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ORIGINAL ARTICLE

Superficial palmar branch of radial artery flap for digital skin reconstruction: anatomical study and clinical applications

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Summary

Background This study investigates the anatomy of the superficial palmar branch of the radial artery (SUPBRA) for palmar skin reconstruction. It aims to detail SUPBRA's anatomical features for hand/finger reconstruction and pinpoint reference points for efficient harvesting.

Materials and methods Nineteen male hand specimens (aged 18–70 years), fixed in 10% formalin, were dissected to study the anatomy of SUPBRA island flap. All measurements such as the external diameter of the SUPBRA, its bifurcation point from the radial artery, length of the SUPBRA pedicle, accompanied by venae comitantes, the number and location of perforators were used analyzed. Two flap techniques based on SUPBRA, the mid-palmar axis and wrist line axis, were studied. SUPBRA flap designs were used in three hand injury cases.

Results The distance from SUPBRA's origin to the styloid process averaged 9.4 ± 1.1 mm, and its mean diameter was 2.4 ± 1.5 mm. It has not been encountered a pattern with a narrow diameter of 1.1 mm or less, which is considered hypoplastic and unsuitable for a flap due to inadequate nourishment, in SUPBRA. Mean length of the SUPBRA pedicle was 31.0 ± 6.3 mm. The SUPBRA was typically accompanied by two vena comitantes. The location of the musculocutaneous perforators, approximately 10 mm distal to the scaphoid tubercle, suggests that when the SUPBRA flap is designed transversely along the distal wrist crease, the direct cutaneous perforators will play a crucial role in providing adequate blood supply to the flap as a pedicle. Flap sizes ranged from 1.5×3.0 mm to 2.5×6.5 mm. To obtain a longer pedicle, the flap was designed with a long-skin pattern along the long-axis direction, and the accompanying veins were dissected proximally to the radial artery. All cases confirmed the SUPBRA flap's viability for microvascular anastomosis in the thenar regions.

Conclusion SUPBRA flap isa valuable option for hand and finger reconstruction,. providing detailed anatomical insights, including its external diameter, bifurcation point from the radial artery, flap length, presence of venae comitantes, and the number and locations of perforators. This flap is particularly suitable for reconstructing palmar defects of the radial digits, palm, and first webspace, and its arterial dimensions and lengths make it well-suited for microvascular anastomosis.

Keywords Superficial palmar branch of radial artery · Palm reconstruction · Finger defect reconstruction · SUPBRA flap · Glabrous skin · Scaphoid tubercle

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Introduction

Reconstruction flap surgery is often employed to address soft tissue loss in the digit and mid-palmar region. This loss may arise from a variety of incidents such as crush injuries, high-energy vehicular accidents, amputations, or animal bites [1, 3, 5, 15, 22]. Plastic surgeons, hand surgeons, and anatomists have shown great interest in finding solutions for soft tissue loss in the hand. The glabrous skin of the thenar eminence provides an excellent color and texture match for defects in the palmar hand and digits. Free tissue from the palm may be based on the superficial palmar branch of the radial artery (SUPBRA) to reconstruct defects on the palmar aspect of the digits (Figs. 1, 2, 3, 4 and 5).

A SUPBRA-based flap provides a 'like-for-like' reconstruction with glabrous skin (Figs. 1, 2, 3, 4 and 5). This non-hair bearing palmar skin is densely connected to the local subcutaneous tissue, and by diverse fascial bands to underlying support structures, making it sufficiently immobile to aid in grip [11, 12, 18]. Previous research reports have highlighted the use of SUPBRA flaps for thumb and index finger injuries [6–8].

The study aims to delineate the anatomy of the SUPBRA flap and to establish the reference points that would facilitate its easy surgical harvesting.

Materials

Study type

This descriptive study involved the dissection of 19 male human cadaver hands, aged between 18 and 70 years, with no macroscopic anomalies detected and no prior surgical procedures performed in the forearm and hand. These specimens, part of the cadaver collection at the Department of Anatomy, Faculty of Medicine, Ege University, are human whole-body specimens that have been preserved in 10% formalin. Additionally, three clinical cases involving a free SUPBRA flap was also included. Ethics approval for the study was obtained from the university's Human Research Ethics Committee (21-6.1T/48).

Methods

Cadaver dissection

Cadaver dissections were performed using the mid palmar axis and the wrist line axis techniques (Figs. 1 and 2) [1, 7, 10]. The colored latex vascular injection technique, which visualizes vascular structures, was used to inject a substance

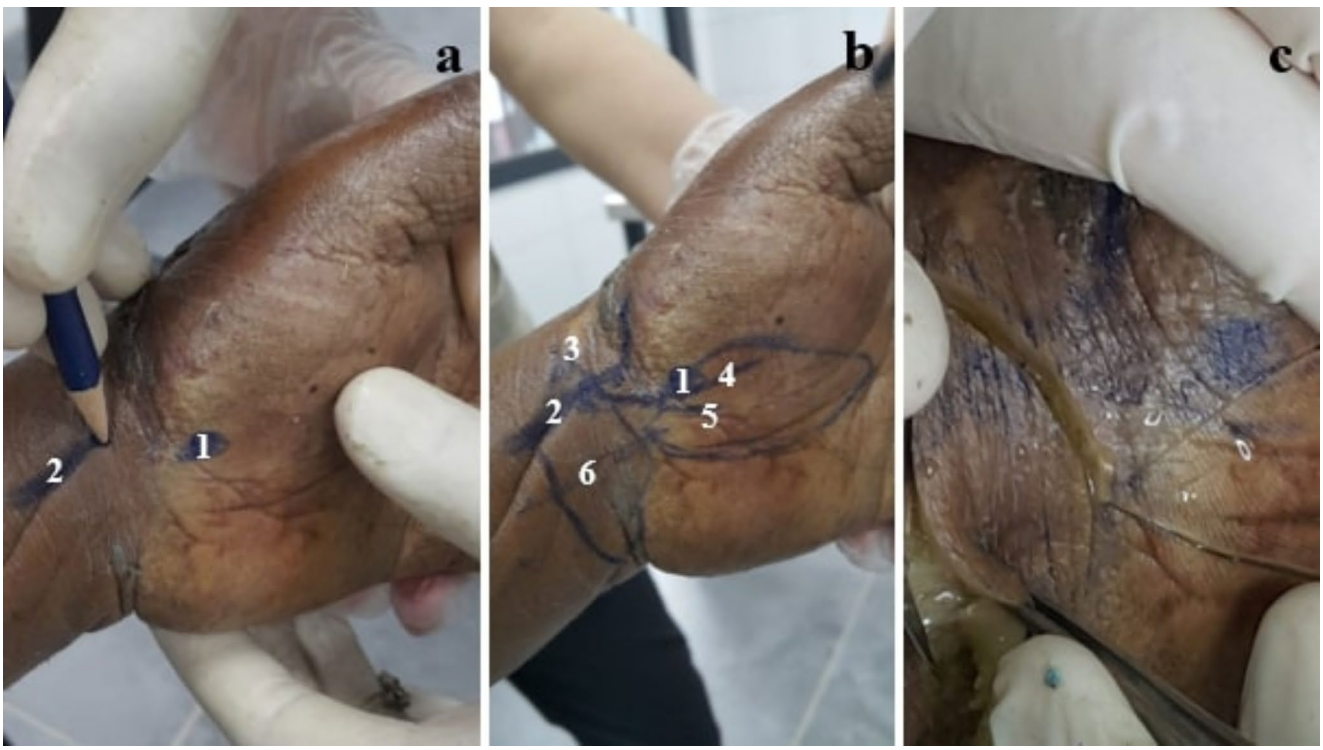

Fig. 1 **a-c**: Mapping the thenar region of the superficial palmar branch of the radial artery flap (depicted as a leaf-shaped drawing) to access the vascular bed using the mid palmar axis technique **1**. Scaphoid tubercle, **2**. Radial artery, **3**. Radial styloid process, **4** and **5**. Superficial and deep branches of SUPBRA **6**. Median nerve, palmar cutaneous branch, **horizontal line on the wrist represent the** paddle flap design on wrist for the finger dorsum

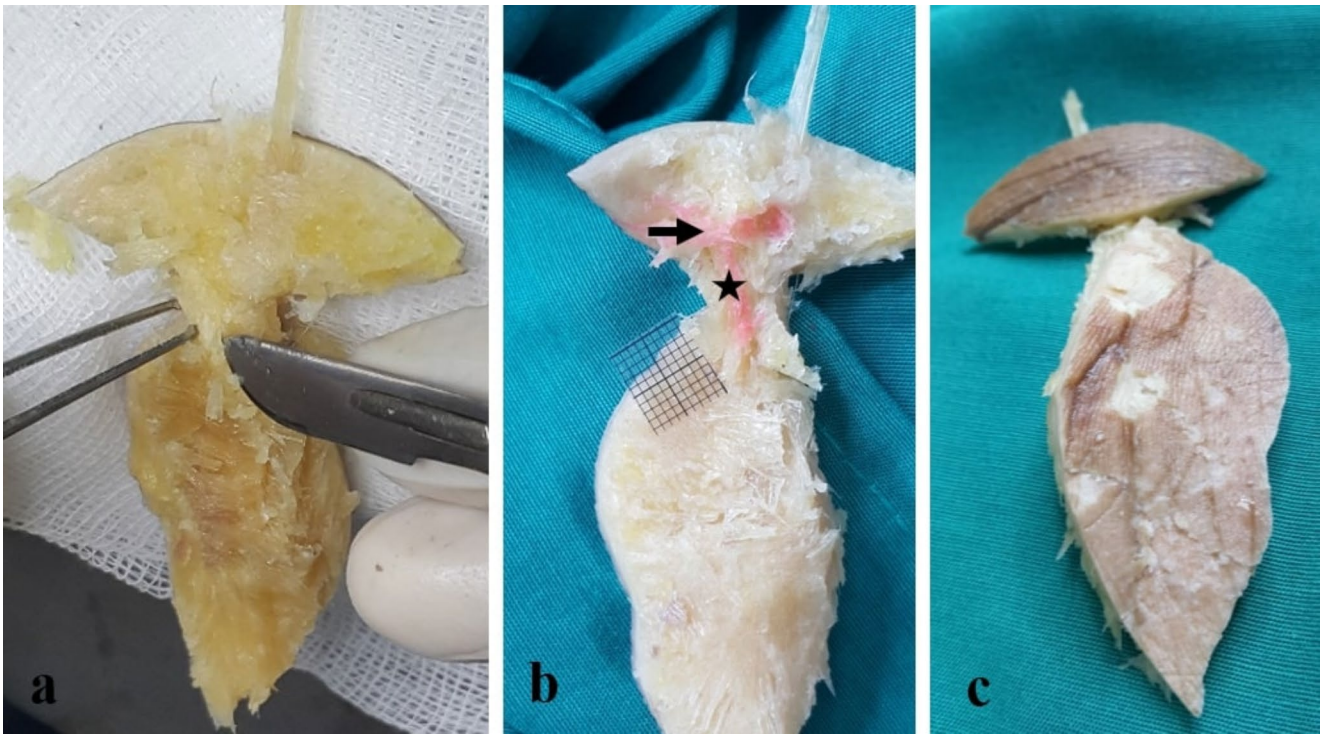

Fig. 2 **a-c**: Detailed view of the SUPBRA pedicle of harvested relative to the mid palmar axis and wrist crease. The superficial and deep branches (**arrow and star**) of SUPBRA are demonstrated as red horizontal and vertical lines, respectively

locally into the artery, clearly revealing the SUPBRA. The size of the SUPBRA, its vascular pedicle, and guide points were determined (Figs. 1, 2, 3 and 4).

SUPBRA flap guide points

Guide points that can be used to obtain the SUPBRA flap were measured by the first author N.K, with each measurement taken three times, and the mean of three results was used in the analysis (Figs. 1, 2, 3 and 4)(Table 1):

- •the external diameter of the SUPBRA.
- •its bifurcation point from the radial artery (the distance from the SUPBRA's origin to the distal wrist crease).
- •length of the SUPBRA pedicle.
- •presence of venae comitantes.
- •the number and location of perforators.
- •the distance between the SUPBRA flap and the first finger.
- •the distance to the superficial palmar arch (SPA) for the mid palmar axis flap.
- •the distance from the SUPBRA's origin until the muscles of the thenar region.
- •the distance from the muscle puncture to the SPA.

Cases

Following the cadaver dissection findings, a SUPBRA flap design was planned for three traumatized hand cases (Fig. 3abc,4abc).

Statistical analysis

Statistical analysis of the data was performed using SPSS version 22.0 software. Comparison of the continuous variables was performed using the independent t-test or the Paired t-test.

Results

Anatomical and vascular details about the SUPBRA are provided in Tables 1 and 2. The distance from SUPBRA's origin to the distal wrist crease or the styloid process averaged 9.4 ± 1.1 mm, and its mean diameter was 2.4 ± 1.5 mm. It has not been encountered a pattern with a narrow diameter of 1.1 mm or less, which is considered hypoplastic and unsuitable for a flap due to inadequate nourishment, in SUPBRA. No hypoplastic SUPBRA was encountered. The SUPBRA passes through the thenar muscles in 56% of cases, anastomoses with the termination of the ulnar artery in 44% of cases, and completes the SPA. The mean length of the

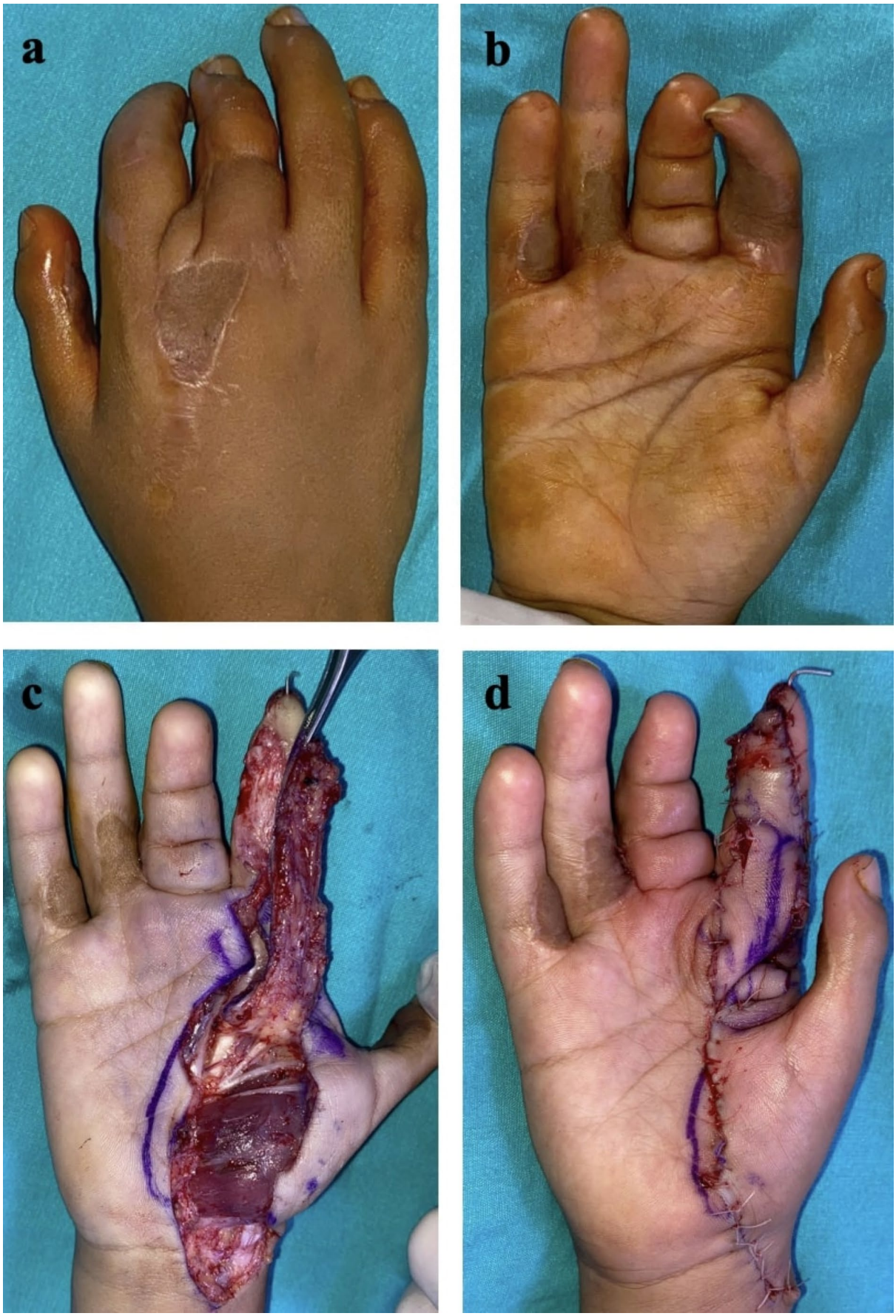
a
b
c
d

Fig. 3 **a.** Bulging appearance was noted in the 1st web space scars from the previously inset grafts, **a-b.** Second finger exhibited ulnar deviation at the distal phalanx, and the third finger showed radial deviation at the distal phalanx, **c.** Elevation of the SUPBRA flap, **d.** Then inset with a radial view showing primary closure of the donor site

SUPBRA pedicle was 31.0 ± 6.3 mm. The SUPBRA was typically accompanied by two venae comitantes.

The scaphoid tubercle should serve as the primary skin surface landmark for cutaneous SUPBRA perforators. All cutaneous perforators were located approximately 10 mm distal to the scaphoid tubercle. The scaphoid tubercle is a blunt, non-articular projection on the lateral edge of the scaphoid bone, easily palpable on the palmar aspect of a wrist that is radially deviated. Including a 15 mm diameter circle around this tubercle in the flap design could eliminate the need for preoperative perforator mapping. It can be accurately palpated on the palmar aspect of the wrist by applying some flexion and radial deviation (Fig. 1).

The SUPBRA flap was harvested using two techniques: the mid palmar axis (Figs. 1, 2, 3c and 4a) and wrist line axis technique (Figs. 2b and 3).

Mid palmar axis technique

The mid-palmar axis technique was utilized to delineate the flap with a palmate leaf or elliptical area of maximum width of 20 mm. This allowed for the complete closure of the traumatized area in a single surgical procedure (Fig. 1a-c). Subcutaneous palmar veins were observed parallel to the SUPBRA's course in the mid palmar axis, approximately 5–10 mm radial to this axis (Fig. 1b). The tissue was cautiously elevated to preserve the SUPBRA flap and subcutaneous vein at the base (Fig. 2a-c).

Both the recurrent motor branch and palmar sensory branch of the median nerve were carefully spared, as the latter could be used for sensory restoration (Figs. 1b, 3c and 4b). It was ascertained whether the distal connection of the pedicle was with the SPA, the first interdigital space, or other vessels of the thumb. The palmar cutaneous branch of the median nerve was predominantly located within the flap. This nerve was observed to originate from the median nerve, 45.6 mm proximal to the distal palmar wrist line, under the palmaris longus and the flexor carpi radialis tendons (Figs. 3 and 4), and innervates the proximal central carpal region and thenar eminence. Typically, in flap anastomosis, vein anastomosis is planned following the initial arterial anastomosis.

By preserving the distal portion of the pedicle and ligation of the proximal, this flap can be elevated in a retrograd fashion. The blood supply to the first web was found to br complex with plentiful anastomoses, which provide the foundation this flap.

The wrist line axis technique, on the other hand, resulted in a flap with an average distance of 25.8 mm from the SUPBRA's origin to the distal wrist crease, with an arterial diameter of 2.4 mm..

SUPBRA flap harvest using the mid palmar axis technique

The diameter of the SUPBRA was observed to be larger than its deep branch. Dissection commenced by identifying the radial artery and SUPBRA as the proximal point with a minor incision in the distal forearm. The SUPBRA was preserved at the flap base, and the radial border of the flap was first incised to create an elliptical shape (Fig. 1bc,2a-c,3c,4ab). The incision was deepened to the fascia above the thenar muscles (Figs. 1c, 2 and 3a and aab), and extended from the proximal half of the ulnar border of the flap to the distal. The flap was elevated with SUPBRA pedicle intact (Figs. 2, 3a and 4a).

Following the puncture of the thenar muscle, the artery's distance to the SPA was 11.8 mm, its diameter was 3.1 mm, and the distance from the origin of the SUPBRA's origin to the distal wrist crease was 9.6 mm (Table 1). The sizes of the SUPBRA flap ranged from 15 × 30 mm to 25 × 65 mm.

Wrist line axis technique

This technique was employed to plan the flap, anchored to the SUPBRA in the distal palmar forearm region, based on the necessary pedicle length (Fig. 2). The flap was drawn transversely at the level of the distal wrist line, and the incision was deepened along the flap margins to the muscles and tendons. One or two vena comitans were secured in the proximal part of the flap for drainaige. The flap could contain the medial cutaneous nerve of the forearm, the palmar cutaneous branch of the median nerve, and the palmaris longus tendon (Figs. 3c and 4a).

SUPBRA flap harvest wrist line axis technique

The mid-wrist line was utilized as the flap's axis. The radial edge of the flap was initially incised to establish the SUPBRA's origin. Dissection proceeded from the ulnar side towards the radial side and distally along the deep fascia, taking care to preserve the SUPBRA pedicle at the base while elevating the flap.

Antecubital propellar perforator

The palmar aspect of the volar wrist, received its blood supply from the two perforators within the radial wrist. Localization of the SUPBRA perforators was demonstrated within

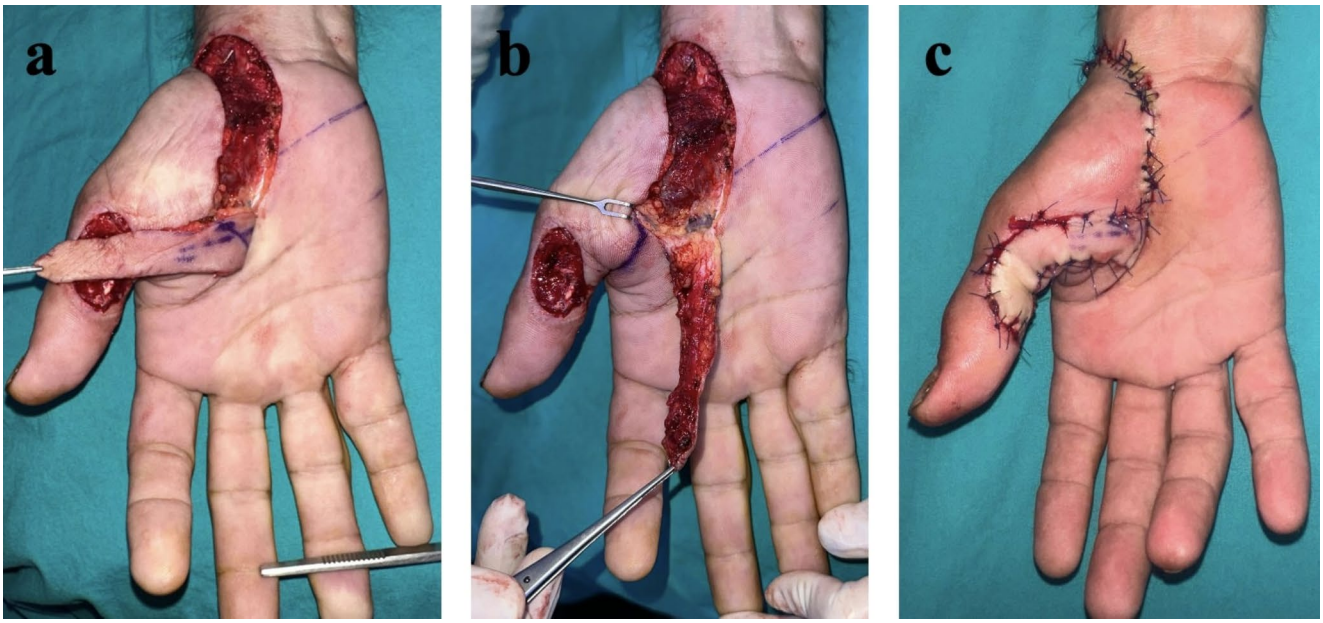

Fig. 4 **a.b.** An elevated reverse SUPBRA flap, **c**. Flap inset into thumb defect with donor site closed

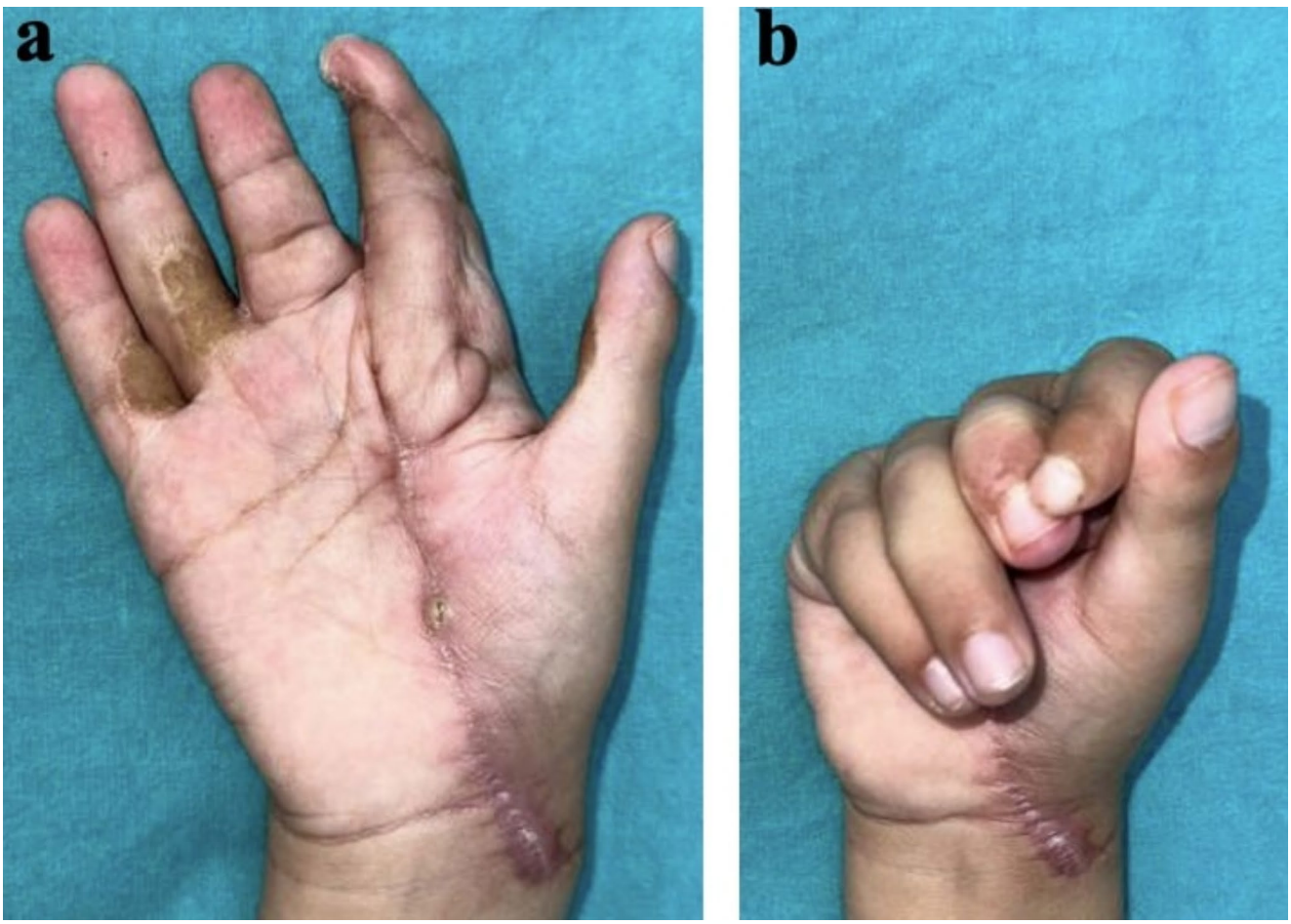

Fig. 5 Post-operative photo of the Case 2 patient showing the healed flap with good colour and texture match and good functional outcomes. **(a)** The deviation curvature of the second and third fingers was corrected. **(b)** Restricted movement of fingers has been corrected

Table 1 Measurements of the arterial anatomical information for creating flap as superficial palmar branch of the radial artery (mm)

Measurements	Right side	Left side	Total
The external diameter of the SUPBRA	2.4 ± 1.5 (0.9–4.40) mm	2.4 ± 1.4 (0.9–4.30)	2.4 ± 1.5 (0.9–4.40) mm
Distance from the origin of the SUPBRA to the distal wrist crease	9.4 ± 1.2 (8.7–10.4) mm	9.4 ± 1.1 (7.9–11.1) mm	9.4 ± 1.1 (8.7–11.1) mm
Length of the SUPBRA pedicle	31.6 ± 7.1(23.2–40.0)	30.9 ± 6.1 (22.2–40.0)	31.0 ± 6.3 (22.2–40.0)
Presence of venae comitantes	2	2	2
The number of perforators	Mean 2 (1–3)	Mean 2 (1–3)	Mean 2 (1–3)
The location of perforators	Around scaphoid tubercle	Around scaphoid tubercle	10 mm distal to scaphoid tubercle
Distance from the thenar muscle puncture to the superficial palmar arch.	11.8 ± 1.6 (10.1–13.3) mm	11.8 ± 1.5 (10.2–13.1) mm	11.8 ± 1.6 (10.1–13.3) mm
Distance from the origin of the SUPBRA until it pierces the thenar region muscles	18.6 ± 1.2 (17.3–20.5) mm	18.5 ± 1.4 (16.8–20.4) mm	18.5 ± 1.4 (16.8–20.5) mm
Distance to the superficial palmar arch for the mid palmar axis flap.	62.1 ± 1.2 (60.1–63.4) mm	61.2 ± 1.3 (59.9–62.4) mm	62.1 ± 1.2 (59.9–63.4) mm
The distance between the SUPBRA flap and the first finger.	65.4 ± 10.8 (62.3–78.5) mm	66.1 ± 11.2 (62.4–77.5) mm	66.2 ± 11.2 (62.3–78.5) mm

superficial palmar branch of the radial artery. $p > 0.05$

Table 2 Comparison of studies: anatomical information about the SUPBRA and details of its flaps

	Omokawa-1997	Yang-2010	Chi-2016	Ilic-2018	Radunovic-2018	Linh-2021	Present study
Material	Fresh frozen cadavers/silicone rubber compound injection	Fresh frozen cadavers/silicone rubber compound injection	Fresh frozen cadavers/red latex injection	Formol-injected dissected hands	Formol-injected dissected hands	CT angiography data of living body	Formalin-fixed cadavers
Anatomical information about the SUPBRA (mm)							
Diameter	Mean, 1.4	1.49 ± 0.46	1.50 ± 0.327	2.9 ± 0.34 (2.4–3.5)	2.01 ± 1.03 (0.55–4.30)	1.12 ± 0.43	2.4 ± 1.5 (1.1–4.30)
Bifurcation point from the radial artery	Mean, 17. proximal to the distal wrist crease	11.56 ± 4.32 proximal to the radial styloid process	12.52 ± 4.97 proximal to the radial styloid process			13.17 ± 8.2 proximal to the radial styloid process	9.4 ± 1.1 (7.9–11.1) proximal to the distal wrist crease
Length of pedicle	N/A	30.85 ± 6.07	31.64 ± 7.086			N/A	31.0 ± 6.3 (22.2–40.0)
Anatomical information about the SUPBRA perforators							
Number	1–5 in the radial wrist and hand	Mean, 2.03 in the radial wrist	≥ 2 in the radial wrist			1–2 in the radial wrist	Mean 2 in the radial wrist
Location	N/A from scaphoid tubercle	Around scaphoid tubercle	Around scaphoid tubercle			Inside a circle 16.4 mm in diameter	inside a circle 15 mm diameter around scaphoid tubercle
Diameter, mm	N/A	0.58 ± 0.26	N/A			0.62 ± 0.11	10 mm
Branching pattern	N/A	N/A	DC:93.33 MC: 76.67 neither, 6.67			DC:77.5; MC:22.5	DC:79.2 MC:34.8
Length, mm	N/A	N/A	N/A			6.43 ± 3.54	
Vena comitans							2 (1–3)

CT, computed tomographic; SUPBRA, superficial palmar branch of the radial artery; N/A, not applicable; DC, direct cutaneous perforators; MC, musculocutaneous perforators

a 15 mm diameter circle around the scaphoid tubercle. This provides the basis for a distal volar antecubital flap which is perfect for defects at the dorsal side of fingers, as well as web spaces due to its thinness, lack of hair, and glabrous subcutaneous bulk (Fig. 2). The palmar artery provided and formed a constant anastomosis with the medial branch of the first dorsal metacarpal artery, nourishing the dorsal skin of the first web (Fig. 24b).

Landmarks

The origin of the SUPBRA should be located 10 to 20 mm proximal to the radial styloid process. Landmarks for forming the thenar cutaneous perforators were started from the scaphoid tubercle and thenar crease proximally, extending 15 to 20 mm towards the ulnar side (Figs. 3c and 4ab). Yang et al. reported that before the SUPBRA penetrated the abductor pollicis brevis, it consistently bore perforators around the scaphoid tubercle that passed directly to the dermis. Subcutaneous tissue surrounding the perforator was preserved to protect the two venae comitans.

The proximal central carpal and the palmar aspect of the thenar eminence are innervated by the palmar cutaneous branch of the median nerve. The palmar cutaneous branch of the median nerve bifurcates from the radial side of the median nerve from 41 to 84 mm proximal to the distal wrist crease and traverses between the flexor carpi radialis and palmaris longus muscles deep to the antebrachial fascia. It then penetrates the flexor carpi radialis sheath, on average, 15 mm proximal to the scaphoid tubercle. The consistent anastomosis between the dorsal perforators of the palmar artery and branches of the first dorsal metacarpal artery formed the anatomical basis for the design of the pedicle reverse flap (Figs. 3c and 4b).

Case examples

Case 1 A 54-year-old manual laborer with a chainsaw injury arrived at our plastic surgery unit with a palmar digital defect measuring 60 × 20 mm, extending from the metacarpophalangeal joint to the distal interphalangeal joint and exposing the flexor tendons. A zone 3 flexor tendon injury was treated elsewhere.

Case 2 A 7-year-old male child, with a history of an electric burn on the right hand's first finger due to contact with an electric cable, was previously treated with debridement followed by reconstruction using a 2nd dorsal metacarpal artery flap + full thickness skin graft (Fig. 3ab). Post-reconstruction, the patient was referred to our department due to burn contractures on the right hand. On examination, the interphalangeal joint of the right hand's first finger displayed limited flexion (Fig. 3ab). Scars from the previously inset grafts were observed on the volar aspect of the proximal phalanges of the right hand's 2nd to 5th fingers (Fig. 3ab). Bulging appearance was noted in the 1st web space on the dorsal aspect of the right hand (Fig. 3a). The right hand's second finger exhibited ulnar deviation at the distal phalanx, and the third finger showed radial deviation at the distal phalanx (Fig. 3ab).

Case 3 A 43-year-old male patient presented with a tissue defect on the flexor and volar aspect of the proximal phalanx of the right hand's first finger, resulting from a work accident two months prior, where a steel plate had fallen onto his hand (Fig. 4).

Subsequently, a free SUPBRA was planned for reconstruction.

Our results collectively suggest that the SUPBRA flap can be designed and harvested more safely by adhering to the following guidelines. First, when planning an SUPBRA flap, the scaphoid tubercle should be used as the key skin surface landmark for locating cutaneous SUPBRA perforators. This tubercle is a blunt, non-articular projection located adjacent to the hollowed capitate facet on the lateral edge of the scaphoid bone. It can be accurately palpated on the palmar aspect of the radially deviated wrist by applying some flexion and radial deviation, which causes the flexor carpi radialis muscle to become prominent; this muscle can then be followed to where it passes over the tubercle, allowing the bony prominence to be felt.

The origin of the SUPBRA is located 10 to 20 mm proximal to the radial styloid process, where it bifurcates. As a propeller flap, it addresses the loss of tissue situated on the radial side of the palm, on the index and middle fingers, or it can also be utilized to open the first web space or to cover defects in that area (Fig. 1bc,3,4).

No complications observed after this flap, and complete closure of the wound was achieved. While the palmar wound healed, the digital wound resulted in a defect, exposing the flexor tendon structures (Fig. 5ab). Postoperative examination conducted two months after a free SUPBRA flap transfer demonstrated that nearly full range of motion had been achieved, along with complete coverage of the defect (Fig. 5).

Discussion

Numerous surgical techniques have been proposed to accomplish success in hand and finger reconstruction surgery [1, 16, 17, 29]. Flap coverage is necessitated by defects including the thumb, the index finger, the palm, the middle

finger, and the first and second webspace, in descending order of frequency [2, 15, 23, 24]. This study explored the anatomical extraction techniques of SUPBRA, which play a crucial role in the vascular structure of the hand, and SUPBRA flap structure, which can be employed in hand traumas involving potential tissue loss (Figs. 1, 2, 3, 4 and 5) [29,25,32].

Cadaveric studies have also reported that the SUPBRA bifurcates from the radial artery on average at 17, 13.2, 12.52, and 11.56 mm proximal to the distal wrist crease or the radial styloid process [9, 16, 23, 28] (Table 2). Previous researchers measured that the mean diameter of the SUPBRA at its origin was 1.4 mm, 1.50 mm, 1.67 mm, and 1.55 mm, respectively [2, 9, 19, 29]. Our study findings are consistent with these reports (Table 2).

The incidence of the SUPBRA with a diameter exceeding 2.00 mm (mean 2.4 mm) was reported to be 16.7% of hands, or according to Bilge et al. 14% [8, 12]. Based on the examined material, Ilic et al. concluded that a SUPBRA with a diameter less than 1.7 mm was locally branching within the thenar area [9]. In those cases, both groups noted the dominant supply to the thumb and index finger, covering the entire area of the thenar eminence, with an incidence lower than in Ilic's research results (31.4%) [9]. Hypoplastic SUPBRA arteries, with a diameter less than 1.1 mm, were frequently observed. In our examined samples, no hypoplastic SUPBRA was encountered. The SUPBRA passes through the thenar muscles in 56% of cases, over the thenar muscles in 0% of cases, and anastomoses with the termination of the ulnar artery in 44% of cases, thereby completing the SPA.

Although several authors have reported that the arterial pedicle of the SUPBRA is approximately 30 mm long, its definition remains unclear [1, 8, 11, 16, 17, 28]. This ambiguity arises because, in some cases, the vessel terminates, while in others, it forms the SPA. The location of the musculocutaneous perforators, approximately 10 mm distal to the scaphoid tubercle, suggests that when the SUPBRA flap is designed transversely along the distal wrist crease, the direct cutaneous perforators will play a crucial role in providing adequate blood supply to the flap as a pedicle. The results of previous studies lead to the conclusion that predicting the occurrence of SUPBRA based on a patient's sex, height, and radial artery size is not possible [9].

Zheng et al. described reverse SUPBRA flaps with the skin paddle oriented transversely at the wrist crease [32]. Flap widths ranging from 15 to 35 mm and length from 22 to 100 mm are reported in various studies [19, 21]. In this study, the pedicled reverse SUPBRA flaps raised from the wrist crease ranged in size from 20×40 mm with primary closure of all donor sites (Fig. 1bc,2,3c,4a,5ab). Most research suggests that the SUPBRA is positioned over the proximal parts of the abductor pollicis brevis and opponens pollicis muscles, and the radial aspect of the eminentia thenaris is assumed to be the donor site [14,25]. In this study, the skin paddle was elevated from the thenar area or slightly medial to it (Figs. 3 and 4).

Other studies show that one or more perforators branch off the SUPBRA to supply the skin in the radial volar wrist and proximal thenar area (Fig. 4) (Table 2). By contrast, the clinical study by Hu reported that the SUPBRA has two or three perforators on the radial wrist, which are located on the radial side of the palmaris longus tendon [8]. Similarly, Yang et al. reported that there are, on average, 2.03 perforators, with at least two perforators in the radial wrist [29]. Linh et al. demonstrated that all direct cutaneous perforators were located inside a 16.4 mm diameter circle with an origin at the scaphoid tubercle [16].

The flap receives its blood supply from one or two of the perforating branches of the SUPBRA (Figs. 1b and 2ab,3c,4b) [1, 19]. The SUPBRA vessel is observed to bifurcate into a superficial-direct cutaneous and a deep branch-musculocutaneous perforators 15 cm from the scaphoid tubercle in cadaveric studies. This study reveals the superficial and deep branches at the scaphoid tubercle (Figs. 1b and 2ab,3c,4b). The deep branch permits the raising of longer flaps (Figs. 1b and 2ab,3c,4b). However, the superficial branch has been debated as a long perforator [1]. As a reverse flow flap, it is nourished by anastomoses of the SUPBRA vessel with another distal vessel or vascular network distally. In this study, all samples were positioned on anastomoses with the SPA or with the arteries of first web space. The first web exhibited a sufficient and complex blood supply with abundant anastomoses (Fig. 3 cd,4ab).

Orbay et al. described a valuable perforator located at the junction of Kaplan's cardinal line and the axis of the third digital ray or the second web space [20]. The point of intersection of Kaplan's line and a line tangent to the radial border of the second web space is marked to design a thenar perforator propeller flap, and the presence of a perforator is confirmed by audible Doppler examination [24, 26]. With this line, the perforators were easily accessed in our cases (Figs. 1b, 3c and 4b).

Kim et al. described flaps where the anastomotic connections are not found on the SUPBRA axis [14] They were advanced in a 'sliding' pattern. The possibility a reverse flow flap based on this design was suggested, but no example was provided. The pivot is placed toward the base of the second metacarpal at the intersection of a longitudinal line along the radial border of the second metacarpal and a transverse line along the ulnar border of the thumb [26, 28]. In the cadaveric hands studied, the pivot was closer to the distal end of the mid palmar crease at the head of the second metacarpal. The article underscores the significance of

preoperative hand-held Doppler in identifying connections [20, 27].

The most common cause of free flap failure is venous compromise, which accounts for over 50% of cases. Sierakowski et al.'s report, the flap required 'venous supercharging' as the distal SUPBRA vessel lacked accompanying vena comitantes [24]. Lee et al. reported the use of venae comitantes in only 5.8% of cases. While previous researchers such as Iwuagwu et al. [12–14], Tsumura et al. [28], and Radunovic et al. [23], reported no use of venae comitantes, Lee et al. noted their use in 50% of cases [15]. Some authors have used the flap in elderly patients, diabetics, heavy smokers, and those with atrial fibrillation undergoing antiplatelet therapy, achieving very satisfactory results [4,7,10,24,25]. The majority of the studies cited early complications, such as distal flap necrosis (6%), and late complications, like thumb adduction contracture in diabetics (2%) [13,20,25,26,29]. In our series, all specimens demonstrated suitable vascularity using both concomitant and superficial veins. The article also alludes to the potential for regaining useful sensation through neurotisation, even without nerve coaptation.

Our case 1 involved a diabetic and a smoker, but crucial functional and cosmetic results were seen during an average follow-up of 2 months. Researchers have outlined the coaptation of the palmar cutaneous branch of the median nerve to the digital nerves, resulting in good sensory recovery. Zheng et al. also discussed nerve coaptation as needed in their reverse SUPBRA flaps from the wrist crease [32]. Nonetheless, some evidence suggests that these flaps can regain useful sensation by neurotisation, even without nerve coaptation, a significant finding previously observed in the free version of the flap [12,30,31].

In our study, we detailed the external diameter of the SUPBRA, its bifurcation point from the radial artery, the length of the SUPBRA flap, the presence of venae comitantes, and the number and location of perforators (Tables 1 and 2). We found that all cases demonstrated vascular suitability for a SUPBRA flap. There were no instances of the SUPBRA terminating in the thenar area or exhibiting hypoplasia due to narrowness. Therefore, it is necessary to perform arteriographic and ultrasound evaluations of the arterial anatomy before any microsurgical interventions. This study performed two primary techniques such as the mid palmar axis and wrist line axis. The distance from the SUPBRA's origin to the distal wrist crease in the flap raised using the transfer wrist crease technique was 9.4 ± 1.1 mm (7.9–11.1), and the diameter of the artery was 2.4 mm (Table 1). In the flap elevated with the mid palmar axis technique, the distance from the SUPBRA's origin to the distal wrist crease was 11.2 mm, and the artery's diameter was 2.9 mm. The distance from the the SUPBRA's origin to the puncture of the thenar muscle's was 18.6 mm, and the artery's diameter was 1.0 mm. Given its proximity to the digital artery or metacarpal artery, anastomosis with SUPBRA was easily performed. It was found that the artery is typically accompanied by one or two vena comitantes. Most subcutaneous veins that would open into the distal forearm were also shown. The SUPBRA flap was deemed appropriate for hand and finger reconstruction for palmar defects of the radial digits, palm, and first webspace. SUPBRA was found to be suitable for microvascular anastomosis given its arterial diameters and lengths (Figs. 3 and 4).

The strength of this study lies not only in detailing the anatomy of the SUPBRA and the critical role of venae comitantes in the flap, but also in providing comprehensive follow-up of cases that employed the SUPBRA flap, discussed extensively in terms of clinical anatomy. Our paper contributes significantly to the literature by offering detailed anatomical measurements of the SUPBRA and exploring the potential surgical conveniences these measurements facilitate. We present new data on the location of perforators and the length of the SUPBRA pedicle, aspects often overlooked or underemphasized in previous studies. Furthermore, our work provides essential guide points for the safer design and harvesting of the SUPBRA flap, demonstrated through successful clinical case results, even in challenging scenarios. Understanding the anatomy and clinical applications of the SUPBRA flap represents a substantial advancement in hand surgery and plastic surgery, with our findings delivering crucial practical information on flap design and application, including innovative techniques for preserving vascular structures and nerve branches.

The study has some limitations. Firstly, one limitation of the study is the small sample size. Secondly, the sample group consists of formalin-fixed cadavers rather than fresh cadavers. We acknowledge that even minimal, this may cause variations in measurements. Better images could have been obtained if red latex or silicone injections were made into the arteries and veins of the hand. Another limitation of the study is that it was conducted only on male cadavers, with no female cadaver samples included. Work accidents, sharp instrument injuries, high-energy vehicular and non-vehicular accidents, animal bites, and firearm injuries are more commonly involved with men, thus hand injuries are also more prevalent in men. From this perspective, the use of only male samples in the study may not necessarily be considered a limitation.

The anatomical experiences to be used for flap elevation were listed to guide young plastic surgeons. Our results collectively suggest that the SUPBRA flap can be designed and harvested more safely by adhering to the following guidelines.

1. **1. Identifying SUPBRA Origin**: The origin of the SUPBRA should be identified with a proximal flap incision over the radial artery, typically 10 to 20 mm proximal to the radial styloid process, but sometimes extending up to 46 mm. The mean diameter of the SUPBRA at its origin is approximately 15 mm. A SUPBRA diameter of 1.1 mm is considered hypoplastic and unsuitable for a flap, as it cannot provide adequate nourishment.
2. **2. Scaphoid Tubercle as a Landmark**: The scaphoid tubercle serves as a key skin surface landmark for locating cutaneous SUPBRA perforators. It is a blunt, non-articular projection on the lateral edge of the scaphoid bone, easily palpable on the palmar aspect of a radially deviated wrist. Including a 15–17 mm diameter circle around this tubercle in the flap design could eliminate the need for preoperative perforator mapping.
3. **3. Exploration of the SUPBRA**: The SUPBRA should be explored just proximal to the origin of the abductor pollicis brevis with a distal flap incision. This allows for harvesting the flap without observing its perforators, as they are always located between the proximal and distal points. The arterial pedicle of the SUPBRA is approximately 30 mm long.
4. **4. Venous Return Systems**: To minimize venous complications, two venous return systems, a subcutaneous vein and the concomitant vein, should be anastomosed as much as possible. It's advisable for beginners to suture at least two veins to prevent venous compromise, a major cause of free flap failure.
5. **5. Flap Innervation**: To improve sensory outcomes, nerve branches, particularly the palmar cutaneous branch of the median nerve, should be incorporated into the flap design. This nerve branch bifurcates from the median nerve and penetrates the flexor carpi radialis sheath near the scaphoid tubercle, providing innervation to the proximal central carpal and the palmar aspect of the thenar eminence.

Conclusion

The study concludes that the SUPBRA flap is a valuable option for the reconstruction of the hand and fingers This study provides a detailed analysis of the SUPBRA flap, including the external diameter and the bifurcation point from the radial artery, as well as the flap's length, the presence of venae comitantes, and the number and locations of perforators. The SUPBRA flap is deemed appropriate for reconstructing palmar defects of the radial digits, palm, and first webspace. It was also found to be suitable for microvascular anastomosis due to its arterial diameters and lengths.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Ethics approval Ethics approval for this study was obtained from our university's Human Research Ethics Committee (21-6.1T/48).

Informed consent For this type of study informed consent is not required.

Competing interests The authors declare no competing interests.

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