Efficacy of Modified Antegrade Digital Artery-Nerve V-Y Island Flap and Bilateral Neurovascular Bundle-Bearing V-Y Island Flap in Repairing Distal Fingertip Defects: A Comparative Analysis

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AIM: Fingertip defects are common injuries in hand surgery, and their functional reconstruction remains a clinical challenge. This study aims to compare the clinical efficacy of the modified antegrade digital artery-nerve V-Y island flap with that of the bilateral neurovascular bundle-bearing V-Y island flap in repairing distal fingertip defects.

METHODS: This single-center retrospective study included 120 patients with distal fingertip defects treated between October 2021 and October 2024. Among them, 50 underwent repair using the modified antegrade digital artery-nerve V-Y island flap (group A), while 70 received the bilateral neurovascular bundle-bearing V-Y island flap (group B). Perioperative metrics (operative time, intraoperative blood loss, hospital stay duration), sensory function (static two-point discrimination [s2-PD], excellent/good rate based on S3+ grading), joint mobility (metacarpophalangeal, proximal interphalangeal, and distal interphalangeal joints), Michigan Hand Outcomes Questionnaire (MHQ) scores, peripheral circulation parameters (transcutaneous partial pressure of oxygen [$TcPO_2$], blood perfusion units [BPU]), and complication rates at 6 months postoperatively were compared between the two groups.

RESULTS: Baseline characteristics showed no statistically significant differences between the two groups ($p > 0.05$). Group A had longer operative times than group B but demonstrated significantly lower intraoperative blood loss and shorter hospital stay ($p < 0.05$). At 6 months postoperatively, group A demonstrated superior s2-PD and a higher excellent/good rate based on S3+ grading ($p < 0.05$); however, there was no significant difference in joint mobility between groups ($p > 0.05$). Compared to group B, group A achieved significantly higher total MHQ scores and subscale scores for hand function, daily activities, work performance, aesthetic appearance, and patient satisfaction, as well as lower pain scores, at 6 months postoperatively ($p < 0.001$). Additionally, $TcPO_2$ and BPU values were higher in group A ($p < 0.001$). No significant between-group difference in overall complication rates was observed ($p > 0.05$).

CONCLUSIONS: Compared to the bilateral neurovascular bundle-bearing V-Y island flap repair surgery, the modified antegrade digital artery-nerve V-Y island flap repair surgery reduces intraoperative blood loss and shortens hospitalization time. This technique offers advantages in sensory recovery, overall hand function, patient satisfaction, and restoration of peripheral circulation without increasing the risk of complications. These results suggest its potential as a more effective reconstructive option for fingertip defects.

Keywords: finger injuries; surgical flaps; treatment outcome; microsurgery

Introduction

Fingertip defects rank among the most common traumatic injuries in hand surgery, frequently caused by lacerations, crush injuries, or stamping accidents [1]. The fingertip is a critical functional unit responsible for precise manipulation and sensory feedback; therefore, injuries to this region—often causing soft tissue loss, exposed phalangeal bone, and concomitant neurovascular damage—can profoundly compromise hand function and overall quality of life of the affected individuals [2]. An ideal reconstruction strategy must simultaneously cover the wound defect, maximize preservation of finger length, restore sensory function, maintain joint mobility, and minimize donor-site morbidity [1,3]. Currently, flap-based repair remains the primary treatment modality for distal fingertip defects [4]. Among these, the V-Y advancement flap is widely adopted at the clinical settings due to its simplicity, minimal invasiveness, and elimination of secondary procedures [5,6]. Despite the matching recipient site's skin texture and the ability to support favorable sensory recovery, advancement distance and coverage capacity of this flap are limited [6,7]. Thus, achieving refined anatomical reconstruction and comprehensive functional restoration of the fingertip continues to pose a significant clinical challenge.

Efficacy of distal fingertip repair has attained substantial enhancement owing to the advancements in microsurgical techniques involving the precise design of local flaps based on vascular anatomy [8,9]. Modifying the classic V-Y flap into an island configuration—incorporating vascular-nervous pedicles—can improve both aesthetic and

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functional outcomes [10,11]. The antegrade digital artery-nerve V-Y island flap, preserving one digital artery and nerve as a pedicle, ensures a reliable blood supply. Extensive mobilization of the vascular leash enables greater advancement, effectively addressing larger defects [12,13]. Conversely, the bilateral neurovascular bundle-bearing V-Y flap leverages dual vascular systems, enhancing perfusion safety while providing additional neural sources for sensory regeneration, thereby promoting sensory and functional recovery [14]. Despite multiple studies validating the efficacy of these two approaches, high-level evidence comparing their outcomes—particularly regarding flap survival rates, sensory recovery, global hand function, and complication profiles—remains scarce [15–18].

To address this gap, we conducted a retrospective study to systematically compare the comprehensive efficacy of the modified antegrade digital artery-nerve V-Y island flap versus the bilateral neurovascular bundle-bearing V-Y flap for distal fingertip reconstruction. By analyzing clinical data from 120 patients, we focused on evaluating differences in flap survival, sensory function, hand function scores, joint mobility, and complication rates between the two groups, aiming to provide evidence-based recommendations for surgical decision-making.

Methods

Study Population

A cohort consisting of 120 patients with distal fingertip defects, who were treated at The First People's Hospital of Linping District between October 2021 and October 2024, was included in this retrospective study. Among them, 50 underwent repair using the modified antegrade digital artery-nerve V-Y island flap (group A), while 70 received the bilateral neurovascular bundle-bearing V-Y island flap (group B). The study protocol was approved by the Ethics Review Board of The First People's Hospital of Linping District (Approval No.: 2024-025), and all procedures were carried out in strict adherence to the principles outlined in the Declaration of Helsinki. All enrolled patients provided written informed consent before participation.

Inclusion and Exclusion Criteria

Inclusion criteria of this study include the following: (1) Age between 18 and 60 years; (2) Fingertip soft tissue defect resulting from trauma (e.g., laceration, crush injury, stamping injury); (3) Fingertip defect with partial exposure of the distal phalanx or nail bed loss; (4) Single-fingertip defect involving the pulp, apex, or obliquely inclined volar/dorsal aspect, without extension beyond the distal interphalangeal joint; (5) At least one intact proper digital artery on the affected side, along with normal function of bilateral proper digital nerves adjacent to the wound, as confirmed by preoperative clinical examination and intraoperative findings; (6) A history of having undergone primary emergency or semi-urgent surgical repair.

Individuals meeting the following conditions were excluded: (1) Severe systemic comorbidities (e.g., uncontrolled diabetes mellitus, coagulation disorders, immunocompromised status, peripheral vascular disease); (2) Grossly contaminated or frankly infected wounds; (3) Segmental destruction of neurovascular bundles precluding flap perfusion or innervation; (4) Concurrent comminuted fracture of the distal phalanx that necessitates tendon insertion repair (extensor/flexor), or joint capsule injury; (5) A history of chronic smoking, psychiatric illness, or poor compliance that would hinder follow-up; (6) Incomplete clinical documentation.

Surgical Methods

Patients of both groups underwent surgery performed by the same team of specialists and surgeons.

Group A: Under brachial plexus block anesthesia or digital root nerve block anesthesia, patients were placed in a supine position with the affected limb abducted. A pneumatic tourniquet was applied to the upper arm to ensure a bloodless surgical field. The fingertip wound was thoroughly debrided, removing contaminated and nonviable tissue. Bone nibblers were used to contour and smooth the fractured phalangeal stump. A triangular flap was designed on the volar non-pressure-bearing side of the injured finger. The key anatomical landmarks for the flap included: the apex of the "V" at the level of the proximal interphalangeal (PIP) joint crease, and the central axis of the flap aligning with the midline of the volar pulp. The width of the flap at its base was designed to be equal to the transverse diameter of the fingertip defect. The length of the flap was sufficient to allow its tip to reach the distal phalangeal stump without tension. The apex angle of the "V" was maintained at $\geq 30°$ to ensure adequate perfusion and tension-free donor site closure. The lateral incision followed the midline of the finger's side to minimize postoperative scar contracture affecting joint mobility. This incision served as one oblique edge of a "V" shape, extending proximally. The aforementioned design principles were strictly adhered to. Under microscopic visualization, sharp dissection was performed from the flap's distal end and sides toward the planned vascular-nervous pedicle (preservation side). The proper digital artery, accompanying veins, and proper digital nerve were carefully identified and dissected. The proper digital nerve was mobilized volarward, preserving its intact dorsal branches within the flap. Microscissors were used to transect longitudinal fibrous septa and dermal attachments beneath the flap until only the vascular-nervous pedicle connected it proximally. After confirming robust flap perfusion, the flap was advanced distally in a rotational manner to cover the phalangeal stump. Care was taken to avoid twisting, tension, or compression of the pedicle. The flap margins were sutured to the wound edges using 5-0 non-absorbable sutures with appropriate stitch intervals to preserve microcirculation. The resulting triangular donor

defect on the finger's side was closed directly by approximating subcutaneous tissues centrally, converting the "V" into a "Y" configuration. Tension-free closure was prioritized; further proximal undermining was performed if necessary.

Group B: Under brachial plexus block anesthesia or digital root nerve block anesthesia, patients were positioned in a supine position with the affected limb abducted. A pneumatic tourniquet was applied to the upper arm to establish a bloodless field. The fingertip wound underwent thorough debridement to excise contaminated and nonviable tissue. Bone nibblers were used to contour and smooth the phalangeal stump. A large "V"-shaped incision was designed on the volar aspect to encompass the defect. The two arms of the "V" started from the junction of the defect and the normal volar skin on each side. These arms extended proximally and converged at a single point on the mid-volar line, which was typically located at the middle-distal third of the middle phalanx. The "V" was designed with an angle of 60°–90°. A wider angle (e.g., 90°) facilitates closure but limits advancement, while a narrower angle (e.g., 60°) allows for greater advancement (typically 10–15 mm) but increases closure tension. Full-thickness skin and subcutaneous tissue were incised along the marked "V," reaching the periosteum while preserving the proximal base of the flap intact. Under microscopic guidance, the distal flap's subcutaneous tissue was meticulously dissected from the germinal matrix at the nail bed base, releasing tethering fibrous septa and fascial bands that restrict forward advancement. Using tissue forceps or manual traction, the entire flap was advanced anteriorly (toward the fingertip). The advanced flap's distal end was secured to the residual nail/nail bed or volar skin margin via interrupted sutures. A critical anchoring stitch using 5-0 monofilament non-absorbable nylon suture was placed between the flap's furthest tip and the nail/nail bed remnant or adjacent volar skin. Subsequently, the flap's bilateral edges were approximated to the wound margins in a proximal-to-distal sequence. Following advancement, a triangular donor defect formed proximally at the original "V" site. Closure began with approximating the apex of the triangle to the most proximal point of the "V" incision (transforming the "V" into a "Y" configuration). The bilateral sides of the triangular defect were then closed by direct opposition. If significant tension occurred during closure, extensive subcutaneous undermining was performed to mobilize the surrounding skin.

After tourniquet release, flap viability was postoperatively assessed in terms of color, capillary refill, turgor, and distal perfusion. The incision was covered with petrolatum gauze, loosely dressed, with a window over the tip for continuous monitoring. A standardized postoperative protocol was strictly followed for all patients (group A and group B):

1. Pharmacological management: (a) Infection prophylaxis: Intravenous cefazolin sodium (H31020824, Xinya Pharmaceutical Co., Ltd., Shanghai, China) was given to all patients (1 g, every 8 hours), commencing 30–60 min preoperatively and continuing for 24 hours postoperatively. For patients with penicillin or cephalosporin allergy, intravenous clindamycin (H20020153, Chongqing Lummy Pharmaceutical Co., Ltd., Chongqing, China) (0.6 g, every 12 hours) was administered instead. (b) Analgesia: Routine oral celecoxib capsules (200 mg, every 12 hours) were prescribed for baseline pain control for 5–7 days. For patients with severe pain (visual analog scale score $\geq$4), sustained-release tramadol tablets (20180327, Pfizer Inc., New York, NY, USA) (50 mg, orally) were provided as rescue analgesia. (c) Anti-vasospastic therapy: Intravenous alprostadil (H23023075, Hagaoke White Swan Pharmaceutical Group Co., Ltd., Harbin, China) (10 μg, once daily) was administered routinely for 5–7 days to improve microcirculation and prevent vascular crisis.

2. Rehabilitation protocol: Rehabilitation commenced on postoperative day 3. Patients were instructed to perform passive and active range-of-motion exercises for the non-immobilized joints (wrist and metacarpophalangeal joints) with the dressing in place. Sutures were removed around postoperative day 14. Upon confirmation of satisfactory wound healing, systematic active and passive flexion-extension exercises of the affected finger's interphalangeal joints were initiated. Patients were advised to perform three sets of 10–15 repetitions daily and were encouraged to use the injured hand in activities of daily living as tolerated. The affected limb was elevated to reduce edema. Strict smoking cessation was enforced for all smokers. Dressings were changed regularly to monitor the wound.

Observation Indicators

(1) Baseline data: Data on age, gender, cause of injury, side of injured finger, type of injured finger, time interval from injury to surgery, and finger defect size of the patients were collected.

(2) Perioperative indicators: Operative time, intraoperative blood loss, and postoperative length of hospital stay were recorded.

(3) Static two-point discrimination (s2-PD) test: The s2-PD test was conducted at 6 months postoperatively. During the test, a blunt-tipped tactile gauge (magnetic needle) was applied to the flap while patients, with their eyes closed, remained in a stationary position. The device was advanced distally from proximal to distal, gradually reducing the distance between its two tips. Patients reported immediately upon perceiving either one or two distinct points. This procedure was repeated until discriminatory capacity ceased, and the shortest discernible distance was recorded [19].

(4) Sensory function grading: Sensory recovery of the affected finger at 6 months postoperatively was classified according to the Medical Research Council (MRC) scale (S0–S4): S4: Normal sensation; S3+: Restoration of useful discriminative perception; S3: Complete tactile sensitivity without abnormal/crude discrimination; S2: Par-

Table 1. Comparisons of baseline and clinical characteristics between the two groups.

Characteristic	Group A (n = 50)	Group B (n = 70)	t/χ^2-value	p-value
Gender (male)	38 (76.00)	57 (81.43)	0.521	0.470
Age (years)	43.78 ± 8.75	44.80 ± 9.68	0.592	0.555
Cause of injury				
Twisting	17 (34.00)	19 (27.14)	0.653	0.419
Crushing	14 (28.00)	23 (32.86)	0.323	0.570
Cutting	19 (38.00)	28 (40.00)	0.049	0.825
Side of the injured finger			0.219	0.640
Right side	30 (60.00)	39 (55.71)		
Left side	20 (40.00)	31 (44.29)		
Type of injured finger				
Thumb	10 (20.00)	13 (18.57)	0.038	0.845
Index finger	11 (22.00)	18 (25.71)	0.220	0.639
Middle finger	21 (42.00)	27 (38.57)	0.143	0.705
Ring finger	5 (10.00)	9 (12.86)	0.231	0.631
Little finger	3 (6.00)	3 (4.29)	Fisher	0.693
Interval between injury and operation (h)	6.37 ± 1.87	6.59 ± 1.97	0.616	0.539
Finger defect size (cm^2)	2.44 ± 0.67	2.39 ± 0.60	0.429	0.669

Table 2. Comparisons of perioperative indicators between the two groups.

Indicator	Group A (n = 50)	Group B (n = 70)	t-value	p-value
Operative time (min)	46.57 ± 9.23	41.36 ± 7.76	3.349	0.001
Intraoperative blood loss (mL)	38.56 ± 6.43	45.18 ± 8.64	4.584	<0.001
Postoperative length of hospital stay (d)	7.62 ± 1.82	8.58 ± 2.14	2.575	0.011

Table 3. Comparisons of s2-PD and sensory function grade between the two groups.

Parameter	Group A (n = 50)	Group B (n = 70)	t/χ^2-value	p-value
s2-PD (mm)	5.24 ± 1.36	8.78 ± 2.25	9.901	<0.001
S3+ or higher sensory recovery grades	96.00% (48/50)	84.29% (59/70)	4.143	0.042

Abbreviation: s2-PD, static two-point discrimination.

Table 4. Comparisons of interphalangeal joint mobility between the two groups.

Mobility of different joint types	Group A (n = 50)	Group B (n = 70)	t-value	p-value
Metacarpophalangeal joint mobility (°)	84.78 ± 8.25	85.57 ± 9.19	0.484	0.629
Distal interphalangeal joint mobility (°)	85.53 ± 6.17	86.32 ± 7.25	0.625	0.533
Proximal interphalangeal joint mobility (°)	90.35 ± 10.73	89.16 ± 8.69	0.670	0.504

tial pain/touch sensitivity with hypersensitivity/paresthesia; S1: Deep pain sensitivity only; S0: No sensation [19].

(5) Interphalangeal joint mobility: At 6 months postoperatively, the active range of motion of the affected finger's joints—including the metacarpophalangeal joint, interphalangeal joint, and proximal interphalangeal joint—was measured using a handheld goniometer.

(6) Michigan Hand Outcomes Questionnaire (MHQ) scores: The MHQ was administered at 6 months postoperatively to evaluate limitations and satisfaction in daily life. The validated questionnaire comprises 37 items across 6 subscales: pain, overall hand function, activities of daily living (ADL), work performance, aesthetic appearance, and patient satisfaction with hand function. Raw scores for each subscale were converted to a 0–100 scale using standardized algorithms. Higher scores indicate greater impairment on the pain subscale and better performance on other subscales [20].

(7) Peripheral circulation status: At 6 months postoperatively, transcutaneous partial pressure of oxygen ($TcPO_2$) in the affected finger was measured with a dedicated $TcPO_2$ monitor. Simultaneously, microvascular blood perfusion

Table 5. Comparisons of MHQ scores between the two groups.

MHQ domain	Group A ($n = 50$)	Group B ($n = 70$)	t-value	p-value
Overall hand function	88.48 ± 5.61	83.14 ± 6.42	4.730	<0.001
ADL	86.36 ± 5.55	81.74 ± 7.04	3.861	<0.001
Pain	9.82 ± 2.55	14.56 ± 4.16	7.150	<0.001
Work performance	80.04 ± 8.44	73.23 ± 11.17	3.632	<0.001
Aesthetic appearance	85.36 ± 6.79	78.91 ± 8.62	4.403	<0.001
Patient satisfaction	87.90 ± 5.62	80.51 ± 9.00	5.132	<0.001
Total score	86.46 ± 1.84	80.57 ± 3.11	11.970	<0.001

Abbreviations: ADL, activities of daily living; MHQ, Michigan Hand Outcomes Questionnaire.

(reported in blood perfusion units (BPU)) was assessed using a laser Doppler flowmetry system [21].

(8) Postoperative complications: Complications within 6 months of follow-up included flap necrosis, wound infection, vascular compromise, flap bulkiness, and joint stiffness.

Flap viability and necrosis were assessed based on color, temperature, turgor, capillary refill, and Doppler ultrasound findings. Viable flaps appeared pink/red, warm, elastic, and exhibited brisk capillary refill, whereas necrotic flaps presented as pale, mottled/cyanotic/black, cold, poorly turgid, lacked capillary refill, and/or showed thrombosed vessels with swelling/purulence.

Vascular compromise was evaluated, encompassing both arterial and venous crises. Venous crisis was characterized by sudden cooling of the transplanted finger, skin pallor replacing erythema, absent nail bed/capillary refill, digital muscle atrophy, absence of bleeding at the wound tip, and slow dark venous leakage, indicating venous obstruction. Arterial crisis was characterized by feeble pallor, coldness, absent capillary refill, and loss of arterial Doppler signal, suggestive of spasm or thrombosis [22].

Statistical Analysis

All data were analyzed using SPSS version 26.0 (IBM Corporation, Armonk, NY, USA). The Kolmogorov–Smirnov test was employed to assess the data normality of continuous variables. The independent samples t-test was utilized to perform group comparisons for data conforming to a normal distribution, which are expressed as mean ± standard deviation. The Pearson χ^2-test, or Fisher's exact test where appropriate, was employed to analyze differences in data of categorical variables, which are expressed as frequencies and percentages. Two-sided p-values were reported, with $p < 0.05$ considered statistically significant.

Results

Baseline and Clinical Characteristics

There were no statistically significant differences between group A and group B in terms of gender, age, cause of injury, side of injured finger, type of injured finger, time interval from injury to surgery, or finger defect size ($p > 0.05$), indicating comparability between the two groups. Details are presented in Table 1.

Perioperative Indicators

As shown in Table 2, the operative time in group A was significantly longer than that in group B. Additionally, group A experienced significantly lower intraoperative blood loss and shorter hospital stays compared to group B ($p < 0.05$).

Sensory Function Recovery

At 6 months postoperatively, group A exhibited significantly improved s2-PD relative to group B ($p < 0.05$). Additionally, the proportion of patients achieving S3+ or higher sensory recovery grades was considerably higher in group A ($p < 0.05$), as shown in Table 3.

Interphalangeal Joint Mobility

At 6 months postoperatively, there were no statistically significant differences between group A and group B in metacarpophalangeal joint mobility, distal interphalangeal joint mobility, or proximal interphalangeal joint mobility ($p > 0.05$), as presented in Table 4.

Michigan Hand Outcomes Questionnaire Scores

At 6 months postoperatively, the total MHQ score in group A was markedly higher than that in group B ($p < 0.001$). Subscale evaluations revealed that group A had better outcomes than group B in overall hand function, ADL, work performance, pain, aesthetic appearance, and patient satisfaction ($p < 0.001$). Details are presented in Table 5.

Peripheral Circulation

At 6 months postoperatively, injured fingers in group A exhibited significantly higher $TcPO_2$ and BPU levels compared to those in group B ($p < 0.001$), as shown in Table 6.

Postoperative Complications

Within 6 months postoperatively, the complication rate was 6.00% (3/50) in group A and 11.43% (8/70) in group B, with no statistically significant difference between the two

Table 6. Comparisons of peripheral blood circulation between the two groups.

Group	Group A (n = 50)	Group B (n = 70)	t-value	p-value
$TcPO_2$(mmHg)	85.62 ± 5.47	74.83 ± 4.42	11.933	<0.001
BPU (mL/min/100 g)	211.36 ± 24.81	194.37 ± 22.24	3.931	<0.001

Abbreviations: BPU, blood perfusion units; $TcPO_2$, transcutaneous partial pressure of oxygen.

Table 7. Comparison of postoperative complications between the two groups.

Group	Group A (n = 50)	Group B (n = 70)	χ^2-value	p-value
Flap necrosis	1 (2.00)	1 (1.43)		
Wound infection	1 (2.00)	2 (2.86)		
Vascular compromise	0 (0.00)	2 (2.86)		
Flap bulkiness	0 (0.00)	2 (2.86)		
Joint stiffness	1 (2.00)	1 (1.43)		
Total	3 (6.00)	8 (11.43)	0.483	0.487

groups ($p > 0.05$). However, group A demonstrated a relative advantage in complication control, particularly in avoiding vascular crises and flap bulkiness. Details are presented in Table 7.

Discussion

This study retrospectively compared the clinical efficacy of the modified antegrade digital artery-nerve V-Y island flap (group A) versus the bilateral neurovascular bundle-bearing V-Y flap (group B) in repairing distal fingertip defects. Results demonstrated that although group A required longer operative time, the flap used in this group of patients outperformed the bilateral neurovascular bundle-bearing V-Y flap utilized in group B, in terms of intraoperative blood loss, hospitalization duration, sensory recovery, digital perfusion, patient-reported outcomes, and overall hand function, with a trend toward fewer complications.

The significantly prolonged operative time in group A stemmed from its requirement for delicate dissection and preservation of the digital artery-nerve bundle to ensure antegrade vascular supply and neural innervation to the flap. This technique is technically demanding, necessitating high surgical expertise. In contrast, group B's approach—utilizing blunt dissection to protect bilateral neurovascular bundles—is relatively simpler and more conventional, thereby reducing operative time. However, to achieve adequate flap advancement and safeguard neurovascular structures, extensive subcutaneous undermining is often required in patients of group B, resulting in larger wound surfaces and consequently greater intraoperative exudation and blood loss compared to group A. The minimally invasive nature of group A's technique was associated with less tissue trauma, milder postoperative pain (corroborated by MHQ scores), and shorter hospital stays, indicating faster postoperative recovery in patients receiving this kind of treatment.

At 6 months postoperatively, group A showed significantly superior s2-PD and higher rates of excellent/good sensory recovery (S3+ grade or above). This advantage is likely attributed to preservation and antegrade coaptation of digital nerves achieved with the technique used in group A, which maximizes neural continuity, as well as facilitates sensory fiber regeneration and functional recovery [23]. While group B's technique is excellent at preserving bilateral neurovascular bundles, the efficiency of sensory regeneration may be compromised due to nerve traction, displacement, and disruption of vasa nervorum during flap advancement [24].

Joint mobility serves as a critical metric for assessing hand function recovery [25]. Active range of motion at the metacarpophalangeal, proximal interphalangeal, and distal interphalangeal joints revealed no significant differences between the two groups of patients. Both techniques involve the use of local advancement flaps designed to cover defects while preserving normal finger architecture and function [26]. Neither procedure requires extensive tendon sheath release, capsulotomy, or prolonged internal fixation, accounting for their comparable joint mobility outcomes.

In this study, the affected fingers in group A exhibited higher $TcPO_2$ and BPU compared to group B, indicating superior flap revascularization and improved physiological recovery of the fingertip. In group A, treatment involved a single subcutaneous pedicle V-Y advancement flap, wherein pedicle skin grafting neither compromised perfusion nor compressed neurovascular structures [27]. Furthermore, the apex angle of the "V"-shaped incision in group A was designed to be $\geq$30°, ensuring adequate flap perfusion while enabling tension-free donor site closure, thereby optimizing arteriovenous circulation. Although group B relied on dual neurovascular bundles for a reliable blood supply, its hemodynamic efficiency and venous drainage were potentially inferior to the flap used in group A [11].

Regarding MHQ assessments, group A showed greater improvements, surpassing group B in total scores and all subdomains (overall function, daily activities, work performance, pain, aesthetics, and patient satisfaction), demonstrating excellence of the flap used not only in objective metrics but also in subjective patient experiences. Superior sensory and perfusion recovery in group A laid the foundation for functional outcomes; lower pain scores likely reflect refined protocols in neural handling and minimal tissue trauma; and improved cosmesis, achieved through flap designs that conform to normal fingertip contours and avoid bulkiness, contributed to higher patient satisfaction. A recent study corroborates that modified island flaps incorporating digital nerves effectively reconstruct complex tip defects involving pulp and nail beds, yielding favorable long-term morphofunctional outcomes [10].

While the overall complication rates showed no statistical difference between the two groups, group A demonstrated advantages in severe complications such as vascular crises and flap bulkiness. The absence of vascular crises in group A likely reflects the reliability and low-tension dynamics of its antegrade vascular design, while the reduced flap bulkiness probably stemmed from thinned flap configurations that align with fingertip anatomy. Higher complication rates in group B suggest potential risks related to vascular stability and flap adaptability [11].

This study has several limitations. Firstly, inherent selection bias and measurement bias are unavoidable due to its retrospective design. For instance, we cannot entirely rule out the influence of 'surgeon skill level' as a potential confounding factor. Nevertheless, this type of bias was somewhat mitigated by having all surgeries performed by a uniformly trained team following standardized protocols, with case allocation according to a non-selective principle. Secondly, the relatively small sample size from a single center limits the generalizability of the findings. More importantly, a limited sample size resulted in reduced statistical power for analyzing outcomes with small intergroup differences, such as complication rates, thereby increasing the risk of Type II error; therefore, complication-related results that lack statistical significance should be interpreted with caution. Furthermore, a longer longitudinal follow-up is required to comprehensively assess long-term sensory recovery and flap efficacy. In summary, multicenter prospective randomized controlled trials (RCTs) involving larger samples are warranted to further validate the conclusions of this study and investigate the long-term efficacy of the tested flaps.

Conclusions

The modified antegrade digital artery-nerve V-Y island flap exhibits significant clinical advantages over the bilateral neurovascular bundle-bearing V-Y flap in repairing distal fingertip defects. While ensuring a reliable blood supply, it not only markedly improves sensory function, overall hand function, and peripheral microcirculation but also effectively reduces intraoperative blood loss and hospitalization time without augmenting complication risks. Therefore, the modified antegrade digital artery-nerve V-Y island flap represents an effective approach that balances blood supply, sensory reconstruction, and aesthetic outcomes, supporting its preferential use and broader clinical application. Future multicenter prospective studies are warranted to further validate its long-term efficacy and cost-effectiveness.

Availability of Data and Materials

The data analyzed are available from the corresponding author upon reasonable request.

Author Contributions

GL designed the research study and wrote the first draft. YY performed the research. YY analyzed the data. Both authors have been involved in revising the manuscript critically for important intellectual content. Both authors gave final approval of the version to be published. Both authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

The study protocol was approved by the Ethics Review Board of The First People's Hospital of Linping District (Approval No.: 2024-025), and all procedures were carried out in strict adherence to the principles outlined in the Declaration of Helsinki. All enrolled patients provided written informed consent before participation.

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Conflict of Interest

The authors declare no conflict of interest.

References

[1] Ma J, Ding Y, Xu L, Zou H, Wu J, Shen L, *et al*. Repair of fingertip defect with reverse digital artery island flap and repair of donor site with digital dorsal advancement flap. Frontiers in Surgery. 2023; 10: 1127356. https://doi.org/10.3389/fsurg.2023.1127356.

[2] Zhang Y, Wang Y, Zhou J, He X, Wu R. Clinical Application of a Modified Local Transposition Flap (Parallelogram Flap) Surgery in Repairing Fingertip Defects. Annals of Plastic Surgery. 2022; 89: 510–516. https://doi.org/10.1097/SAP.0000000000003283.

[3] Wang X, Lv J, Liu S, Xu S, Yan G. Effect of dorsal nerve fascial island flap on repairing distal soft tissue defects at the proximal segment of the index, middle, ring, and little fingers. Journal of Orthopaedic Surgery and Research. 2022; 17: 413. https://doi.org/10.1186/s13018-022-03309-9.

[4] Lu H, Peng H, Peng Z, Liu D, Wu Q, Liu R. The Application of Digital Design Combined with 3D Printing Technology in Skin Flap Transplantation for Fingertip Defects during the COVID-19 Epidemic. BioMed Research International. 2021; 2021: 5554500. https://doi.org/10.1155/2021/5554500.

[5] Dou H, Zhang X, Chen Y, Xiang G, Zhou F. Resurfacing the complex finger defect and sensation reconstruction with the free distal ulnar artery perforator flap: a self-controlled case series study. Annals of Translational Medicine. 2022; 10: 543. https://doi.org/10.21037/atm-22-1975.

[6] Yang ZL, Peng YH, Yang C, Cheng B, Ji MK, Zhao Y. Preoperative Evaluation of V-Y Flap Design Based on Computer-Aided Analysis. Computational and Mathematical Methods in Medicine. 2020; 2020: 8723571. https://doi.org/10.1155/2020/8723571.

[7] Sano K, Ozeki S, Kimura K, Hyakusoku H. Relationship between sensory recovery and advancement distance of oblique triangular flap for fingertip reconstruction. The Journal of Hand Surgery. 2008; 33: 1088–1092. https://doi.org/10.1016/j.jhsa.2008.02.022.

[8] Hodea FV, Hariga CS, Bordeanu-Diaconescu EM, Cretu A, Dumitru CS, Ratoiu VA, *et al*. Assessing Donor Site Morbidity and Impact on Quality of Life in Free Flap Microsurgery: An Overview. Life (Basel, Switzerland). 2024; 15: 36. https://doi.org/10.3390/life15010036.

[9] Pak CS, Jeon JI, Myung Y, Lee YK, Kim BJ, Jeong JH, *et al*. Palmar Ulnar Artery Perforator Free Flap for Fingertip Reconstruction: Anatomical and Clinical Study. BioMed Research International. 2018; 2018: 2862879. https://doi.org/10.1155/2018/2862879.

[10] Huang Y, Lin F, Hao CY, Liang JL, Zhou DP, Wang HY. Effects of modified proper digital artery island flap in repairing complex fingertip defects. Zhonghua Shao Shang Yu Chuang Mian Xiu Fu Za Zhi. 2023; 39: 947–952. https://doi.org/10.3760/cma.j.cn501225-20230109-00008.

[11] Mohsen I, Mahmoud M, Shaheen A. Modified Bilateral V-Y Rotation Advancement Flap for Coverage of Fingertip Amputations. The Journal of Hand Surgery Asian-Pacific Volume. 2022; 27: 1013–1020. https://doi.org/10.1142/S2424835522500977.

[12] Su PH, Hsu CE, Ho TY, Wei BH, Wang WC, Chiu YC. Mathematical analysis in the design of digital artery-based V-Y advancement flap in treating proximal interphalangeal joint flexion contracture. BMC Musculoskeletal Disorders. 2023; 24: 33. https://doi.org/10.1186/s12891-023-06158-7.

[13] Shenqiang Q, Zengtao W, Jingguo C, Di Z, Jun S, Wei K, *et al*. Anatomical research and clinical application of multistage advancement in dorsal finger V-Y flap. Journal of Plastic Surgery and Hand Surgery. 2024; 59: 132–140. https://doi.org/10.2340/jphs.v59.41373.

[14] Jayachandiran AP, Rajendran S, Ananthappan M, Mahipathy SRRV, Durairaj AR. "Flap-in-Flap" Technique: Double V-Y Flap in Fingertip Injury Management. Indian Journal of Plastic Surgery: Official Publication of the Association of Plastic Surgeons of India. 2024; 57: 364–371. https://doi.org/10.1055/s-0044-1787278.

[15] Siriwittayakorn W, Siritattamrong W. Dorsal V - Y Advancement Flap for Lateral Finger Defect Based on Dorsal Skin Branch of Proper Digital Artery. Techniques in Hand & Upper Extremity Surgery. 2023; 27: 165–168. https://doi.org/10.1097/BTH.0000000000000431.

[16] Wang H, Yang XX, Wang B, Huo YX, Chang H, Yang SH, *et al*. Effect of venous anastomosis of the pedicled digital artery dorsal branch island flap in repairing fingertip or pulp defects of the same finger. Zhonghua Shao Shang Za Zhi = Zhonghua Shaoshang Zazhi = Chinese Journal of Burns. 2020; 36: 1065–1069. https://doi.org/10.3760/cma.j.cn501120-20191113-00427. (In Chinese)

[17] Estoppey D, Pomares G, Jager T. Long-term outcome of a "short" anterograde homodigital neurovascular island flap with a simple or double V-Y plasty. Orthopaedics & Traumatology, Surgery & Research: OTSR. 2021; 107: 102981. https://doi.org/10.1016/j.otsr.2021.102981.

[18] Sungur N, Kankaya Y, Yıldız K, Dölen UC, Koçer U. Bilateral V-Y rotation advancement flap for fingertip amputations. Hand (New York, N.Y.). 2012; 7: 79–85. https://doi.org/10.1007/s11552-011-9389-6.

[19] O'Brien M. Aids to the examination of the peripheral nervous system: 6th edition. Practical Neurology. 2023; 23: 263–264. https://doi.org/10.1136/pn-2022-003686.

[20] Chung KC, Pillsbury MS, Walters MR, Hayward RA. Reliability and validity testing of the Michigan Hand Outcomes Questionnaire. The Journal of Hand Surgery. 1998; 23: 575–587. https://doi.org/10.1016/S0363-5023(98)80042-7.

[21] Belcaro G, Cesarone MR, Nicolaides AN, Geroulakos G, Di Renzo A, Milani M, *et al*. Improvement of microcirculation and healing of venous hypertension and ulcers with Crystacide. Evaluation of free radicals, laser Doppler flux and PO2. A prospective-randomized-controlled study. Angiology. 2003; 54: 325–330. https://doi.org/10.1177/000331970305400308.

[22] Wang X, Wang W, Liu J, Li X. Clinical application and influencing factors of free flap transplantation for the reconstruction of skin and soft tissue defects: A retrospective cohort study. Medicine. 2025; 104: e42976. https://doi.org/10.1097/MD.0000000000042976.

[23] Wei P, Chen W, Mei J, Ding M, Yu Y, Xi S, *et al*. Repair of Fingertip Defect Using an Anterograde Pedicle Flap Based on the Dorsal Perforator. Plastic and Reconstructive Surgery. Global Open. 2016; 4: e730. https://doi.org/10.1097/GOX.0000000000000732.

[24] Higgins GC, Thomson SE. Peripheral nerve regeneration: The resolution revolution. Journal of Plastic, Reconstructive & Aesthetic Surgery: JPRAS. 2021; 74: 223–243. https://doi.org/10.1016/j.bjps.2020.08.118.

[25] Li J, Liu J, Li C, Zhang H, Li Y. Wearable Wrist Movement Monitoring Using Dual Surface-Treated Plastic Optical Fibers. Materials (Basel, Switzerland). 2020; 13: 3291. https://doi.org/10.3390/ma13153291.

[26] De Ruiter BJ, Finnan MJ, Miller EA, Friedrich JB. Fingertip Injuries: A Review and Update on Management. The Journal of the American Academy of Orthopaedic Surgeons. 2024; 33: 961–970. https://doi.org/10.5435/JAAOS-D-24-00818.

[27] Appukuttan A, Ragoowansi R. The unilateral perforator V-Y flap for fingertip reconstruction-a versatile technique. JPRAS Open. 2019; 23: 1–7. https://doi.org/10.1016/j.jpra.2019.10.004.