Reconstruction of Soft-Tissue Defects of the Thumb Using Reverse-Flow Homodigital Flaps: A Systematic Review

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J Hand Microsurg

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Abstract

Introduction Soft-tissue thumb defects are common reconstructive challenges, the main goals being restoration of tactile sensibility, range of movement, pulp padding, length, and cosmesis. The reverse-flow dorsoulnar and dorsoradial collateral artery flaps are homodigital flaps used to cover both distal dorsal and volar thumb defects. These flaps can be used as compound flaps including skin, fat, and/or nerves. As there is no critical analysis of these studies, this study aims to create a synthesized comprehensive systematic review.

Methods Systematic review was performed using the databases PubMed, Embase, and Medline. Eligible studies followed the inclusion criteria: English language and all studies published to date. The primary outcome was flap survival. Other data collected included anatomical area of the defect, flap constituents and dimensions, donor-site closure and complications, transfer method, reoperation, revision, and functional outcomes.

Results A total of 19 articles incorporating 189 flaps met the inclusion criteria. These flaps were categorized and analyzed as dorsoradial (50%), dorsoulnar (39%), and turnover flaps (11%). Dorsoradial flaps were used in fasciocutaneous fashion alone. Partial flap failures occurred in five cases. Dorsoulnar flaps were used as fasciocutaneous or as osteocutaneous flaps. Complete flap failure was reported in one patient alone, whereas partial necrosis was reported in four patients. Adipofascial turnover flaps had two partial flap failures reported but no complete failures. The overall complete and partial flap failure rates were 0.5 and 6.5%, respectively.

Conclusion Reverse-flow homodigital random or axial-based flaps provide a reliable means of reconstruction for soft-tissue defects with reasonable success rate and good functional outcomes. They have a consistent anatomy with a good potential for personalization and therefore increased versatility.

Keywords
- dorsoradial flap
- dorsoulnar flap
- homodigital flap
- thumb flap

Introduction

Soft-tissue thumb defects are common yet unique reconstructive challenges. The reconstructive goal includes the restoration of tactile sensibility, range of movement (ROM), pulp padding, length, and cosmesis, while minimizing risk of infection and donor-site morbidity. The reverse-flow dorsoulnar and dorsoradial collateral artery flaps (►**Fig. 1** and ►**Fig. 2A, B**), popularized by Brunelli[1] and Moschella et al,[2] respectively, are homodigital axial nonglabrous flaps that can cover both distal dorsal and volar thumb defects.

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Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

DOI https://doi.org/10.1055/s-0042-1758671.
ISSN 0974-3227.

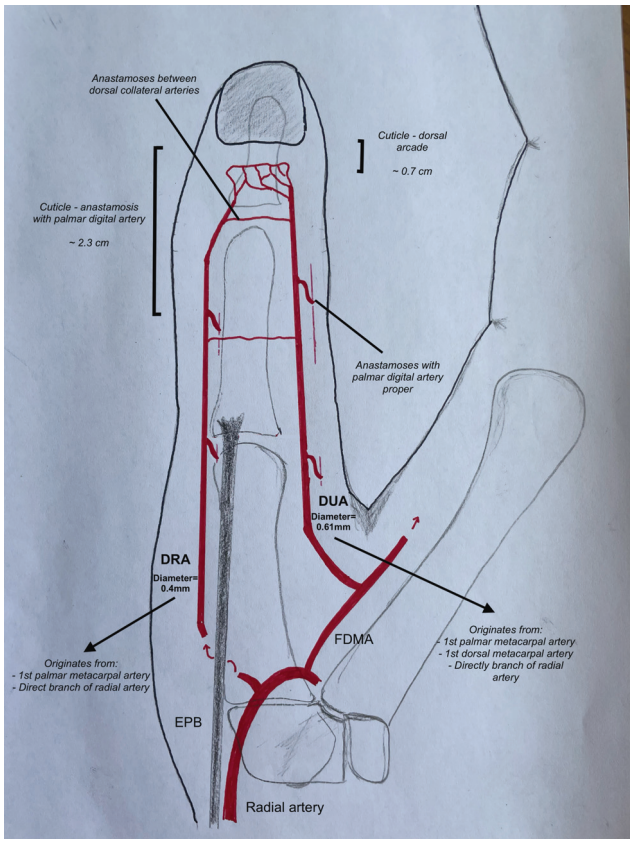

Fig. 1 Illustration of the arterial anatomy basis of the dorsoulnar and dorsoradial reverse-flow flaps from a dorsal thumb perspective. Both DRA and DUA have anastomoses with the palmar digital artery proper and with each other. Note that there are anatomical variations and origin of these collateral arteries may differ. DRA, dorsoradial artery; DUA, dorsoulnar artery; EPB, extensor pollicis brevis; FDMA, first dorsal metacarpal artery.

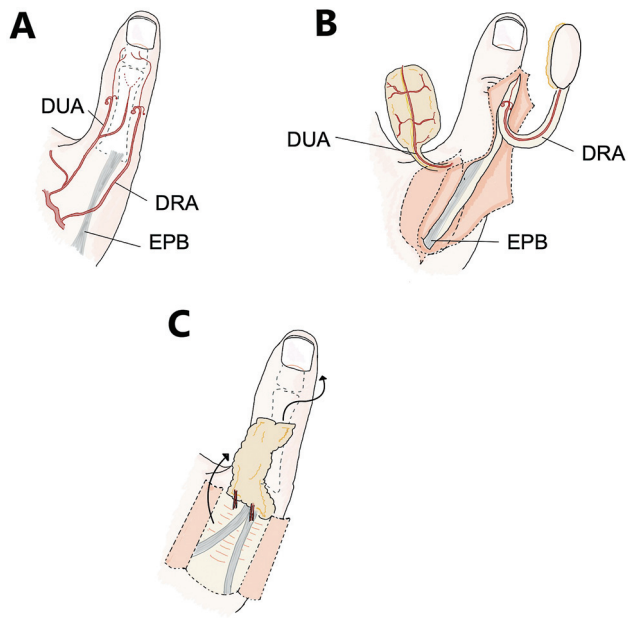

Fig. 2 Illustration of reverse-flow dorsally based homodigital thumb flaps. (**A**) Anatomical layout of the dorsoradial and dorsoulnar artery. (**B**) Dorsoradial and dorsoulnar fasciocutaneous pedicled flaps. (**C**) Adipofascial turnover flap. EDB, extensor digitorum brevis; DRA, dorsoradial artery; DUA, dorsoulnar artery.

They can be used as compound flaps including skin, fat, and/or nerves, and transferred by advancement, transposition, or rotation. The donor site is closed primarily or covered with a skin graft, depending on flap size. ►**Fig. 3** demonstrates a case report using the dorsoulnar pedicled flap. Additionally, the adipofascial random-type turnover flaps (►**Fig. 2C**), described by Lai et al,[3] provide another option for dorsally based digital defects. Despite the occasional case reports studying reverse-flow homodigital thumb flaps, there is no critically analyzed and synthesized comprehensive systematic review.

Anatomical Basis of Reverse-Flow Homodigital Thumb Flaps

The dorsoulnar artery originates from the first dorsal metacarpal artery (FDMA) or as direct branches from the dorsal branch of the radial artery at the neck of the thumb metacarpal. It has an average diameter of 0.6 mm and runs along the dorsoulnar supra-aponeurotic plane of the thumb within the subcutaneous tissue.[4,5] This artery is reinforced by an anastomosis with the palmar digital artery 2.3 cm from the cuticle and terminates in a dorsal arcade 0.7 mm from the cuticle.[4] Anatomical studies have confirmed a reliable presence of the dorsoulnar artery,[2,4,6] including consistent connections with the palmar vascular system, at the middle third of the proximal phalanx. In 50% of cases, venae comitantes are present; otherwise, drainage occurs via tiny venules in the perivascular fatty tissue. The terminal sensory branch of the superficial radial nerve is located 1 to 2 cm to the medial axis of the thumb.

The dorsoradial artery, with an average diameter of 0.4 mm, arises from the radial artery at the level of the anatomical snuffbox and passes on the palmar aspect of the extensor pollicis brevis tendon.[2,4,5,7] It travels in the same plane as the dorsoulnar artery, on the radial side of the thumb, adjacent to a superficial radial nerve branch, running at an approximate 1-cm average distance from the medial axis.[4] This flap is thought to be drained by tiny venules contained in the perivascular fascia adipose tissue[8] rather than specific veins that follow the dorsoradial artery. The dorsoradial artery also communicates with the proper digital artery at the midproximal phalanx level and with the nail matrix via subcutaneous capillaries; however, in 4/25 cadavers it did communicate with the nail matrix arcade of vessels with a narrower caliber vessel diameter.[4]

The adipofascial flap has random type of vascularity and is designed with a base-to-length ratio of 1:1.5 to 1:2.[9] It is raised at the subdermal plane from the area just proximal to the defect, with a base located at the edge of the defect. The flap is then turned over to cover the defect, and a skin graft is used to cover the flap.

Aim

This study aimed to systematically review articles using reverse-flow homodigital thumb flaps to provide an evidence-based report of its indications, complications, and

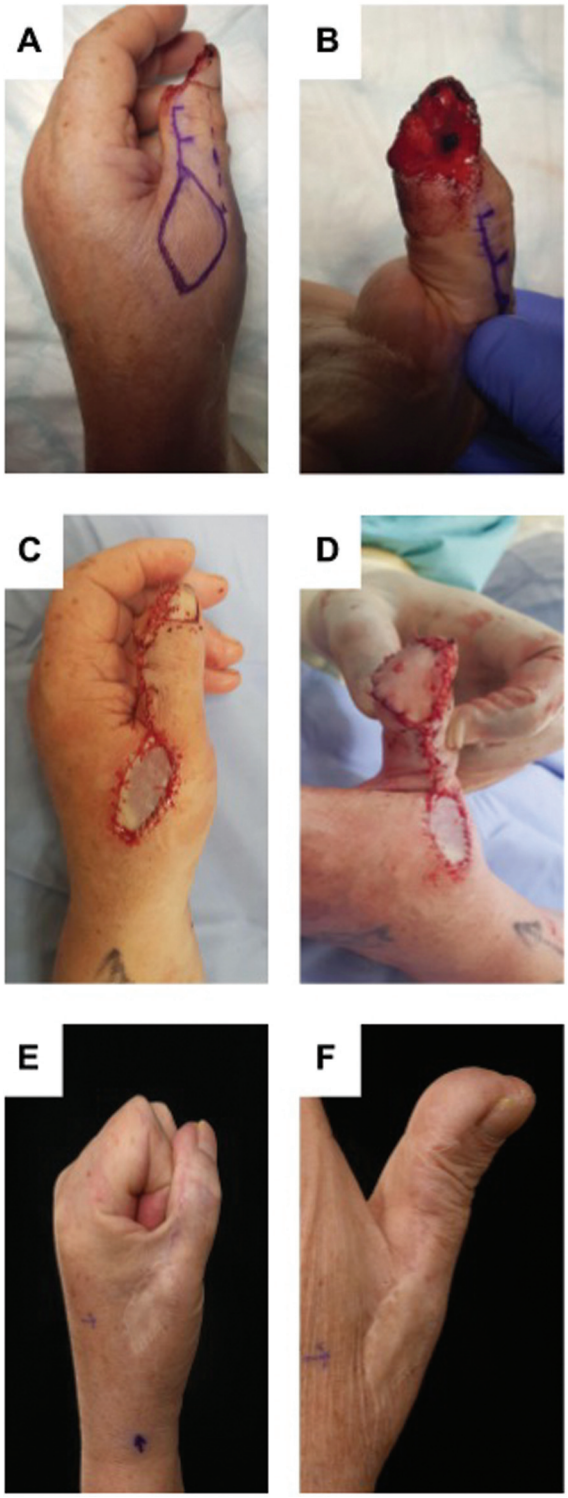

Fig. 3 Case report of dorsoulnar homodigital flap reconstruction of thumb. (**A, B**) A 66-year-old retired patient presented with a chop-saw isolated nondominant left thumb injury resulting in 2.5 × 2.5 cm ulnar pulp defect exposing the distal phalanx. (**C, D**) On day 1 postinjury, a dorsoulnar flap was raised with a pivot point 2.5 cm proximal to the nail fold to reconstruct the defect. No neurorrhaphy was performed. A full-thickness skin graft was used to resurface the donor site. (**E, F**) The patient healed without complications, scoring a maximal 10 points on the Kapandji opposition score, and suffered no first webspace contracture. MCPJ and IPJ extension and flexion were −9/40 degrees and −28/42 degrees at 1 month postoperatively, and −9/48 degrees and −30/66 degrees at 2 years postoperatively, respectively.

outcomes, thereby clarifying the utility of this flap to reconstructive hand surgeons. The review question in terms of PICO (participants, interventions, comparisons, and outcomes) was as follows:

- Participants: patients of any age.
- Interventions: patients undergoing thumb reconstruction using reverse homodigital thumb flaps.
- Comparison: nil, or to other flaps for the same indications.
- Outcomes: donor site, complications, functional outcomes, and microvascular outcomes.

Materials and Methods

This review was performed following Cochrane methodology modified to suit the clinical question and reported following PRISMA guidelines, where applicable.[10]

PubMed, Embase, and Medline databases were searched in January 2021 using the boolean terms "(thumb).af AND ((dorsoradial flap).af OR (dorsal radial flap).af OR (moschella).af OR (dorsoulnar flap).af OR (dorsal ulnar flap).af OR (brunelli).af OR (dorsal homodigital flap).af) OR (adipofascial).af) OR (turnover flap).af)." Two authors (E. G., F. M.) independently screened titles and abstracts for eligibility. Full texts of relevant articles and their references were assessed to identify additional relevant articles.

Clinical studies of all evidence levels were eligible based on the following inclusion criteria: English language and published to date. Cadaveric and studies relating to non-homodigital reverse-flow flaps of the thumb were excluded, including flaps based on the dorsal intermetacarpal artery of the first web and the FDMA, and those cases in which different flaps were used in combination to address the same reconstructive site. Duplicates were removed from the analysis.

The data collected included anatomical area of the defect, flap constituents and dimensions, donor-site closure and complications, transfer method, and flap survival. The main outcomes were flap survival, reoperation, revisions, and functional outcomes.

Risk of bias assessment was performed using the National Institutes of Health (NIH) quality assessment tool for observational cohort and cross-sectional studies (►**Supplementary Fig. 1**).[11] The accuracy of data collection was confirmed by two authors (E.G., F.M.). Descriptive statistics were used to describe the data synthesis.

Results

A total of 19 articles qualified (►**Fig. 4**) with a total of 189 flaps performed. These articles were categorized according to dorsoulnar blood supply, dorsoradial blood supply, and turnover adipofascial flaps (►**Tables 1**, **2**, and **3**). All studies were of level IV or V evidence.[11] The risk of bias assessment is depicted in ►**Fig. 5**.

Clinical Outcomes

The relative proportions of each flap were as follows: dorsoradial, 95 (50%); dorsoulnar, 74 (39%); and turnover flaps,

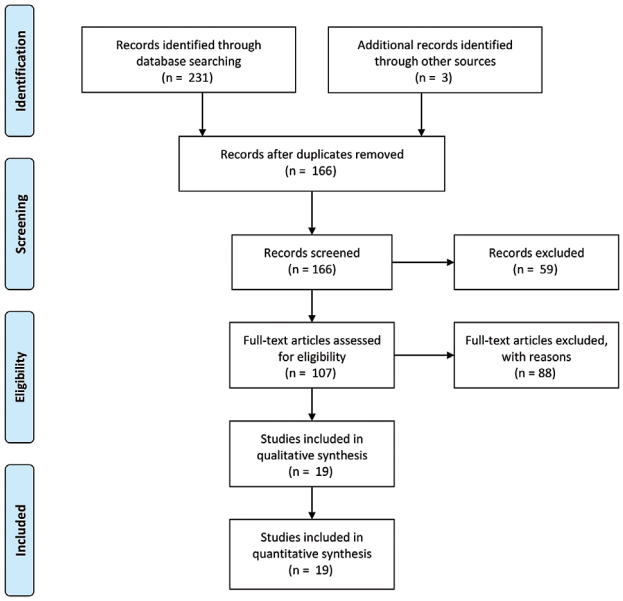

Fig. 4 PRISMA flowchart.

20 (11%). The overall complete and partial flap failure rates were 0.5 and 6.5%, respectively.

Dorsoradial Flap

All six papers (95 cases) reported soft-tissue thumb reconstruction using fasciocutaneous flaps alone or with dorsal collateral nerve neurorrhaphy ($n = 7$) in patients with a mean age of 45 years (range, 18–78).[13–17,28] Indications for reconstruction included traumatic injuries and tumor resections. Sites of thumb reconstruction included tip (11%), pulp (31.9%), radial aspect distal phalanx (13.2%), dorsum of distal phalanx (37.4%), dorsum of proximal phalanx (1.1%), volar proximal phalanx (1.1%), and interphalangeal joint (IPJ) stump (4.4%). The mean defect and flap size averaged 3.88 cm^2 (range, 1.95–5.95) and 7.48 cm^2 (range, 1.6–16), correspondingly. One article[13] alone was deemed high risk of bias.

In 1979, Pho[16] described the composite neurovascular fasciocutaneous island flap raised on the dorsoradial side of the thumb to address extensive pulp loss in six patients. There were no failed flaps; however, one case required intraoperative conversion to a rotational flap due to potential flap ischemia. Therefore, the defect site was not closed completely. Two patients showed significant improvement in pulp-to-pinch strength from before to after the operation. No patients reported hyperesthesia, pain, or autonomic disturbance.

Moschella and Cordova[14] popularized the reverse-flow dorsoradial fasciocutaneous flap ranging from 2×2 cm to 5×4 cm to reconstruct distal defects of the thumb in 16 patients. Nerve coaptation from the dorsal collateral nerve to volar digital nerve was used in one case that showed no improvement in sensitivity with epineural anastomosis. Three cases reported venous congestion that resolved with removal of sutures over the pedicle. There was one case of distal margin necrosis that healed spontaneously.

Table 1 Summary of thumb dorsoradial homodigital reverse-flow flaps reported in the literature

Study	Number of patients/total number of flaps/homodigital thumb flaps (M/F)	Mean age for thumb flaps (range)	Blood supply (dorsoulnar or dorsoradial or random) (*n*)	Indication/etiology (*n*)	Defect location	Structures exposed	Flap type (fasciocutaneous/adipofascial/other)	Donor-site closure (PC or SG) (*n*)	Flap failure (partial or complete) (%)	Other complications	Mean sensory outcome (S2PD) (mm) (*n*)	Other notes
Qin et al (2020)[15]	42 patients (35 M, 7 F)/42 flaps/42 homodigital thumb flaps (group A = 17; group B = 25)	46 (19–73)	DR (42)	Crush (22), avulsion (12), sharp laceration (8)	Dorsal thumb distal phalanx (21) Radial thumb (7) Pulp (8) Tip (6)	Bone and tendon	Fasciocutaneous	Group A (narrow): PC (17/17) Group B (wide): PC (4/25), partially open (7/25), skin bridge (6/25), SG (8/25)	Congestion with no or partial flap loss: group A, 18% Group B, 24% No complete flap failure	Venous congestion with no flap loss (total, 6: group A, 2; group B, 4). Venous congestion with partial loss (total, 3; group A, 1; group B, 2)	Group A: 9.59 ± 1.42 Group B: 9.76 ± 2.19	Group A: pedicle width ≤ 0.8 cm Group B: pedicle width > 0.8 cm Also assessed: MCPJ ROM and IPJ ROM: no difference Time to return to work (group A: 7 wk vs. group B: 9.6 wk) Final aesthetic satisfaction (group A better than group B) F/u (group A, 12.8 mo; group B: 13.8 mo)
Sun et al (2015)[17]	19 patients (17 M, 2 F)/19 flaps/19 homodigital thumb flaps (group A = 10; group B = 9)	41 (18–64)	DR (19)	Avulsion (5), explosion (1), crush (13)	Tip and pulp (7) Tip alone (4) Pulp (8)	Bone and tendon	Fasciocutaneous	NS	Partial (1/19)	Mild venous congestion (6/19)	Group A size: 6.9 Group B size: 14.78 Overall mean: 10.63	Group A size: 6.52 Group B size: 9.22 None had neurorrhaphy 4 had phalangeal fractures Appearance: strongly satisfied (12), satisfied (4) Function (Michigan Hand Outcomes Questionnaire): strongly satisfied (13), satisfied (4)

Table 1 (*Continued*)

Study	Number of patients/ total number of flaps/homodigital thumb flaps (M/F)	Mean age for thumb flaps (range)	Blood supply (dorsoulnar or dorsoradial or random) (*n*)	Indication/ etiology (*n*)	Defect location	Structures exposed	Flap type (fasciocutaneous/adipofascial/other)	Donor-site closure (PC or SG) (*n*)	Flap failure (partial or complete) (%)	Other complications	Mean sensory outcome (S2PD) (mm) (*n*)	Other notes
												Cold intolerance: mild (6) Pain (VAS): mild pain in flap (4) and donor site (4) No statistically difference between S2PD and age, sex, F/u Statistical difference between S2PD and flap size F/u: 34–46 mo (mean, 39)
Bao et al (2014)[28]	8 patients (5 M, 3 F)/ 8 flaps/8 homodigital thumb flaps	28 (3–52)	DR (8)	Trauma (4), infection (1), tumor (2), failed replantation (1)	Pulp (1) Stump (1) Radial (3) Dorsal proximal phalanx (1) Radiovolar (2)	Bone and tendon	Fasciocutaneous + dorsal collateral nerve neurorrhaphy (6/8)	PC (7/8) SG (1/8)	0%	Venous congestion (1) requiring removal of sutures over pedicle	9.4 (6–12) No reinnervation = 9 mm (1/8) Neurorrhaphy = 9.2 mm (5/8)	6/8 had neurorrhaphy (includes 3-year-old male patient) 1 case developed IPJ flexion deficit of 30 degrees and MCPJ flexion deficit of 11 degrees compared with the contralateral side. Otherwise, all other cases had less than 5 degrees compared with normal side at IPJ and MCPJ No neuroma pain F/u: 3–14 mo (mean, 8.5 mo)
Moschella and Cordova (2006)[14]	16 patients (12 M, 4 F)/16 homodigital thumb flaps	55 (18–78)	DR (16)	Tumor (8) Avulsion (5) Scar reconstruction (2) Burn (1)	Dorsal thumb (7) Pulp (3) Palmar (1) Subungual (2) Amputation stump (3)	Bone & tendon	Fasciocutaneous + dorsal collateral nerve neurorrhaphy (1/16)	PC (14/16) SG (2/16)	Partial (1/16)	Venous congestion (3/16) resolved by removal of sutures around pedicle	Mean: 9.78 (7–11) Reinnervated: 9 mm (1/16) No innervation: 9.88 mm (7–11) (8/16)	Attempted reinnervation in 1 case, which did not prove beneficial
Niranjan and Armstrong (1994)[13]	25 patients (20 M, 5 F)/25 flaps/5 homodigital thumb flaps	NS (1.5–77)	DR (4) DU (1)	Trauma (22), burn (2), tumor (1)		NS	Fasciocutaneous	PC (6/25) STSG (1/25) FTSG (18/25)	Complete (2/25) 8% Not specific to thumb flaps	Delayed healing (5), partial loss of graft requiring further grafting (1)[a]	8 mm (10)[a]	Complications not separated by location of flap All patients able to detect light touch and had moistened skin Only 1 thumb case presented that required FTSG to donor
Pho (1979)[16]	6 patients/6 flaps/6 homodigital thumb flaps	NS	DR (6)	Avulsion (4), clear cut pulp loss (2)	Pulp thumb	NS	Fasciocutaneous	FTSG (6)	1/6 (17%) conversion to rotational flap due to ischemia	Unable to close defect (1)	3–6 mm (5)	Ninhydrin test: return of sudomotor activities (4/4). Pulp-to-pinch: significant improvement (2/2) All healed in 2 wk and returned to work in 6 wk

Abbreviations: DR, dorsoradial; F/u, follow-up; FTSG, full-thickness skin graft; IPJ, interphalangeal joint; MCPJ, metacarpophalangeal joint; NS, not stated; PC, primary closure; ROM, range of movement; S2PD, static two-point discrimination; SG, skin graft; STSG, split-thickness skin graft; VAS, visual analog scale.
[a]Not specific to thumb homodigital thumb flaps alone.

Table 2 Summary of thumb dorsoulnar homodigital reverse-flow flaps reported in the literature

Study	Number of patients/total number of flaps/homodigital thumb flaps (M/ F)	Mean age for thumb flaps (range)	Blood supply (dorsoulnar or dorsoradial or random) (*n*)	Indication/ etiology (*n*)	Defect location	Structures exposed	Flap type (fasciocutaneous/ adipofascial/ other)	Donor-site closure (PC or SG) (*n*)	Flap failure (partial or complete) (%)	Other complications	Sensory outcome (S2PD) (mm) (*n*)	Other notes
Mao et al (2020)[19]	10 patients (9 M, 1 F)/10 flaps/10 homodigital thumb flaps	47 (24–60)	DU (10)	Machine injury (8), crush injury (2)	Distal phalanx: thumb tip	Bone and/or tendon	Fasciocutaneous + dorsal collateral nerve neurorrhaphy	PC (6/10) SG (4/10)	Partial (2/10) (distal flap necrosis requiring debridement and SG)	Postoperative venous insufficiency (1) requiring release of suture and hematoma washout	S2PD inferior to normal side	Pinch strength (kg): at 6 mo (affected 3.62 ± 1.77, normal 3.82 ± 1.8, *p*-value 0.175); at 12 mo (affected 3.73 ± 1.85, normal 3.82 ± 1.8, *p*-value 0.137). Grip strength (kg): at 6 mo (affected 27.3 ± 8.3, normal 32.0 ± 11.4, *p*-value 0/186); at 12 mo (affected 28.4 ± 7.12, normal 32 ± 11.4, *p*-value 0.143) At 6–12 mo, grip strength recovered 85% compared with normal side
Adani et al (2019)[22]	4 patients (3 M, 1 F)/4 flaps/4 homodigital thumb flaps	41 (17–54)	DU (4)	Trauma	Dorsum distal phalanx thumb (4)	Periosteum exposed Nail only (2) Nail and skin (2)	Fasciocutaneous	PC (1/4) STSG (3/4)	0%	Nil	NS	All flaps survived, no reported cases of congestion
Han et al (2013)[18]	8 patients (6 M, 2 F)/8 flaps/8 homodigital thumb flaps	35 (21–53)	DU (8)	Crush injuries with amputations (6), avulsion amputations (2)	Distal thumb tip: proximal to germinal matrix Distal to IPJ	Bone (8)	Composite periosteal-fasciocutaneous flaps (pedicled) with bone and nail bed composite grafts from amputate	FTSG (1/1)	0%	Hypertrophic nail plate in distal edge	9.88 (8–11)	Only range of flap size given F/u 6–10 mo (mean 8) No patient complained about the resulting scar, painful neuroma, or persistent cold intolerance
Daniali and Azari (2013)[29]	1 patient (1 M)/1 flap/1 homodigital thumb flap	61 (61)	DU (1)	Distal dorsal SCC of thumb with excision of dorsal cortex of distal phalanx	Distal dorsal thumb	Bone	Fasciocutaneous	Rotational advancement local flap and FTSG (1/1)	0%	0%	NS	
Terán et al (2010)[21]	15 patients/15 flaps/15 homodigital thumb flaps	NS	DU (15)	Thumb volar pulp loss (7), distal amputation (8)	Distal thumb tip and pulp	NS	Fasciocutaneous + ulnar dorsal collateral nerve neurorrhaphy	PC (15/15) STSG to pedicle (15/15)	Marginal necrosis (1/15)	Poor sensory outcome despite reconnection of ulnar dorsal digital nerve to volar digital nerves	5 mm (1) 10 mm (10) Protective sensibility alone (4)	• Technical modifications: • Adipofascial extension • SG over pedicle
Henry (2008)[39]	108 patients (98 M, 10 F)/108 flaps/6 homodigital thumb flaps	36 (NS)	DU (6)	NS	Thumb tip	NS	Fasciocutaneous	NS	0%	Superficial epidermolysis (13/108)[a] Venous congestion (4/108) Second surgery required for 15/108 (debridement, 3; revisions, 3)	NS	Flap failure and complications include all the flaps evaluated in the study[a] Unable to specifically state type of flap for all 19 thumb defects[a]
Cavadas (2003)[24]	1 patient (M)/1 flap/1 homodigital thumb flap	38 (38)	DU (1)	Subacute defect	Dorsum distal phalanx	Bone	Composite osteocutaneous	PC (1/1)	0%	Cosmetic debulking intervention	NS	Case report
Pelissier et al (2001)[20]	3 patients/3 flaps/3 homodigital flaps	31 (25–34)	DU (3)	Osteocutaneous defect: distal	Distal phalanx: thumb tip (3)	Bone and nail bed	Composite osteocutaneous	PC (1/3) FTSG (2/3)	0%	Joint stiffness (2/3)	NS	Skin paddle size (2.5, 4.5, 5) × (1.5, 2.5, 3) Bone grafts size: (1.2, 1.5,

Table 2 (*Continued*)

Study	Number of patients/total number of flaps/homodigital thumb flaps (M/ F)	Mean age for thumb flaps (range)	Blood supply (dorsoulnar or dorsoradial or random) (*n*)	Indication/ etiology (*n*)	Defect location	Structures exposed	Flap type (fasciocutaneous/ adipofascial/ other)	Donor-site closure (PC or SG) (*n*)	Flap failure (partial or complete) (%)	Other complications	Sensory outcome (S2PD) (mm) (*n*)	Other notes
				amputation (2), avulsion injury (1)								1.5) × (0.5, 1, 0.7) Return to work at a mean of 2.3 mo
Brunelli et al (1999)[4]	32 patients/32 flaps/25 homodigital flaps to thumb	NS	DU (25)	NS	Thumb IPJ stump (7) Thumb pulp (12) Dorsal skin loss of proximal phalanx of thumb (6)	NS	Fasciocutaneous ± dorsal collateral nerve neurorrhaphy	PC (12/32) SG (20/32)	Partial loss: 1/25 Complete loss: 1/25 (required further surgery for shortening)	Cosmetic debulking intervention (2/32)	4 mm (1/11), 10 mm (7/11), only protective (3/11)	Slight loss in active motion of thumb MCPJ and webspace opening; did not cause any inconvenience Protective sensation obtained in all pulp and stump thumb reconstructions ($n = 19$) No difference between those with or without nerve reconnection F/u 11 patients with pulp reconstruction for 6 mo minimum.

Abbreviations: DU, dorsoulnar; F/u, follow-up; FTSG, full-thickness skin graft; IPJ, interphalangeal joint; MCPJ, metacarpophalangeal joint; NS, not stated; PC, primary closure; S2PD, static two-point discrimination; SCC, squamous cell carcinoma; SG, skin graft; STSG, split-thickness skin graft.
[a]Not specific to thumb homodigital flaps alone.

Bao and colleagues[28] further explored dorsoradial flap innervation. Six of eight patients had the dorsal collateral branch of the radial nerve included in the pedicle and coapted to the proper digital nerves of the thumb. The mean two-point discrimination (2PD) was 9.6 mm with no improvement with neurorrhaphy. All flaps survived completely. One case reported venous congestion, which settled with removal of sutures. In a mean 8.5-month follow-up, one case developed IPJ flexion deficit of 30 degrees and metacarpophalangeal joint (MCPJ) flexion deficit of 11 degrees compared with the contralateral normal side. The other patients restored to near-normal ROM arc of both joints with deficits less than 5 degrees after rehabilitation.

Sun et al[17] investigated the factors affecting sensory recovery without neurorrhaphy. In 19 patients, those with a group mean flap size of 6.52 cm^2 had a 2PD of 6.9 mm compared with those with a group mean flap size of 9.22 cm^2 with a 2PD of 14.78 mm, thus highlighting the importance of the relationship of flap size and sensory outcome. They reported cold intolerance in six patients and mild pain in flap ($n = 4$) and in donor site ($n = 4$). No statistical difference was found in the ROM of the IPJ and MCPJ between the injured and opposite thumbs.

Qin and colleagues[15] investigated the effects of pedicle width (less or greater than 0.8 cm) on clinical outcomes in 42 cases of dorsoradial homodigital thumb flaps. The narrow pedicle group had less time lost from work (7 vs. 9.6 weeks) and better aesthetic outcome. There were no differences in gender, age, pedicle length, flap size, mean 2PD, MCPJ, and IPJ ROM in both groups.

The mean 2PD for dorsoradial flaps with and without neurorrhaphy was 9.17 mm (range, 6–12; $n = 6$) and 9.6 mm (range, 3–18; $n = 76$), respectively. There were no complete flap failures reported, whereas partial flap failures occurred in 5.5% ($n = 5$) of cases. Donor sites were either closed directly ($n = 42$, 58%), with a skin graft ($n = 17$, 23.6%), or by secondary intention healing ($n = 13$, 18.1%). The main complication reported was venous congestion in 20% ($n = 19$) of cases, which conservatively resolved by removal of stitches. There were no reported revision surgeries required. Mild cold intolerance was reported in 6.6% ($n = 6$) of cases.

Dorsoulnar Flap

Ten articles (74 cases) reported on the use of the dorsoulnar flap for reconstruction of the thumb as osteocutaneous ($n = 12$)[18,20,24] or fasciocutaneous ($n = 62$) flaps,[4,19,21,22,29] with and without dorsal collateral nerve coaptation. The mean patient age was 40 years (range, 3–61) and the sites of reconstruction were as follows: tip (56.7%), pulp (16.2%), dorsal distal phalanx (9.5%), dorsal proximal phalanx (8.1%) and IPJ stump (9.5%). The mean defect size and mean flap size were 4.84 cm^2 (range, 2–9) and 5.8 cm^2 (range, 2–12), respectively. Two articles were considered high risk of bias.[13,29]

Regarding fasciocutaneous flaps, Adani et al[22] explored four approaches, one of which included a reverse-flow homodigital flap, to reconstruct soft-tissue defects to the dorsum of the thumb. They reported no complications in the

Table 3 Summary of thumb homodigital reverse-flow turnover flaps reported in the literature

Study	Number of patients/total number of flaps/homodigital thumb flaps (M/F)	Mean age for thumb flaps (range)	Blood supply (dorsoulnar or dorsoradial or random) (*n*)	Indication/etiology (*n*)	Defect location	Structures exposed	Flap type (fasciocutaneous/adipofascial/other)	Defect size (surface area, cm^2)	Mean defect size length (cm)	Mean defect size width (cm)	Flap size (width)	Donor-site closure (PC or SG) (*n*)	Flap failure (partial or complete) (%)	Other complications	Other notes
Chung et al (2016)[26]	12 patients (11 M, 1 F)/14 flaps/2 homodigital thumb flaps (2 M)	58 (46–71)	Random (2)	Soft-tissue defect (11), boutonniere deformity (1)	Dorsum of thumb (2)	Tendon	Adipofascial	NS	2.25	3.25	0.3–1	PC (2/2)	0%	No complications in thumb flaps	100% skin graft recipient survival
Braga Silva et al (2013)[27]	12 patients (9 M, 3 F)/12 flaps/12 homodigital thumb flaps	29 (22–43)	Random (12)	Trauma (8), tumor (2), burn (2)	Dorsal thumb: just proximal phalanx (4) Proximal and distal phalanx (8)	Bone (8), tendon (4)	Adipofascial	NS	3.07 (flap 10-mm longer than defect)	2.38 (flap 2- to 4-mm wider than defect)	2.68	PC (12/12)	Partial (2/12)	Distal margin necrosis (2): consequently compromising overlying graft (conservative management)	There were no instances of donor-site skin necrosis, postoperative infection at donor or recipient sites, or long-term residual edema of the thumbs 2/12 lost to follow-up 3/12 pre-op superficial infection, 4/12 pre-op bone infection
Al-Qattan (2004)[9]	15 patients (15 M)/15 flaps/2 homodigital thumb flaps	39.5 (22–57)	Random (2)	Industrial injuries (14): associated tuft fracture (1), skin only (1)	Dorsum distal phalanx (1) Dorsum proximal phalanx (1)	Tuft fracture (1)	Adipofascial	NS	NS	NS (flap 2- to 4-mm wider than defect)	NS	PC (2/2)	0%	Presence of nail deformities in patients with nail bed or matrix defects (1/2) No loss of overlying skin graft No epidermolysis	Mean F/u 4 mo (3–6) Flaps were raised superficial to dorsal veins rather than in subdermal plane. All compound fractures healed with no infection or delayed union. No finger or thumb stiffness noted
Al-Qattan (2001)[30]	12 patients (12 M)/12 flaps/4 homodigital thumb flaps (4 M)	35 (20–55)	Random (4)	Industrial injuries: cutting machine/saw (6), rotating belt (3), heat press (3)	Dorsal IPJ thumb (4)	Open IPJ and missing extensor and germinal/sterile matrix defects	Adipofascial	1–2	NS	NS (flap 2- to 4-mm wider than defect)	NS	PC (4/4)	0%	Superficial epidermolysis at donor site with no additional intervention required (5/12).[a] Extension lag (3/12). Nail bed deformities (7/12)	No distinction made between thumb and finger defects

Abbreviations: F/u, follow-up; IPJ, interphalangeal joint; NS, not stated; PC, primary closure; SG, skin graft.
[a]Not specific to thumb homodigital flaps alone.

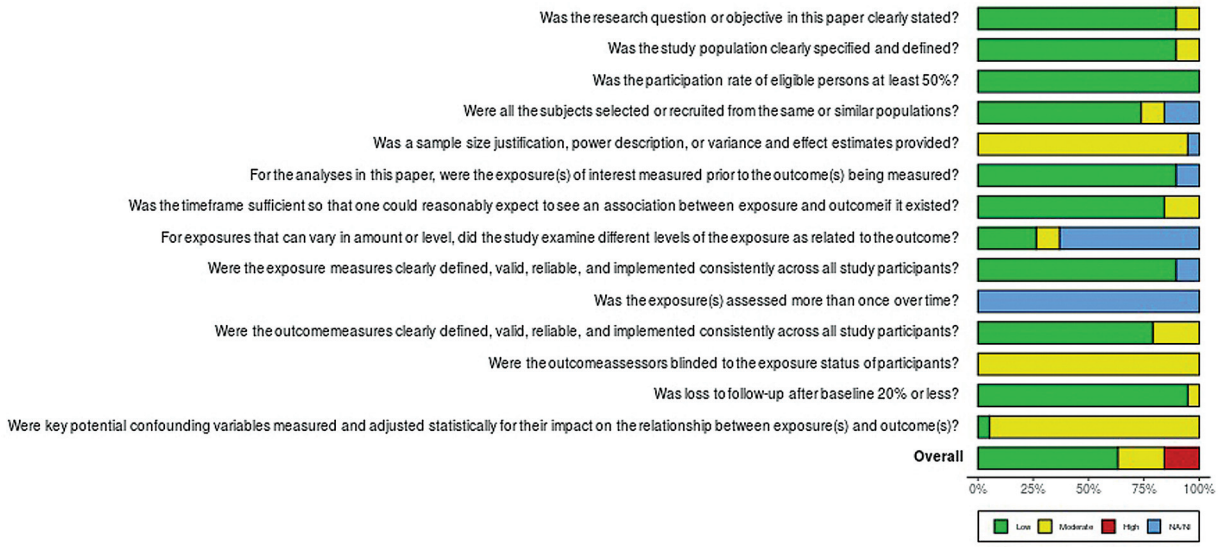

Fig. 5 Summary of the risk of bias assessment as per the criteria from the National Institutes of Health quality assessment tool for observational cohort and cross-sectional studies.

use of this flap to defects affecting the nail and dorsal skin of the distal phalanx. Equally, Daniali and Azari[29] described a case report of a dorsoulnar flap to reconstruct a post–squamous cell carcinoma excision from the dorsal distal phalanx with no reported complications. The donor site was closed with a rotational advancement flap and with a full-thickness skin graft.

Three papers analyzed the composite reverse-flow dorsoulnar flap incorporating the dorsal collateral nerve.[4,19,21] Brunelli at al[4] studied this technique on 25 thumb defects with 1 case of marginal necrosis and 1 case of complete failure (requiring shortening). No difference in sensibility was reported between those with or without nerve reconnection. Mao and colleagues[19] modified the flap tail to an equilateral triangle to facilitate pedicle suturing by applying less tension and reducing venous disorders. Although all flaps survived, one case required hematoma evacuation, while two others had partial postoperative necrosis needing debridement and grafting. At 6- and 12-month follow-up, reconstruction resulted in 85% restoration of grip and comparable pinch strength to the normal side. Terán et al[21] investigated the dorsoulnar flap in 15 patients, while skin grafting the pedicles in all cases, with all flaps achieving primary healing without major complications. One case had marginal necrosis resolving with conservative management. The authors concluded that there was poor sensory outcome despite reconnection of ulnar dorsal digital nerve.

The use of osteocutaneous dorsoulnar flaps was published in three articles.[18,20,24] Pelissier et al[20] introduced this concept to reconstruct thumb tip traumatic injuries using a skin paddle with a mean size of 4×2.3 cm and a mean bone graft (from the neck of first metacarpal) size of 1.4×0.73 cm in three patients. These patients returned to work at 2.3 months, although two patients developed IPJ stiffness. Cavadas[24] described a case report where an 8×5 mm piece of bone was harvested from the neck of the first metacarpal as part of a composite dorsoulnar flap to reconstruct a defect affecting the midthird of the distal phalanx and dorsal skin. A portion of adductor aponeurosis was included in the flap to preserve the osseous branches from the dorsoulnar artery. The patient required cosmetic debulking of the flap. Han et al[18] used composite periosteal-fasciocutaneous pedicled flaps with bone and nail bed composite grafts harvested from the amputate in eight different patients. The only reported complication was hypertrophic nail plate.

In summary, the mean 2PD for dorsoulnar flaps with neurorrhaphy was 9.5 mm (range, 5–10; $n = 11$) and without neurorrhaphy was 9.9 mm (range, 8–11; $n = 8$). There was doubtful benefit to 2PD with nerve coaptation to the proper digital nerves.[4,21] Complete flap failure was reported in one patient (1.5%) that required further surgery for shortening.[25] Partial or marginal necrosis was reported in four patients (6%), of which two required debridement and skin grafting.[19] The donor site was closed directly in 53.7% ($n = 36$) and with a skin graft in 46.3% ($n = 31$). Complications included a hematoma causing venous insufficiency (1.5%), nail plate deformity (1.5%), and need for cosmetic debulking (4.4%).

Turnover Flaps

Four articles (20 flaps) reported on the use of the reverse-flow homodigital thumb flap by turnover movement. These adipofascial flaps were used for thumb defects over the dorsum of the distal phalanx (25%), dorsum of the proximal phalanx (25%), both proximal and distal phalanx (40%), and dorsum of IPJ (20%). The mean patient age was 42 years (range, 20–57). The mean defect size was 7.4 cm^2 (range, 20–57), while the mean flap size was 10.9 cm^2 (range, 7–13.3). No indication was made as to which perforator was responsible for the nutrition of the flap given the random nature of the vascularity. All articles except one were low risk of bias.

Chung et al[26] explored the use of adipofascial flaps for two defects on the dorsum of the thumb measuring an average of 2.3×3.3 cm. Like other papers, they did not report any complications. Braga Silva and colleagues[27] studied this flap in 12

cases with mean sizes of 2.4 × 4.1 cm. The authors were the only to report on ROM in the operated thumb: mean −15.5-degree flexion and −10.1-degree extension at the MCPJ, and −8.6- and −11-degree extension in the IPJ, when compared with the contralateral thumb. They reported distal margin necrosis of 25% of the surface area in two cases compromising the viability of the overlying skin graft. Both healed with conservative management. Al-Qattan[9,30] explored the same flap in two papers demonstrating no complications, except for nail plate deformity in one case. Unfortunately, in his earlier paper,[30] the results from those with defects affecting the long fingers and those affecting the thumb were not separated, thus compromising the ability to extract meaningful data.

All defect sites required skin grafting over the adipofascial flap and donor sites were closed directly. There were no complete flap failures and two (10%) partial flap failures requiring no further operative intervention. One case was complicated by nail deformity.

Discussion

Dorsally based reverse homodigital flaps carry multiple benefits when reconstructing thumb defects, including limiting the donor-site morbidity to the thumb. This holds particularly true in multiple-digital injury, where dissection of vessels of the adjacent fingers may jeopardize their own blood supply. Thus, dorsally based reverse-flow homodigital thumb flaps are useful, dependable, and versatile alternatives for resurfacing soft-tissue defects.

Dorsoradial Flap

The dorsoradial flap provides a fasciocutaneous reconstruction for small thumb defects (mean, 7.48 cm^2) with a pedicle length of approximately 2.3 cm.[15] Its reconstructive sites include the pulp, radial, and dorsal aspect of the distal phalanx, unlike the dorsoulnar flap, which is used mostly for tip injuries, and it holds the possibility of neurorrhaphy of the dorsal collateral nerve to the recipient sites, albeit with no proven benefit.[28]

In addition to its versatility, the dorsoradial flap has a consistent anatomy, donor-site strengths, and low complication rates.[14] Its donor site permits more aesthetically inconspicuous scars than the first webspace dorsoulnar flap, which also results in a reduced risk of limited first web span and thumb MCPJ movements.[28] Additionally, this flap has a high rate of primary closure of donor sites ($n = 42$, 58%), particularly when using a narrower pedicle.[15] And although inconsistent venous flow led to raising the flap with a wider strip of subcutaneous tissue, albeit with no proven difference in venous congestion rates, Qin and colleages[15] demonstrated that narrow-based pedicles (0.7–0.9 cm) also showed favorable outcomes in patient-reported factors, such as aesthetic satisfaction, return to work, and freedom of mobility.

This demonstrates the flap's evolving nature and scope for further modifications; however, it should be avoided in those with extensive scars in the harvesting area or with vascular occlusions of the radial artery.

Dorsoulnar Flaps

The dorsoulnar flap has been reported primarily as a fasciocutaneous flap, with or without nerve coaptation, and occasionally as a composite osteocutaneous reconstruction. It has been used for small defects with a mean of 5.8 cm^2 with only one reported complete flap failure (1.5%) requiring reoperation. Two other cases required further debridement and skin grafting for partial failure. Given the limitations of this review, this is an acceptable rate of flap failure.

Three patients (4.4%) required cosmetic debulking, a recognized consequence due to overlapping of the donor site and pedicle[31]; however, a bulky pedicled flap was not featured in the studies reported.

The functional outcomes displayed promising results. Mao et al[19] demonstrated 85% restoration of grip and pinch strength of the affected hands. Brunelli et al[4] reported a slight loss in active motion of thumb MCPJ and webspace opening but with no inconvenience to their patients. Terán and colleagues[21] highlighted the risk of first webspace contracture and reduced MCP joint ROM when donor sites are larger than 2 × 1 cm.

This flap originates from a constant anatomical supply from the FDMA or dorsal branch of the radial artery. Due to its reliable anatomical site at the level of the neck of the thumb metacarpal, the dorsoulnar flap can be adapted to a composite flap. Three studies reviewed osteocutaneous flaps, which were found to be dorsoulnar based, and harvested the osteal component from the neck of the first metacarpal.[18,20,24] While the case series of Pelissier and colleagues[20] described a high rate of IPJ stiffness, other bone graft case series[18,24] did not report this limitation in thumb motion. The homodigital nature limits its use in more extensive traumatic thumb injuries.

Turnover Flaps

The turnover flap provides an adipofascial reconstruction of dorsal thumb defects, including the distal phalanx and/or proximal phalanx.

The mean defect size of 7.4 cm^2 was larger than the mean dorsoulnar (4.84 cm^2) and dorsoradial (3.88 cm^2) flap. Benefits of the turnover flap include a simple one-stage procedure and minimal donor-site deformity.[27] Results showed that there is a marginally decreased ROM in the MCPJ (mean, −6.5 degrees) and the IPJ of the thumb (mean, −9.5 degrees).[27] Additionally, the adipose component of the flap benefits of the distal thumb, when it is applied over the exposed tendon, as it does not hinder the gliding mechanism.[3] However, this flap is to be avoided in burn injuries, partial degloving, and circumferential crush injuries due to potential vascular compromise.

Braga Silva et al[27] executed a cadaveric study revealing two main dorsal branches of each ulnar and radial proper digital artery emerging nearby the IPJ—one proximal and one distal to the joint. The branching site varies unpredictably, but to avoid vascular compromise, they advocate avoiding dissection 1 cm proximal and distal to the IPJ and taking an extra 2 to 4 mm wider flap than the defect.

Despite not using thumb defects in their series, Idone et al described a fenestrated bipedicled adipofascial turnover flap for distal fingertip injuries, which allows for reconstruction of the nail bed and avoiding terminalization or matrixectomy.[32] In patients with an intact nail lamina, a window is created in the center of the flap and the adipofascial flap is turned over and contoured into the defect, allowing for continuity of the nail bed. Key surgical points include leaving approximately 5 mm of intact tissue just proximal to the nail fold to protect the pedicle and extending laterally the base of the flap so that the window can be created without compromising the flap vascularization.

It is noteworthy that resurfacing the adipofascial flap with a skin graft is not imperative. It is the author's experience that the adipofascial flap itself typically re-epithelializes in approximately 3 weeks with simple wound care, thereby reducing donor-site morbidity.

Chimeric Flaps

A chimeric flap consists of several flaps, each with its independent vascular supply from the same source vessel.[33,34] They offer further flexibility in the use of reverse-flow homodigital flaps for thumb reconstruction.

Hao et al[35] described the repair of distal degloving thumb injuries using both the reverse-flow dorsoradial flap and the proper digital artery island flap of the middle finger. Although the source vessel was not dissected to its origin, the gross perfusion of these flaps originates from the same site. Twelve patients were described with reconstruction of both the palmar and dorsal aspects of the thumb tip. The average 2PD of the reverse dorsoradial flap of the thumb was 9 mm and of the middle finger proper digital arterial island flap was 7 mm. No flap failures were reported. On follow-up, a few patients complained of pain and cold intolerance, but there were no differences in the IPJ and MCPJ thumb ROM as compared with the contralateral.

Chimeric flaps allow coverage of defects involving the dorsal and palmar aspect of the thumb. Their limitations include a steep learning curve and the existence of other flaps that carry less morbidity and technical know-how.

Sensation

Sensate and nontender thumb tip is the foremost goal that surgeons consider when evaluating flaps for thumb reconstruction. The dorsoradial and dorsoulnar flap carry the option of nerve coaptation; however, this increases the risk of neuroma formation, even though it was not reported in any of the included studies.

The mean 2PD for dorsoradial flaps with and without reinnervation was 9.17 and 9.6 mm, while the mean 2PD for dorsoulnar flaps with reinnervation was 9.5 mm and without reinnervation was 9.9 mm. Comparatively, the 2PD of the Foucher flap is between 10 and 15 mm and that of Littler flap ranged from 7 to 10 mm.[23,36–38]

Nerve coaptation in both dorsoradial and dorsoulnar flaps remains controversial; however, there is suggestion that smaller-sized dorsoradial flaps carry a sensate advantage.[17] From this review, there is no conferred benefit of neurorrhaphy based on the sensory outcomes.[14,28]

Complications

One complete flap failure of a dorsoulnar flap was reported in the 189 cases reviewed. Partial flap failure rates were 5.5% in dorsoradial, 6% in dorsoulnar flaps, and 10% in turnover flaps. These relatively low rates emphasize the reliable nature of reverse-flow homodigital flaps.

Venous congestion is a complication of all types of flaps reported in this review. The congestion rate for dorsoradial flaps was 20% and for dorsoulnar flaps it was unreported. In some patients, venae comitantes are present within the pedicle; otherwise, these flaps are thought to be dependent on random pattern venules on the perivascular fascia adipose tissue. This explains the vulnerability for congestion due to excessive compression of the pedicle. Furthermore, the pattern of blood flow in reverse-flow flaps is, as implied, reversed. The venous return typically occurs against the direction of blood flow. The segment of tissue in its native position is designed to drain blood through the end, which, once inset into its new position, is likely the distal tip of the finger and the arterial inflow and venous outflow will likely occur on the same proximal side of the flap. This inherent design means it is natural for the flap to become swollen and undergo a degree of venous congestion as it settles into its new position.

Given that these flaps drain via the venules on the perivascular fascia, most cases reported resolved through conservative management and removal of sutures.[15,28] Generally, there was no noticeable difference in venous congestion by closing the donor-site incision by primary closure or by skin graft cover. To reduce the risk of complications, the authors recommend:

- Dissecting and raising these flaps in a bloodless field, using accurate bipolar diathermy as appropriate.
- The use of a blade for dissection to create clean sweeps of the tissue, as opposed to the use of tenotomy scissors to spread the tissue apart, as this inadvertently damages the tissues and tears microscopic vessels, resulting in swelling.
- Keeping the perivascular sleeve of adipose tissue around the pedicle is important to reduce damage to the delicate concomitant veins.
- Not taking too much adipose tissue with the flap, particularly at its margins. This may create compression with the onset of postoperative swelling as well as make the flap inset challenging.
- Suturing the flap loosely using a minimal number of small-sized sutures. If there are concerns about closure over the pedicle, then the surgeon should perform a delayed inset after a few days or place a skin graft over the pedicle.

Overall, the low complication rates reflected the safe nature of these flaps. There were no reported revision surgeries required for dorsoradial flaps, whereas the dorsoulnar flaps required shortening for the single case of complete failure, in addition to three patients requiring cosmetic debulking. Other minor complications reported

such as mild intolerance or nail deformity were described but were a result of the injury itself.

Limitations

Studying reverse-flow homodigital thumb flaps is challenging due to the lack of high-level evidence, possibly secondary to a deficiency in clinical equipoise. The heterogeneity in outcome reporting of the studies analyzed introduces bias into the narrative synthesis and prevents a more robust quantitative analysis. This systematic review is affected by the same biases affecting the eligible studies. Some studies investigated and presented the results for both homodigital thumb and finger flaps. This left us unable to elucidate the complications specific to thumb reconstruction, thereby reducing the overall number of cases reviewed.[30,39] On evaluation of bias as per the criteria from the NIH quality assessment tool, only three studies had a high risk of bias. There was no uniformity on follow-up time, which varied from 3 to 46 months. The lack of long-term follow-up may underestimate the sensory outcomes of these flaps, as certain outcomes improve with time.[40] We encourage the use of a finger injury outcome tool score to evaluate and compare the functional outcome of fingertip injuries appropriate to the anatomical site of the defect.

Despite these limitations, we have provided a comprehensive systematic review of the currently available literature on thumb reconstruction with reverse-flow homodigital flaps.

Conclusion

Reverse-flow homodigital random or axial-based flaps provide a reliable means of reconstruction for predominantly soft-tissue thumb defects with notable success rates and good functional outcomes. They have consistent anatomy and carry the potential for individualized development. Their versatility can be used to reconstruct composite defects, ranging from soft tissue alone, together with small bone defects, with or without neurorrhaphy. The most prominent complication is venous congestion, which is largely reversible. These flaps are limited by the size of the defect, trauma in the harvesting area of the flap, or vascular occlusions of the radial artery.

Informed Consent

Relevant written consent was obtained for the patient included within this manuscript for teaching and publication purposes.

Conflict of Interest

None declared.

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