Reverse Palmar Flaps for Triphalangeal Finger Defects: An Anatomical Study and Case Series

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ABSTRACT

Objective: To describe the anatomical consistency of palmar cutaneous branches and commissural arteries, and to evaluate patients treated with reverse palmar flaps. **Materials and Methods:** Anatomical study: five cadaveric hands were analyzed to assess the consistency of palmar cutaneous branches, as well as commissural and transverse interphalangeal arteries. Clinical study: patients with palmar digital injuries in triphalangeal fingers treated with palmar flaps were included, with no age restriction, no prior surgical history, with or without associated injuries, and a minimum follow-up of 24 months. Subjective evaluation included the Visual Analog Scale (VAS) for pain and the QuickDASH score. Objective evaluation included the two-point discrimination test and goniometric assessment of total active motion (TAM) according to the Strickland system. **Results:** The anatomical study demonstrated consistent palmar cutaneous branches (2–4 branches per flap island), as well as the presence of commissural and transverse interphalangeal arteries. The clinical study included 10 patients (8 men and 2 women). Eight short and two long palmar flaps were performed. The postoperative VAS score was 1/10 and the QuickDASH score was 2.5. Two-point discrimination was 7 mm. According to TAM (Strickland classification), 6 results were excellent, 3 good, and 1 fair. **Conclusions:** Palmar cutaneous branches and anastomotic systems were found to be consistent. The reverse pedicled palmar flap proved to be an effective option for the treatment of digital defects.

Keywords: Reverse pedicled palmar flaps.

Level of Evidence: IV

Colgajos inversos del hueco de la mano en defectos de dedos trifalángicos. Estudio anatómico y evaluación de una serie de casos

RESUMEN

Objetivos: Describir la constancia anatómica de ramas cutáneas de la palma de la mano y las arterias comisurales, y evaluar a pacientes tratados con colgajos inversos del hueco de la palma. **Materiales y Métodos:** *Estudio anatómico:* 5 manos cadavéricas para analizar la constancia de ramas cutáneas palmares de la mano, arterias comisurales y transversas interfalángicas. *Estudio clínico:* pacientes con heridas digitales palmares en dedos trifalángicos de la mano, tratados con colgajos del hueco de la palma, sin restricción de edad, sin antecedentes quirúrgicos, con o sin lesiones asociadas y un seguimiento mínimo de 24 meses. Las evaluaciones se realizaron con la escala analógica visual para dolor, el QuickDASH, y la prueba de discriminación de 2 puntos y goniometría del rango de movilidad activa total por el sistema de Strickland. **Resultados:** El estudio anatómico demostró la constancia de ramas cutáneas (2-4 ramas por isla) del hueco de la palma, de la arteria comisural y transversas interfalángicas. El estudio clínico incluyó a 10 pacientes (8 hombres y 2 mujeres). Se realizaron 8 colgajos del hueco de la palma cortos y 2 largos. El puntaje posoperatorio de la escala analógica visual fue de 1/10 y el del QuickDASH, 2,5; y la prueba de discriminación de 2 puntos fue de 7 mm. Según el rango de movilidad activa, 6 resultados fueron excelentes; 3, buenos y uno, regular. **Conclusiones:** Las ramas cutáneas y los sistemas anastomóticos resultaron constantes. El colgajo pediculado inverso del hueco de la palma resultó eficiente en el tratamiento de defectos digitales.

Palabras clave: Colgajos pediculados inversos; hueco; palma.

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INTRODUCTION

Palmar injuries of the fingers involving soft-tissue, osseous, or combined defects are common conditions associated with occupational and recreational activities. When these injuries involve the distal half of the fingers, they can often be treated with random or axial advancement flaps. However, when they are located in the proximal half or involve extensive defects that exceed local coverage capacity, other reconstructive options must be considered.[1-3]

At the beginning of the 20th century, Harold Gillies, a pioneer of plastic surgery, established "the replacement of like with like" as a fundamental principle in soft-tissue reconstruction.[4] More recently, Upton et al. stated that the ideal reconstruction of palmar defects should be performed using glabrous (hairless and glandless), sensate, durable, relatively immobile, and thin tissues.[5]

The study of cutaneous vascular territories divides the hand into digital, digitopalmar, thenar, hypothenar, and, finally, the midpalmar area (MPA). The latter, with an average surface area of 18 cm² in adults, is densely supplied with cutaneous branches that can be used for flap design. Within this framework, reverse and pedicled flaps from the MPA may be considered.[6] Reverse flaps are defined as those in which blood flow is reversed through proximal pedicles or that can be rotated distally, even without true reversal of flow direction.[7]

The objectives of this study were to describe the anatomical consistency of the cutaneous branches of the MPA, together with the palmar-dorsal and digital anastomotic systems, and to clinically evaluate a series of patients with finger defects treated with reverse MPA flaps.

MATERIALS AND METHODS

Anatomical Study

Five cadaveric hands were analyzed (3 female and 2 male; mean age 70 years; range 54-80). After cannulation of the axillary artery, each specimen was injected with red-colored latex, followed by sealing of the cannulas and preservation using a mixture of formaldehyde and phenolic acid according to the Cozzi technique.

Under 3.5x magnification, the palmar vasculature of the hand was dissected. The frequency and consistency of the cutaneous branches of the MPA were analyzed, as well as the presence of commissural arteries (communicating between the palmar and dorsal systems) and of the proximal and distal transverse interphalangeal arteries, also known as Edwards' vascular arcade. Using a micrometric caliper, the mean diameter of the cutaneous branches and palmar vascular axes was measured, along with their angle of origin relative to the vascular axis.

Clinical study

A retrospective study was conducted including patients treated between January 2013 and January 2018. The inclusion criteria were: patients with palmar digital wounds involving the four fingers, treated with reverse MPA flaps (short or long), without age restriction, without prior surgical history, with or without associated injuries (partial amputation of the distal phalanx or distal interphalangeal disarticulation, digital nerve injury distal to the Edwards arcade used as the pivot point, or tendon injury), and a minimum mean follow-up of 24 months. Patients who did not meet these criteria or who had infectious processes were excluded.

All procedures were performed by a single hand surgeon in a single operative stage, at a mean of 4 days after trauma (range 1–9). The anatomosurgical classification proposed by Zancolli for reverse MPA flaps was used, based on the cutaneous branches of the arteries supplying the skin and their pivot point. This classification divides the flaps into short and long, according to the pivot point (commissural confluence or transverse interphalangeal artery, respectively) and their distal reach (Figures 1 and 2).[6] The surgical technique is described below.

Surgical Technique

The procedure is performed under supraclavicular plexus block, with gentle inflation of the tourniquet. After marking the anatomical landmarks (the common and proper digital neurovascular bundles, as well as the probable location of cutaneous perforators in the MPA), the extent of digital tissue loss is determined, and both the size and shape of the defect are transferred to the skin of the MPA (according to the finger to be reconstructed).

The first step consists of an approach at the interdigital commissure, under 3.5x magnification, to confirm the commissural communication between the dorsal and superficial palmar systems (common digital artery).

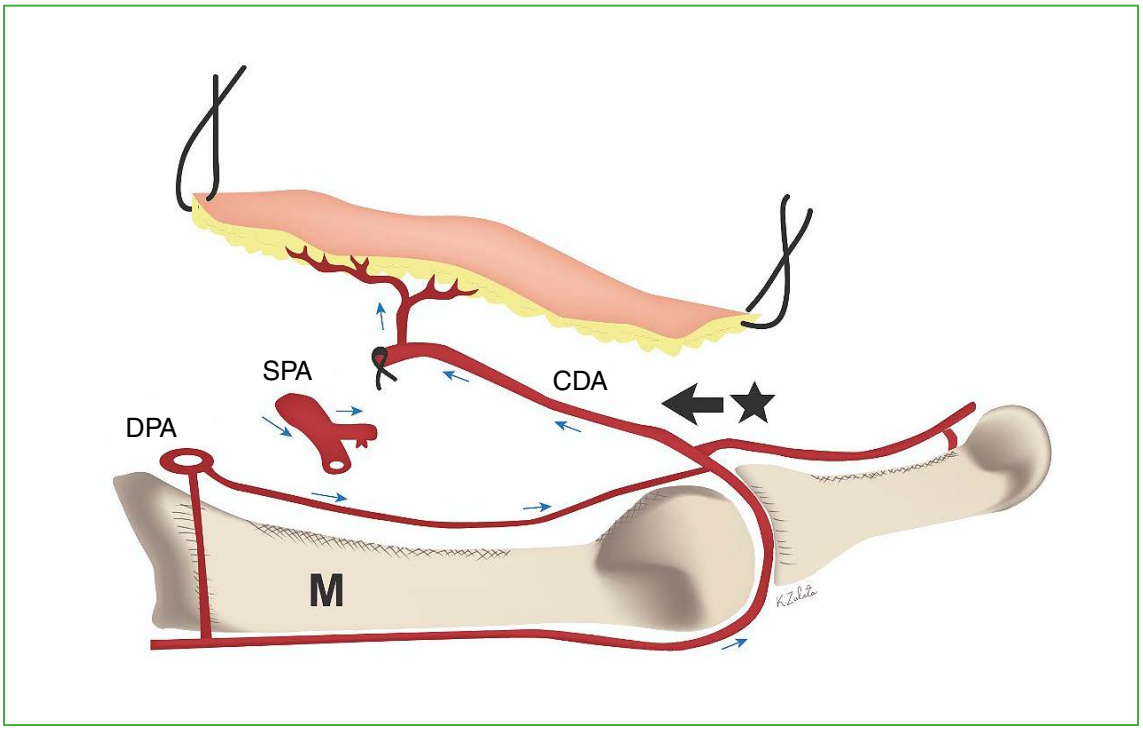

Figure 1. Illustration of the short variant of the midpalmar flap, as described by Zancolli. DPA = deep palmar arch; SPA = superficial palmar arch; CDA = common digital artery; M = metacarpal.

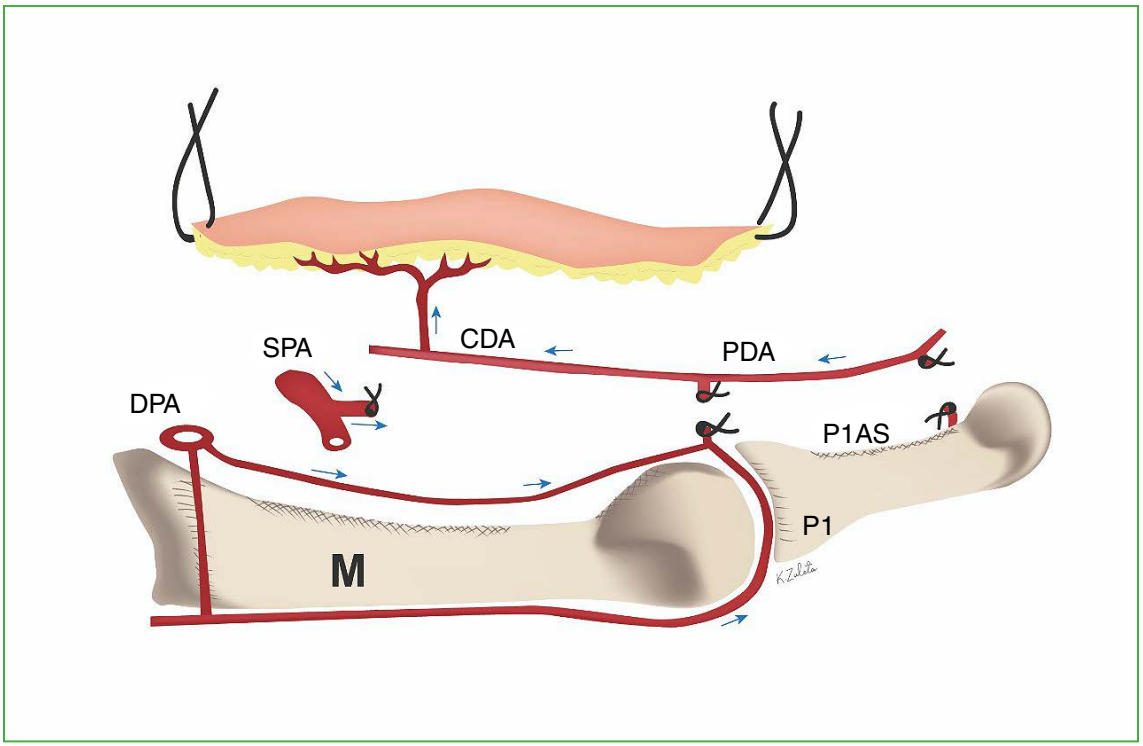

Figure 2. Illustration of the long variant of the midpalmar flap, as described by Zancolli.
DPA = deep palmar arch; SPA = superficial palmar arch; CDA = common digital artery; PDA = proper digital artery; M = metacarpal; P1 = proximal phalanx; P1AS = proximal phalanx anastomotic system.

Once confirmed, the skin island is designed, including an average of 2 to 4 cutaneous branches. The flap is dissected with the least possible amount of subcutaneous tissue. The fibers of the central palmar aponeurosis are divided; the common digital artery is dissected and ligated proximally at its junction with the superficial palmar arch. The island flap is elevated, handling the pedicle carefully and avoiding stretching or twisting along its axis. From the digitopalmar region, the approach is continued in a zigzag fashion, separating the common digital artery and the bifurcation of the proper digital arteries (with their venae comitantes) from the common digital nerve, which is preserved and protected.

Through a lateral digital approach, dissection proceeds until reaching the defect to be covered. The commissural confluence must be preserved (short midpalmar area flap [MPA]) or ligated and divided together with the collateral artery of the adjacent finger to increase advancement (long MPA). The tourniquet is released, meticulous hemostasis is performed, and flap viability is assessed by irrigation with warm saline solution. The recipient site is then covered with the skin island and approximated using 4-0 monofilament sutures, avoiding excessive tension.

Finally, a split-thickness skin graft is harvested from the elbow crease, medial aspect of the arm, or groin (with primary closure) to cover the donor site. An elastic anti-edema dressing is applied, and the hand is immobilized with a short arm plaster splint extending to the digits.

Postoperative Course

Daily wound care was performed during the first 5 days after surgery to assess flap viability (evaluating clinical parameters such as color and capillary refill, without Doppler or other adjunctive methods). Subsequent wound care was performed weekly until suture removal. The patient then began hand occupational therapy. Time to return to usual activities (work/sports) was recorded. Patients were contacted by telephone for long-term follow-up (12 and 24 months).

The sample was evaluated subjectively using the visual analog scale for pain and the QuickDASH questionnaire. Objective evaluation was performed using the two-point discrimination test, and the Strickland scoring system was used to assess total active range of motion by goniometry, defined as the sum of active flexion of the metacarpophalangeal, proximal interphalangeal, and distal interphalangeal joints minus the extension deficit of these joints.[6] Results >150° were considered excellent; 125°-149°, good; 90°-124°, fair; and <90°, poor.

Secondary complications related to the surgical procedure (partial or total necrosis, dehiscence, retractile scarring) were recorded.

RESULTS

Anatomical Study

The anatomical study demonstrated the consistent presence of cutaneous branches of the MPA. An average of 2 to 4 branches per flap island designed at the intermetacarpal level was identified in the cadaveric specimens (Figure 3). These branches emerged at an angle of approximately 70° (range 65°-75°) relative to the common digital artery, perforating the central palmar aponeurosis. In all specimens, a commissural artery (communicating between the palmar and dorsal systems) was consistently identified at the digital commissure, with a mean diameter of 0.4 mm (range 0.3-0.5) (Figure 4).

The mean diameter of the common digital arteries was 1.9 mm (range 1.7-2.1), while the mean diameter of the proper digital arteries was 1.1 mm (range 1-1.2).

In all dissections, transverse interphalangeal arteries, also known as Edwards' vascular arcade, were identified, serving an anastomotic function between the collateral vessels of the same finger. These vessels emerged at an average angle of 80° (range 78°-82°) relative to the proper digital artery and were located at the neck of the proximal and middle phalanges, respectively. They contributed to the arcade together with the articular branch of the proper digital nerve (in two specimens, two articular branches were identified per side) (Figure 5).

Clinical Study

A series of 10 patients (8 male and 2 female) with a mean age of 25 years (range 6-45) was included. The non-dominant hand was affected in 80% of cases. The most frequently involved finger was the middle finger (6 cases), followed by the index finger (3 cases) and the ring finger (1 case). In most cases, the injury was work-related. In two cases, neurorrhaphy of the injured proper digital nerve was performed. In one case, partial amputation of the distal phalanx was present, and in another, distal interphalangeal disarticulation. The mean defect size was 15.1 x 11.3 mm. In eight cases, short MPA flaps were performed, and in two cases, long MPA flaps were used due to the distal location of the defect. All flaps survived.

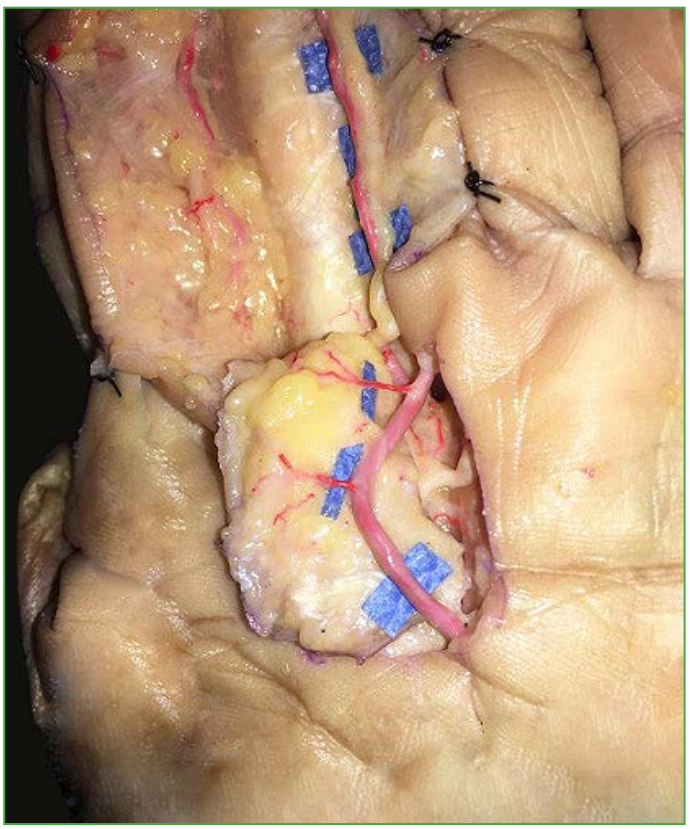

Figure 3. Anatomical dissection of the midpalmar area showing the presence of cutaneous branches within the designed flap island.

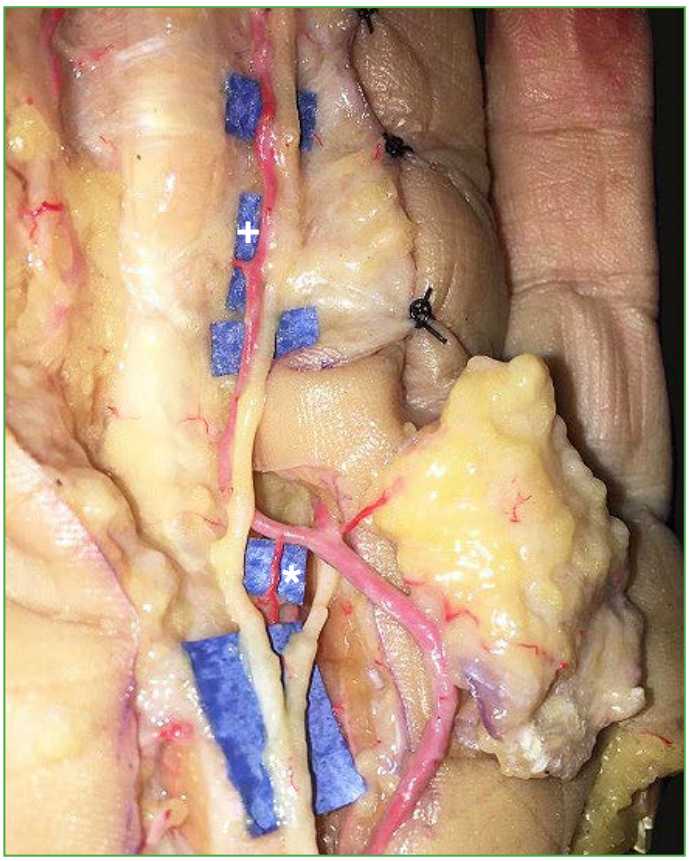

Figure 4. Anatomical dissection of the midpalmar area showing the commissural confluence (commissural artery) and the proximal transverse interphalangeal artery. (*) Commissural confluence; (+) Proximal transverse interphalangeal artery.

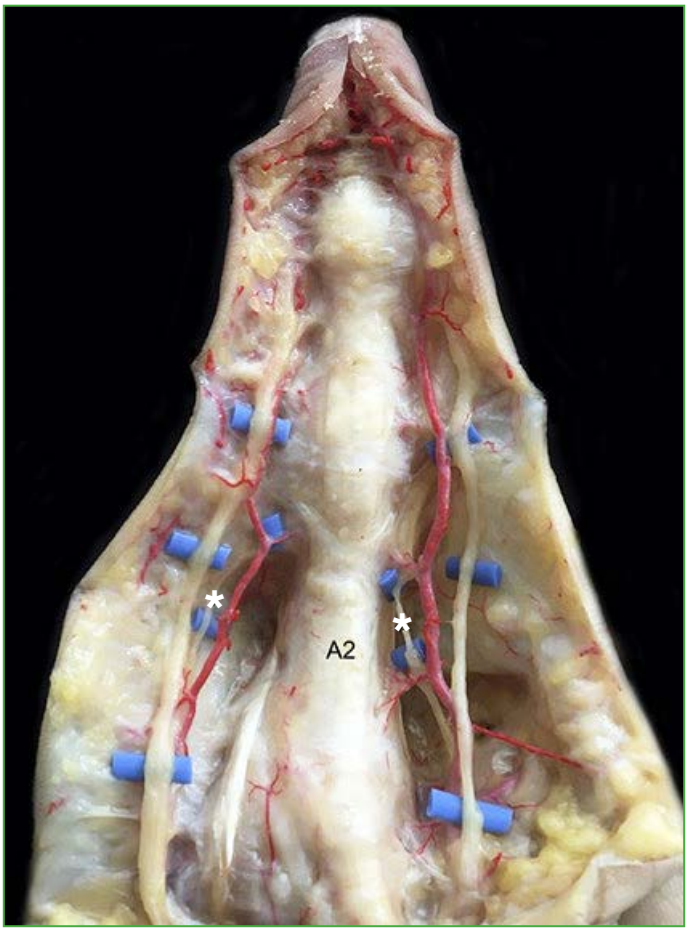

Figure 5. Digital anatomical dissection. The entry of articular nerve branches into Edwards' vascular arcade is observed on each side of the finger, together with the proximal and distal transverse interphalangeal arteries. A2 = A2 pulley; (*) articular nerve branches.

The mean time from admission to discharge, including return to work/sports activities, was 7 weeks (range 6–8). The mean postoperative pain score was 1/10 on the visual analog scale, and the mean postoperative QuickDASH score was 2.5 (Figure 6).

Mean two-point discrimination was 7 mm. Total active range of motion, according to the Strickland scoring system, showed 6 excellent, 3 good, and 1 fair result. The data for this group are summarized in the Table.

Three cases of partial wound dehiscence were recorded (2 long MPA flaps and 1 short MPA flap), all resolved by secondary intention healing. Two cases of partial necrosis of the distal flap edge (both long MPA flaps) were also managed with surgical debridement followed by secondary healing. One case of digital scar contracture (after a long MPA flap) required Z-plasty for correction.

Figure 6. Chronological sequence, as an example, of distal interphalangeal disarticulation of the index finger, the surgical procedure, and long-term follow-up.

Table. Demographic data and subjective and objective assessment by patient.

Patient	Lesion size (mm)	Affected finger	Type of MPA flap	Pain according to VAS (post-op)	Quick DASH score (post-op)	2PDT (mm)	TAM Strickland System
1	19 x 12	Middle	Long	1/10	2.5	9	Average
2	15 x 10	Index	Short	0/10	2	6	Excellent
3	14 x 12	Ring	Short	2/10	3.4	7	Excellent
4	14 x 10	Middle	Short	1/10	2.3	8	Good
5	13 x 11	Middle	Short	2/10	3.5	7	Excellent
6	18 x 12	Index	Long	1/10	2.5	8	Good
7	12 x 10	Index	Short	0/10	2	7	Excellent
8	16 x 12	Middle	Short	1/10	2	7	Good
9	15 x 12	Middle	Short	1/10	2.6	6	Excellent
10	15 x 12	Middle	Short	1/10	2.8	6	Excellent
Average	15.1 x 11.3			1/10	2.5	7	

MPA = midpalmar area; VAS = visual analog scale for pain; 2PDT = 2-point discrimination test; TAM = total active motion.

DISCUSSION

Due to the characteristics of palmar skin, the range of options for intrinsic hand coverage (excluding extrinsic and free flaps) described in the literature is varied, although not extensive.

Melone et al.[8] and Dellon[9] described the random thenar flap and its variant, respectively. In both cases, these flaps are reserved for lesions predominantly involving the fingertips and the distal phalanx. They reported excellent sensory outcomes; however, flexion contracture was the main complication, related to the period of immobilization required before separation from the donor site. Their use in proximal defects is now considered obsolete.

Zancolli's description of reverse MPA flaps, in a small series of patients, represents the first report of pedicled, glabrous reverse flaps in the literature. Based on a detailed analysis of hand vascular anatomy, he indicated their use for massive palmar defects of the four fingers or the base of the thumb, with exposure of bone, tendons, vessels, or nerves. He reported acceptable outcomes, with no flap loss, although sensory outcomes at final follow-up were not addressed.[6]

Vasconez et al. reported the use of a palmar flap to correct contractures of the first web space, based on cutaneous branches of the digital artery of the index finger, with acceptable outcomes and no scar contracture.[10]

Zaidenberg and Angrigiani proposed a "rational organization" of reverse MPA flap design, incorporating digital and dorsal variants (in short and long forms). In a series of 88 patients, 24 underwent reverse MPA flaps, with a 6% rate of total loss and 3% of partial loss; however, the specific subgroup was not detailed, nor were final sensory outcomes reported.[7]

Omakawa et al. conducted an anatomical study of 30 cadaveric hands and described two regions: the distal midpalmar region, with 8 to 15 cutaneous branches (arising from the three common digital arteries) capable of perfusing an area of 5 x 3 cm, and the radial midpalmar border, with 3-6 cutaneous branches (arising from the superficial palmar arch). They proposed two flaps: a transversely designed distal midpalmar flap, with a pivot point at the proximal Edwards' arcade for finger defects, and a radial midpalmar border flap for thumb defects. They highlighted favorable aesthetic outcomes without scar contracture as an advantage.[11,12]

Meanwhile, Orbay et al., in a clinical anatomy study, proposed a reverse flap based on the superficial palmar branch of the radial artery, extending from the wrist crease to the transverse palmar crease, with a maximum width of 2.5 cm and a length of 10 cm. In a series of 36 patients, they reported a single case of necrosis, which healed by secondary intention.[13]

In the present study, the anatomical consistency of cutaneous branches, together with the palmar-dorsal and digital anastomotic systems, was analyzed, highlighting their regularity and making flap design predictable. Regarding clinical outcomes, a higher rate of complications was observed compared with the reference literature; these included wound dehiscence and marginal necrosis, which resolved by secondary intention healing, except for one case of scar contracture that required Z-plasty.

Regarding the reinnervation of a non-innervated flap, published studies support the role of axonal sprouting from the recipient bed into the flap, contributing to the final outcome in the two-point discrimination test. This is further supported by histochemical evidence of nerve regeneration at the margins of the studied flaps.[14-19]

The limitations of this study include its retrospective design, the small sample size, and the heterogeneity in age and occupations (predominantly manual workers). However, we consider as strengths the cadaveric confirmation of palmar and digital vascular anatomy, as well as the inclusion of a relatively homogeneous series of patients treated by a single surgeon.

FINAL CONSIDERATIONS

The palmar cutaneous perforating branches, together with the palmar-dorsal and digital anastomotic systems, were found to be consistent and reliable, allowing predictable flap design. The reverse pedicled midpalmar flap, in both its short and long variants, proved effective for the treatment of patients with finger defects.

Conflicts of interest: The authors declare no conflicts of interest.

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