDAIF), and the ulnar palmar digital artery of the thumb (UPDAT). This anastomosis would be the basis for flap elevation on either side of the skin. Nevertheless, no studies mentioned exact perforator locations.

Among studies that examined CP from the second DMA,[11,22–24,29–32,40] two studies were conducted by the same author groups.[11,31] The total number of perforators ranges from four to eight branches spread constantly in two clusters (Fig. 2).[32,40] Because the second DMA passes the midpoint of second metacarpus to the second web edge in a slightly oblique manner, they presented the branching perforators' locations in correspondence to this route. Nanno et al[40] found perforator locations by ultrasonography, but did not pinpoint their location. The green circles represent the cluster of perforators most commonly found in their live subjects.[40]

Table 2. Number of Cutaneous Perforators in Each Metacarpophalangeal Space and Its Origin Artery

Author	Main Artery	Average Number of CP	Pedicle Length (mm)
Hu et al[33]	First DMA	3	1.3±0.23
Sherif[25]	First DMA	4	NS
Liu et al[31]	Second DMA	6.6	6.38±1.94
Liu et al[11]	Second DMA	6.4	6.24±1.64
Nanno et al[40]	Second DMA	2.8	NS
Facchin et al[32]	Second DMA	4.2	NS
Facchin et al[32]	Third DMA	2.6	NS
Facchin et al[32]	Fourth DMA	4	NS
Yoon et al[27]	Fourth DMA + PCB	1–3+2	NS
Yoon et al[10]	Fourth DMA + PCB	1–3+1-2	NS
Raigosa et al[39]	Fourth DMA + PCB	2–3+2	NS
Omokawa et al[14]	First–fifth DMA	4–8	NS
Valenti et al[29]	Second–fifth DMA	2–3	NS
Quaba et al[30]	Second–fourth DMA, PCB	1	NS
Yang & Morris[22]	Second–fourth DMA, PCB	1–2	NS
Khanfour et al[24]	DMA (unspecified)	3	5.2±0.7
Beldame et al[23]	LRA	2	NS

*LRA, longitudinal reticular artery; NS, not stated; PCB, palmar communicating branches.

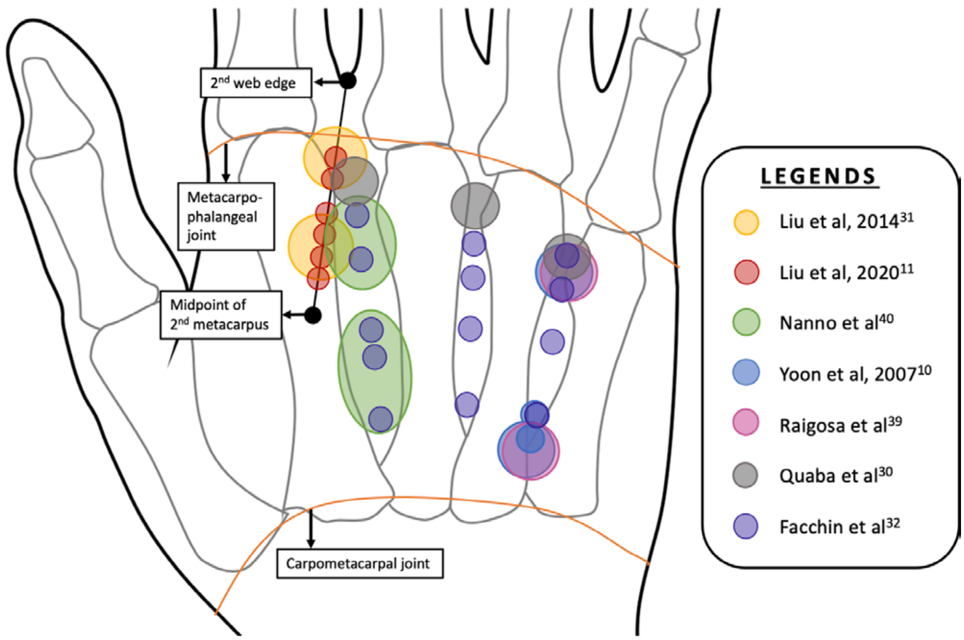

Fig. 2. Dorsal hand perforator locations. Only studies that presented detailed perforator locations were included. The colorful circles and ellipses indicate the area on which at least one cutaneous perforator is most likely found. Their different colors are meant to distinguish results from different studies. Some studies analyzed all intermetacarpal spaces, whereas some analyzed only one space. Areas covered by several different-colored ellipses stacking on top of each other have a higher chance of having cutaneous perforators, as proven by several studies. To depict the location of perforators into this figure, an estimated length of 46, 68, 64, 58, and 53 mm for the first, second, third, fourth, and fifth metacarpus (Buryanov & Kotiuk[67]) was used, respectively.

Although the nature of the third and fourth DMA is often inconsistent, the number of perforators in this space is not significantly different from the other spaces.[22,29,32] When these DMAs were not found, the branches were replaced by direct perforators from the distal and proximal communicating branches of the palmar arteries.[10,27,39] Studies on dorsal hand flaps show clinical usefulness (Table 3). However, all included studies elevated flaps from the distal area of the dorsal hand.

Palm

Figure 3 depicts perforators of the palm, excluding the hypothenar and the digits. The proximal aspect of the midpalm contains a dense aponeurosis and thin subcutaneous tissue, perfused by three to nine perforators with a diameter of 0.1–0.3 mm.[13] The distal aspect contains a loose aponeurosis and abundant subcutaneous tissue, perfused by 8–15 perforators with a diameter of 0.1–0.5 mm. A 50 × 20 mm flap from the distal midpalmar region based on the common palmar digital artery and PPDA perforators, with a pivot point at the PIPJ level, is recommended to cover defects up to the finger pulp. The radial aspect was perfused by 3–6 perforators from the superficial palmar arch (SPArch), with diameter of 0.1–0.5 mm. SPArch perforators on the radial aspect of the midpalm connect with the palmar digital artery of the thumb. This perforator could be the base of radial midpalm flap to cover defects up to the thumb pulp.

The thenar area corresponds to its opposing first web space. The RPDAIF and UPDAT divide into a total of three perforators: one to two ulnar and radial perforators, and an intermediate perforator that anastomose with the ulnar and radial perforators (Fig. 3),[33] with a diameter of 0.6–0.7 mm and a pedicle length of 1–1.2 mm. The superficial palmar branch of the radial artery (SPBRA) supplies the radial aspect of the thenar eminence, branching one to five (2.1 ± 0.3) perforators with diameters of 0.3–1.1 mm (0.6 mm).[8] These perforators have a constant perfusion territory of 40 × 30 mm above the proximal abductor pollicis brevis and opponens pollicis.

The hypothenar skin is supplied by branches from the ulnar artery and the SPArch (Fig. 4).[15,18] CPs in the hypothenar area are numerous, mostly greater than 1 mm in diameter, with a pedicle length of 2–29 mm. Han et al[18] found 7–10 perforators in the hypothenar. Omokawa et al[15] found around three CPs (2–6) consistent perforators that arise from the UPDALF, but did not record the characteristics of perforators from the deep UA or the SPArch. Postan and Poitevin[19] found numerous perforators along the hypothenar, but only mentioned one CP location. Other studies did not examine the entirety of the hypothenar, rather only specific areas of known flap donor sites.[17,35–37] Four clinical studies were performed on different sites of the ulnar aspect of the hand (Table 3), which included distal and proximal hypothenar flaps, and a postero-medial dorsal ulnar flap design, successfully transferred.

Table 3. Clinical Studies from Included Authors

Author	Region	No. CP	Width (mm)	Pedicle (mm)	Clinical Subjects	Flap	Donor	Outcome
Braga-Silva et al[20,41]	Dorsal 1st – 5th digits	5 per digit	0.3 (0.2–0.4)	NS	54 patients, 56 flaps, age 5–60 y (av. 27). Defects on dorsal digits of the middle and distal long fingers, and proximal and distal thumb	Adipo-fascial flap (18×16–42×18mm) from proximal & middle phalanx, based on the 3rd and 4th PPDA CPs, flipped distally. Pivot: lateral PIPJ. The flap was then covered by STSG	DC	Success in all flaps, no necrosis, infection, or remarkable tendon adhesion. 15% loss of skin graft (1), dissatisfied with donor scar (2). Active flexion deficits: 50%–80% deficit
Endo et al[28]	Dorsal digit	5 per digit	0.4 (0.2–0.6)	NS	3 patients. Only 1 case was presented, with a defect on the left ring distal finger pulp	Innervated reverse vascular pedicle digital island flap (size 20×15mm) at the dorsolateral side of finger base (4th digit) based on PPDA CPs	FTSG	Success (1 case). 10 months post-operative: good sensation in flap, moving 2PD = 4mm, recovered full flexion, slight extension lag in DIPJ. (No information on the other 2 cases)
Valenti et al[29]	Dorsal proximal digits	3 per digit	NS	NS	Defect on dorsal distal phalanx of the 3rd digit	Dorso-commisural flap between MCP heads, based on 3rd PPDA CP that anastomose with DMA CPs. Pivot: lateral PIPJ	DC/SG	NS
Quaba et al[30]	Distal third of dorsal hand	1 per intermetacarpal space	0.3–0.5	NS	21 patients, age 9–60 y (av. 31). Defects on the intermetacarpal space (11), dorsal MCP (4), dorsal phalanx (3), distal palm (3)	Skin flap (size 10×15mm up to 90×30mm) based on the distal DMA CP, 5–10mm proximal to MCPJ, distal to JT, taken from the 3rd (11), 2nd (8), and 4th (2) intermetacarpal spaces	3 STSG, 4 FTSG, 14 DC	1 failed, 1 partial loss (venous congestion results in superficial necrosis), 1 tip necrosis (in long flap meant to cover distal palm). In 1 case, venous micro-anastomosis is done to relieve venous congestion
Liu et al[31]	Dorsal distal hand	4–8 per intermetacarpal space	0.42±0.16	6.38±1.94	1 patient, age 30 years. Defect on the dorsal middle and distal phalanx of right index finger	Skin chain-link flap (size 45×25mm) based on 2nd DMA CP + neurorrhaphy. Pivot: 1st cluster (between MCP heads)	DC	Successful. 12 months postoperative, static 2PD = 6.5mm
Facchin et al[32]	Dorsal distal hand	1–3 per intermetacarpal space	0.6±0.27	NS	1 patient, age 35 years, defects at the 2nd–5th dorsal finger	Adipofascial turnover flap based on 2nd–5th distal DMA CPs (size: wrist dorsal crease to distal DMA CPs) (syndactilization) + tendon graft + dermal substitute, then covered with skin graft. Pivot: distal DMA	DC	Full recovery after 3 months, ROM 72%, reduced sensitivity of fine touch on dorsal hand, normal sensitivity on all dorsum phalanx
Hu et al[33]	1st intermetacarpal space	3–5 in palmar, 3 in dorsal	0.1–1.1 (av. 0.73)	0.6–1.9	7 patients, age 30–54 y (av. 42). Defects on proximal dorsal index finger (2), proximal palmar index finger (2), distal dorsal thumb (2), thenar (1)	Skin flap from UPDAT/RPDAIF (size 15×10mm up to 56×31mm). Pivot: 1cm proximal middle palmar crease edge, 1cm proximal thumb palmar crease edge	<1 cm: DC, >1 cm: SG	6 flaps survived, 1 flap for dorsal thumb defect had partial necrosis and healed well after treatment. 2–36 months follow-up: healthy skin color, 2PD +, no contracture on 1st web

Continued

Table 3. *Continued*

Author	Region	No. CP	Width (mm)	Pedicle (mm)	Clinical Subjects	Flap	Donor	Outcome
Hu et al[34]	Dorsal wrist	2–7	0.1–1 (av. 0.45)	0.4–1.4	9 patients, age 5–47 y (av. 24.5). Defects in the dorsal hand	VY-advancement flap (50×28–100×50 mm) based on dorsal wrist perforators. Pivot: dorsal wrist perforator origin	≤3 cm: DC >3 cm: SG	All flaps survive; 3–40 months follow-up: excellent color, texture, satisfactory appearance, normal movement of wrist joint
Omokawa et al[13,54]	Midpalm	14–30	0.1–0.5	NS	15 patients, age 23–68 y (av. 41). Fingertip amputation (10), soft tissue defects (5)	Skin flap (25×15–45×0 mm) from transverse distal mid palm (11) and longitudinal radial mid palm (4). Neurorrhaphy done in 6 cases	DC (12), SG (3)	All flaps survived, no complications. Follow-up ± 4 y. Additional Z-plasties (2) and nail plasty (1). Fingertip atrophy due to bone resorption (1). No pain, joint contracture, cold intolerance. Moving 2PD at innervated flap 6 mm, at non-innervated flap 10 mm
Uchida et al[35]	Distal hypothenar	3–7 (av. 5)	NS	NS	1 patient, 56 y, Dupuytren contracture on left little finger (flexion contracture > 60 degrees) grade 3 Meyerdling Classification	Skin flap (21×38 mm) from distal ulnar palmar digital artery perforator	DC	Successful, after 2 months, contracture improved, no recurrence/complications, good color and texture
Hao et al[36]	Postero-medial dorsum of the ulnar hand	1	0.8±0.2	NS	16 patients, age 17–62 y (av. 31.5). Crush (8), planers (4), explosion (2), burn (2) resulting in little finger and distal hypothenar defects	Skin flap (25×15–60×35 mm) based on the ulnar palmar digital artery perforator. Pivot: 13±3 mm proximal to the 5th metacarpophalangeal joint	DC/SG	All flaps survived, no complications, sometimes there was slight congestion in early postoperative that subsided subsequently. After 7–16 weeks follow-up, color was similar and patients could resume daily activities
Pak et al[37]	Proximal hypothenar	1	0.9±0.15	11.25±1.67	44 patients, age 20–62 y (av. 42.7). Defects on fingertips	Free skin flap (up to 25×35 mm) from palmar ulnar artery perforator for fingertip defects + neurorrhaphy	DC	One had partial loss due to venous congestion. 6 months postoperative 2PD = 5.7 mm
Daniel Postan[42]	Proximal hypothenar	1	NS	NS	1 patient, 50 y. Defect on the volar wrist	Skin flap (width: 20 mm, length: wrist skin fold to MCPJ), based on CBDPA. Pivot: 10 mm distal from distal edge of pisiform. Neurorrhaphy was done	DC + SG	Successful, no complication, complete wrist movements, 2PD before = 6 mm, after 2 months postoperative = 8 mm

av., average; CBDPA, cutaneous branch of deep palmar artery; CP, cutaneous perforator; DC, direct closure; DIPJ, distal interphalangeal joint; DMA, dorsal metacarpal artery; FTSG, full thickness skin graft; MCP, metacarpal; MCPJ, metacarpophalangeal joint; NS, not stated; PIPJ, proximal interphalangeal joint; PPDA, proper palmar digital artery; RPDAIF, radial palmar digital artery of the index finger; SG, skin graft; STSG, split thickness skin graft; yo, years old; UPDAT, ulnar palmar digital artery of the thumb; 2PD, 2-point discrimination.

Wrist

Two dominant groups of arteries vascularize the dorsal wrist; the neurocutaneous CPs from the radial and ulnar arteries, and fasciocutaneous CPs from the anterior and posterior interosseous arteries that pierce the extensor retinaculum.[26,34] The radial, ulnar, and anterior interosseous arteries each give off around two to four CPs to the dorsal wrist. Meanwhile, the posterior interosseous artery gives off two to three CPs, but vascularized only a small area on the distal radioulnar joint. One study found an ascending CP from the deep palmar arch. All these perforators are located approximately 5 mm proximal up to 7 mm distal to the styloid process line.[34] Pedicle length is at an average of 5–11 mm, and diameters at an average of 0.12–0.7 mm. By the aid of ultrasound to locate the perforators, VY-advancement flaps with sizes up to 100×50 mm could be elevated.[34]

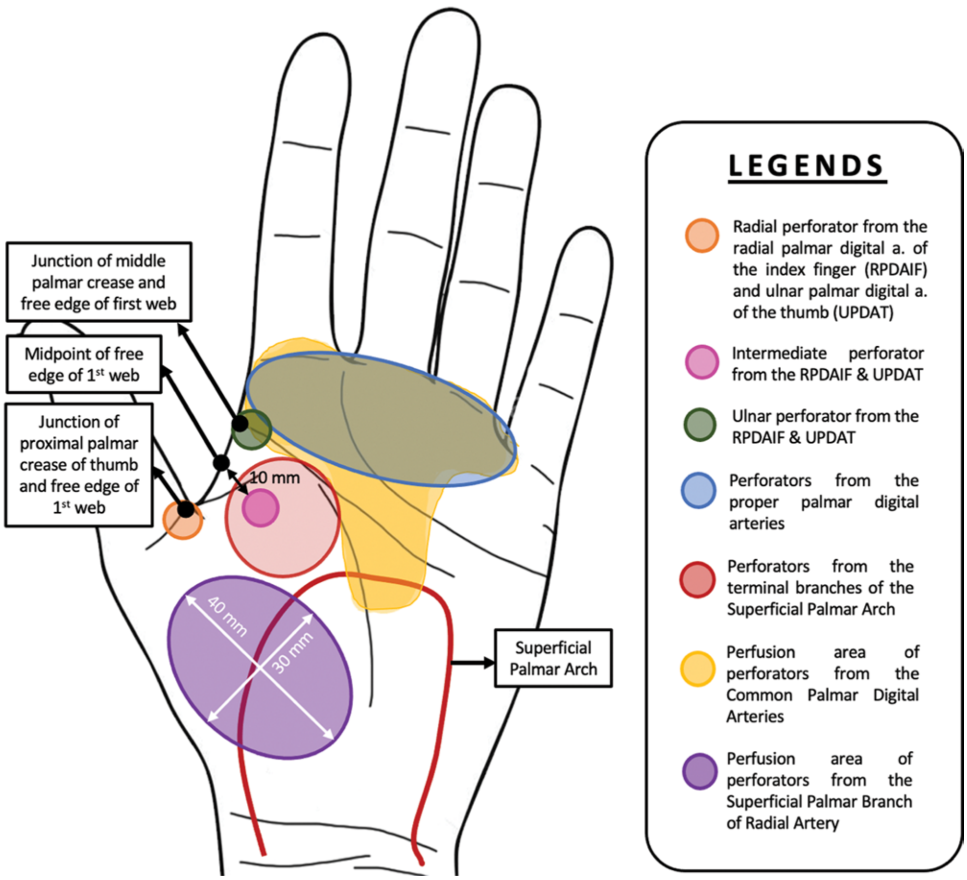

Fig. 3. Perforator locations on the midpalm and thenar eminence. All of the midpalmar perforators shown branched off from the superficial palmar arch. The colorful circles and ellipses indicate the area on which at least one cutaneous perforator is most likely found. Their different colors are meant to distinguish perforators branching from different arteries. Areas covered by several different-colored ellipses stacking on top of each other have a higher chance of having cutaneous perforators. An estimated hand *length* (distal wrist crease to furthest tip of the digits) of 200 mm and *breadth* (distance between lateral edges of the second and fourth metacarpophalangeal joints) of 90 mm (NASA-STD-3000 HSIS Vol I, Section 3[43]), an estimated ratio of finger and palm length of 1:1, and an assumed location of the superficial palmar arch being on the midpoint of the palm (McLean et al, 2008[68]), was used.

Clinical Cases

Among 13 case reports/series from the included articles, subjects range from children to elderly, with various defects, such as laceration, post-excisions, burns, contractures, necrosis, syndactyly, fingertip amputations, and crush injuries (Table 3).

There were a total of 174 patients, and flap sizes from 15 × 10 mm up to 100 × 50 mm. All 58 cases of dorsal digital flaps were successful. One study[28] transferred sensate flaps and achieved two-point discrimination (2PD) of 4 mm, whereas another study[41] recorded a 50%–80% deficit in flexion movements of the digits. The proper digital artery perforator flap is robust to help reduce re-contracture in the dorsal and volar joint area of the finger and thumb, including burnt digits.

Meanwhile, among 39 cases from the dorsal hand flaps (including dorsal wrist), one flap failed, three flaps had partial necrosis, and two flaps had venous congestion. Three studies[31–33] successfully transferred sensate dorsal hand flaps. Only one study raised 15 flaps from the midpalm, and all flaps survived and were sensate with 2PD of 6–10 mm. Three cases required repairs and one underwent atrophy due to bone resorption. There were 62 cases of hypothenar flaps, all of which survived except for one free skin flap, which had partial loss due to venous congestion. Two studies[37,42] achieved sensate flaps with 2PD of 5.7–8 mm. Almost all studies did direct closure on donor sites, split thickness skin graft, or full thickness skin graft when necessary, and one study[28] closed their donor areas strictly with full thickness skin grafts. Although none of the included studies published clinical series on thenar flaps, rich perforators on the thenar skin could be detected by a hand-held Doppler. These perforators arose from the SPBRA and can produce sizeable, glabrous skin that can be utilized as local, regional, or free flaps.[43–45]

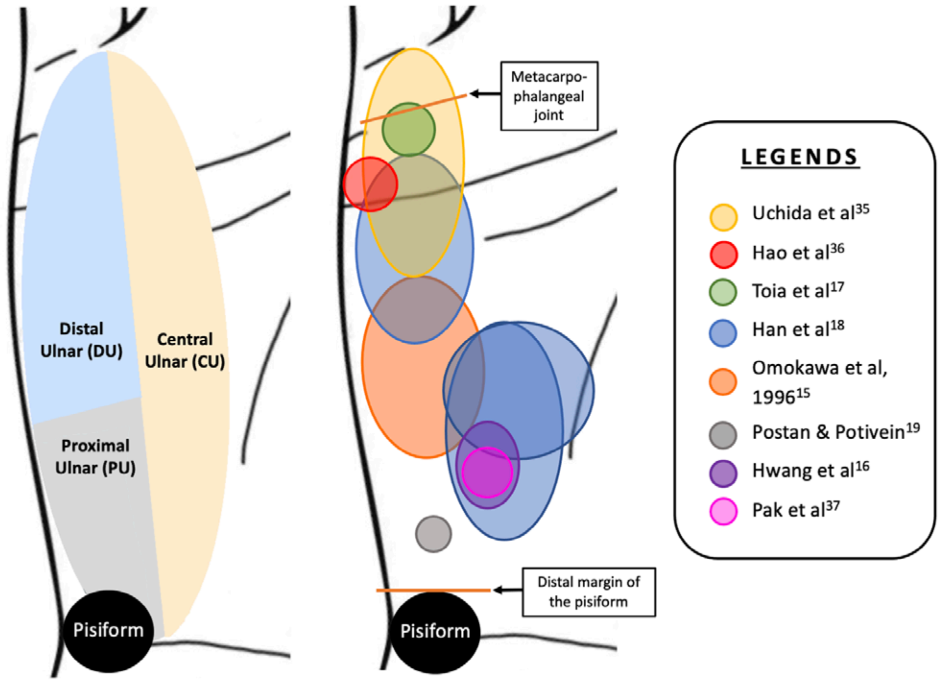

Fig. 4. Left: The hypothenar region divided into three areas. The distal ulnar (DU) area including 40–100% distance from midpoint of pisiform to the volar crease of the fifth digit, the proximal ulnar (PU) including 0%–40% distance from midpoint of pisiform to the volar crease of the fifth digit, and the central ulnar (CU) area on the radial side of the hypothenar. The ulnar palmar digital artery of the little finger (UPDALF) usually runs beneath the ulnar digital nerve branch, pierces the fasciocutaneous layer, and supplies the DU area. Perforators from the superficial palmar arch/common palmar digital artery and superficial palmar ulnar artery (SPUA) that pierce through the palmar aponeurosis supplied the CU area. The deep proximal branches of the ulnar artery (DPUA) pierce the hypothenar muscles and supply the PU area. Right: Distribution of cutaneous perforators in the hypothenar eminence. The colorful circles and ellipses indicate the area on which at least one cutaneous perforator is most likely found. Their different colors are meant to distinguish results from different studies. Some studies analyzed the whole hypothenar eminence, whereas some analyzed only one area. Areas covered by several different-colored ellipses stacking on top of each other have a higher chance of having cutaneous perforators, as it is proven by several studies. An assumed length of 8 cm from midpoint of pisiform to the edge of the fourth web was used.

DISCUSSION

Perforator-based intrinsic hand flaps' popularity has increased due to advantages such as minimal donor site morbidity, thin pliable skin flaps, and possible single stage reconstruction without the need of vessel microanastomosis.[28,41,46] The hand contained densely interlinked cutaneous perforators of varying sizes and pedicle lengths, reliable for intrinsic hand flaps. The dorsal aspect of the hand has been studied frequently and found to have many reliable perforators for flap surgery. Owing to the study by Quaba and Davison[30] that produced the Quaba's flap, the distal third of the dorsal hand is the most favorite site for flap elevation, which is able to cover various defects on the dorsal hand, on distal digits, and even on the distal palm. However, other studies proved that there are constant perforators on the distal, middle, and proximal aspect of the second–fourth intermetacarpal spaces (Fig. 2). Further, the connection between the DMA and the PPDA perforators[29] coupled by the dorsal hand skin laxity enables large flap sizes, up to 90 mm × 30 mm,[30] 80 mm × 55 mm,[46] or more.

Evidently, there is a constant connection between first and third DMA to the palmar arterial system.[14] The third and fourth DMA was known to be inconsistent, and would sometimes be replaced by distal communicating branches from palmar arteries.[10,27,30,39] This consistency of connections between the dorsal and palmar systems would be crucial when raising reverse flaps based on the DMA itself, but when raising flaps based on perforators, the source artery would not be of utter importance. However, there were no clinical studies that raised flaps solely based on perforators from the palmar communicating branches; therefore, its use as flap base is still unknown. Among all studies, only Omokawa et al[14] specifically mentioned the fifth DMA CP in the hypothenar area. However, they did not specifically mention each DMA CP's location and presented them only as means, as did other authors.[24,29,32,40]

Eight studies analyzed perforators in the dorsal digits. All of these studies inspected the proximal phalanx, but there are only four studies on the middle, and two studies on the distal phalanx. These perforators originated from the PPDA on each side of the digit and form a constant anastomosis near the PIPJ and DIPJ. When harvesting donor sites from the MCP heads or proximal phalanges, the anastomosis on the PIPJ became the pivot point.[29,41] Surgeons have been harvesting various digital flaps for decades, mostly focusing on the proximal and middle phalanges.[47] Many have successfully raised island flaps from the proximal and middle phalanx,[46,48–50] and some even raised free flaps from the middle phalanx.[51] Given these facts, with adequate anatomical knowledge and microsurgical skills, the proximal and middle phalanges can be reliable donor sites for flap elevation.

In the palm, the hypothenar is known to be a good flap donor due to its glabrous skin and laxity. As seen in Figure 4, studies found numerous large diameter-perforators throughout the hypothenar eminence. Pak et al[37] and Kim et al[52] performed fingertip reconstructions using free perforator flaps from the hypothenar, elevating it from the underlying fascia or muscle. Omokawa et al[53] performed finger reconstructions using local hypothenar flaps, excising from the fascia. Both authors raised flaps up to 15×45 mm, with 91.7%–100% success rate. Han et al[18] then confirmed the reliability of these perforators, mentioning that the central and proximal ulnar area had a high rate of greater than 1 mm diameter perforators, enabling free flap transfers. Although the distal area seemingly had smaller perforator diameters,[17,18,36] Kim et al[52] successfully combined the proximal and distal ulnar areas to elevate larger free flaps. Furthermore, all the authors made sensate flaps and closed the donor site primarily, adding to the advantages of hypothenar flaps.

Omokawa et al[13,54] studied the midpalm, and found 14–30 CPs from the SPArch, common palmar digital artery, and PPDA with the distal and radial areas containing bigger vessels than the proximal area. The distal and radial parts were successfully raised to cover defects for fingertip amputations and digital soft tissue defects. Kim et al,[45] and Kim and Hwang[55] successfully conducted two clinical studies using the radial midpalmar flap to cover defects on the thumb tips and the first intermetacarpal space.

First web flaps had been utilized for decades to cover defects on the palm.[56] Hu et al[33] successfully raised flaps based on the UPDAT and RPDAIF vessels that connect with the first DMA branches. However, this flap was known to result in donor site flexion contracture, stiffness, and unsightly donor scars. On the other side, the thenar eminence contained even larger vessels, up to 1.1 mm in diameter. Due to their large skin size and bulky nature, thenar flaps have been frequently used for soft tissue reconstruction. Many studies[57–60] have used thenar flaps to cover fingertip defects and amputations and achieve satisfactory outcomes of flexibility, function, and appearance. Yang et al[44] did a more detailed study and found a mean of 2.03 direct CPs around the scaphoid tubercle. They also found that the abundantly vascularized thenar skin was consistently innervated by the palmar cutaneous branch of the median nerve, radial nerve, and lateral antebrachial cutaneous nerve, allowing a reliable sensate glabrous skin flap transfer. Several studies had successfully transferred local thenar flaps based on SPBRA CPs.[61–63]

Flaps raised from the wrist are uncommon. Although the dorsal wrist skin has great laxity, its position and joint function raise the risk of contractures and limit donor size. We found only two perforator studies on the wrist; both found around two to four perforators on the radial, ulnar, and central aspects of the dorsal wrist. VY advancement and reversed island flaps could be used to cover dorsal hand defects.[26,34]

No study regarding the volar side of the digits and the wrist was found. The volar digit is not a popular donor area, as it contains precious highly sensate glabrous skin. The volar wrist, however, is sometimes used as donor area. The fact that this area does not appear in our search algorithm could be due to differences in the term “hand,” taking into account that volar wrist flaps are usually based on arteries branching from the forearm.

There are some limitations in this review. First, the small number of mixed anatomical and clinical studies limits our ability to compare across results. Most of the studies did not mention cadaver genders or specific specimen race. Pham et al[64] found that women had smaller artery diameters than men, and that the Hispanic race had the smallest and the African race had the largest artery diameters. Some authors[23,28,33,35] worked on embalmed cadavers, whereas some others[11,24,34,36,38,39] did not mention whether their cadavers were fresh or embalmed. Formalin fixation is known to denaturalize proteins, resulting in blood clotting, more brittle and rigid tissues, and blood clots that could cause failure of distal perforator coloring.[65,66] Moreover, information on perforator locations were averaged, and some were not mentioned in detail. It is also important to note that the translation of data from studies into figures is the result of approximation from numeric and textual descriptions and lacking three-dimensional aspect. Consequently, there may be differences of perforator location and incidence in clinical settings.

CONCLUSIONS

The hand contains densely interlinked cutaneous perforators of varying sizes and pedicle lengths, reliable as the basis for intrinsic hand flaps. Although some parts of the hand are still unexplored, the knowledge on the anatomical profile of these perforators in each area of the hand will help surgeons in locating and raising flaps. These packed cutaneous perforators open a large window of opportunity in designing various perforator flaps of the hand in the future.

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