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Results of innervated digital artery perforator flap and direct-flow homodigital flap application in fingertip soft tissue amputations

Numan Atilgan[1*] and Numan Duman[2]

Abstract

Objective The purpose of this study is to compare the results of the innervated digital artery perforator (IDAP) flap and the direct-flow homodigital flap as reconstruction methods for fingertip soft tissue amputations. This issue is important in hand surgery, and we aim to identify the method that provides the best functional and cosmetic outcomes.

Methods Between 2020 and 2022, 32 patients with fingertip amputations were reconstructed by the same surgeon using two different methods. The patients were retrospectively divided into two groups: those who underwent IDAP ($n=14$) and those who had a direct-flow homodigital flap ($n=18$). We compared the groups in terms of defect size, cold intolerance, venous congestion, Sollerman hand function test scores, Seddon sensory test scores, and follow-up periods, as well as flap viability, flexion contracture, and static two-point discrimination (s2PD).

Results Of the 32 patients (26 men, 6 females; age: mean 28.72 ± 11.5 years), the injuries were caused by different mechanisms, including sharp (57.1% IDAP), crush (75% IDAP) and entanglement (66.7% homodigital). The average area of tissue loss was approximately 2.70 ± 1.37 cm^2, while the average s2PD measurement was approximately 4.94 ± 1.04 mm. Postoperatively, the Seddon sensory test results for the homodigital flap group were S4 (61.5%), S3 (23.1%), S3+ (7.7%), and S2 (7.7%), compared to the IDAP group, which showed S4 (57.9%), S3+ (21.1%), and S3 (21.1%). Complications occurred in five patients, though no flap loss or revision was required. The postoperative mean Sollerman hand function scores were higher for the homodigital group than for the IDAP group, with values of 75 ± 2.64 and 73 ± 3.34, respectively. Although not statistically significant, the results numerically suggest that the IDAP flap is better in terms of sensory recovery and hand function compared to the homodigital flap ($p>0.05$).

Conclusions This is the first investigation to compare direct-flow flaps with IDAP. The average follow-up period for patients who underwent homodigital surgery was also shorter than that of the IDAP group. Furthermore, the mean postoperative two-point discrimination and postoperative Sollerman function score were higher in patients who had homodigital surgery.

*Correspondence:
Numan Atilgan
doktor_dao@hotmail.com

Full list of author information is available at the end of the article

Keywords Soft tissue amputations, Innervated digital artery perforator, Direct-flow homodigital flap, Sollerman function score

Introduction

Fingertip injuries, which are the most common type of finger injury and affect people of all ages, can result in significant aesthetic loss and impact daily activities. These injuries can cause considerable disability and a reduced quality of life, highlighting the need for reliable and efficient reconstruction methods [1]. Fingertip injuries are highly prevalent both at work and at home due to their frequent occurrence. The severity can range from minor cuts to severe amputations, often requiring extensive surgical procedures to restore function and aesthetics. Timely management is crucial to reduce long-term disability and support the return to daily routines and employment for those affected [1–4]. Various reconstruction techniques have been developed to address large-scale fingertip injuries where bones, joints, and tendons are exposed [4]. Included in these methods are composite grafts, local advancement flaps, homodigital/heterodigital neurovascular island flaps, perforator flaps and free flaps. However, all these methods have limitations, such as small skin flaps, poor nerve sensitivity, donor area morbidity, limited flexion movements, long-term limb immobilization, and delayed return to work. Therefore, Koshima et al. described a technique for closure of fingertip defects, namely the innervated digital artery perforator (IDAP) flap [5]. The IDAP flap is a proximal-based neurovascular island flap that can rotate into the defect and provides sensory reconstruction for fingertip defects.

Moberg and Littler described an "Antegrade flow island flap" for fingertip soft tissue reconstructions [6, 7]. In 1960, Peacock described the antegrade flow digital artery flap [8]. The antegrade flow digital artery flap is a reconstruction method that can create tissue with a versatile and good sense of sensation in critical soft tissue defects.

Direct-flow homodigital flap and IDAP flap have advantages and disadvantages in fingertip soft tissue amputations. Donor site morbidity complications are less with IDAP flap, two-point separation will be better after surgery with the application of direct-flow homodigital flap, plastic surgeries performed with IDAP flap bring shorter surgery times and faster recovery periods to patients [9]. A comparison between the advantages and disadvantages of using either of these two techniques (IDAP and direct-flow homodigital flap) is needed.

The aim of this study is to address this gap by comparing the innervated digital artery perforator (IDAP) flap with the direct-flow homodigital flap in fingertip soft tissue amputations, focusing on functional and sensory outcomes, as well as the required postoperative recovery time.

Materials and methods

Study design and patient selection

Between 2020 and 2022, 32 patients who presented with fingertip amputations underwent reconstruction by the same hand surgeon using two different techniques. Patients who underwent IDAP or direct-flow homodigital flap procedures and provided informed consent were included in the study. The two groups (IDAP and direct-flow homodigital flap) were retrospectively evaluated. We compared flap viability, amputation type, defect size, cold intolerance, venous congestion, static two-point discrimination (s2PD), flexion contracture, Sollerman hand function test scores, Seddon sensory test scores, and follow-up periods.

In terms of inclusion and exclusion criteria, patients with thumb injuries, bone or tendon injuries, or vascular injuries at the donor site were excluded, while acute cases with soft tissue injuries of at least 1.5 cm^2 and involving up to 3/4 of the pulp were included. For fingers other than the 5th, the ulnar side was preferred for aesthetic reasons if there were no contraindications. If there was no vascular injury on the donor side, the ulnar side was used for the 2nd, 3rd, and 4th fingers, and the radial side was used for the 5th finger.

IDAP flap surgical technique

The procedure was performed with the patient in the supine position, using a tourniquet and under x3.5 magnification [9]. The IDAP flap was dissected from the ulnar side of the same finger using a loupe magnifying glass under digital block anesthesia [8]. The distal part of the flap was extended from the wound border, and the proximal part was extended towards the dorsal side of the middle phalanx. When necessary, the flap was extended to the distal middle phalanx. Subcutaneous tissue is lifted to the periosteum of the middle phalanx. The extensor tendon was preserved for skin grafting. Cleland ligament left to view neurovascular structures. Cleland ligament was cut. Once the neurovascular bundle was identified, the palmar incision was carefully dissected down to the periosteum. The flap was mobilized as a digital artery island flap. It was dissected along with surrounding perivascular tissues for better mobilization. To allow the return from the artery to the venous plexus, the length of the neurovascular pedicle and surrounding subcutaneous tissue must be at least 4–5 mm, and the pedicle of the flap must contain 2–3 mm of subcutaneous tissue. The flap length should be 5 mm longer than the measured defect size to avoid tension on the pedicle. The pedicle should include the terminal branches of the terminal digital nerve, the

Fig. 1 Application of IDAP flap surgical technique

Fig. 2 Application of homodigital direct flow flap surgical technique

terminal artery, the perforators, and the subcutaneous venous system. The flap was rotated 180 degrees for transverse defects and 90 degrees for volar dorsal oblique defects. The donor site was covered with a full-thickness skin graft taken from the ulnar side of the wrist (Fig. 1). Neither orthosis nor anticoagulant therapy was used. The patient was instructed to exercise after 72 h.

Direct-flow homodigital flap surgical technique

The procedure was performed with the patient in the supine position, using a tourniquet and under x2.5 magnification [9]. After the affected fingertip was debrided, the soft tissue defect was measured. Paper or gloves were used for dimensioning and planning. The finger was drawn on its ulnar or radial side to center the neurovascular bundle flap. The flap was not raised without finding the neurovascular pedicle. Ensuring that the pedicle entered the flap allowed the flap to be redirected if necessary. Then a midlateral incision was made from the proximal part to the flap. The neurovascular pedicle was cleared of surrounding tissue. In this way, the Cleland and the Grayson ligaments and small arterial branches were separated and completely freed. By keeping the artery and nerve together, the venous drainage of the flap was preserved. Once the neurovascular bundle was isolated, it was dissected up to the entry point. Following the pedicle allowed the flap to be resized before elevating it. After the flap was confirmed, its volar portion was lifted toward the flexor tendon sheath. Then it was dissected through incisions on the radial and dorsal sides (or ulnar, depending on the location of the flap). Fat tissue was not cut around the pedicle to protect the flap. The flexion of the interphalangeal joint contributed to the mobilization of the pedicle. If the amount of progress was to be excessive, the pedicle was dissected from the proximal part of the metacarpophalangeal joint (MCP). The flap was sutured in the defect area with 4−0 or 5−0 prolene sutures. The tourniquet was released and the viability of the flap was checked. The pedicle and connection point were checked for viability of the flap. In such a situation, the pedicle was further mobilized or interphalangeal joint flexion was increased, and the flap was repositioned. Grafting was performed by taking a full thickness skin graft on the wrist to cover the donor area. A splint was placed in the dorsal region to protect finger flexion. Wrapping a circular bandage around the finger was avoided. The flap was dissected from the radial side because it was easier to hide it as aesthetically as possible (Fig. 2).

Patient follow-up

Follow-up visits were made after one month, three months and six months after operation. Such visits included the evaluation of flap viability, sensory recovery, functional outcomes and any complications. Structured follow-up ensured standard monitoring which facilitated comprehensive postoperative data collection.

Statistics

Statistical analysis was performed using statistical package for the social sciences version 27 (SPSS Inc; Chicago, IL, USA). Descriptive data were given as mean and standard deviation (SD) for quantitative variables in frequencies and percent for qualitative variables. Depending on how the data are distributed, we performed a comparative analysis between surgical techniques using the

chi-square test for categorical variables and Mann-Whitney U test for continuous ones. For a statistical significance level of 0.05 we accepted p-values below it.

Results

Data for patients who underwent IDAP and direct-flow homodigital flap are shown in Table 1. Thirty-two patients were included in the study. Of these, 26 (81.3%) were men and 6 (18.8%) were women. The mean age was 28.72±11.5 years (min: 10; max: 55). The injury occurred on the right hand in 19 patients (59.4%) and on the left hand in 13 patients (40.6%). An IDAP flap was applied to 14 patients (40.6%), and a direct-flow homodigital flap was applied to 18 patients (59.4%).

In terms of the type of flap applied according to the injury mechanism, an IDAP flap was used in 57.1% of sharp injuries, 75% of crush injuries, and a homodigital flap was applied in 66.7% of injuries resulting from entanglement.

In terms of age, side (r/l), defect size (cm^2), Sollerman test score, 2-point discrimination (mm), follow up time (month), affected finger, and amputation types, there wasn't any statistical differences between the groups ($p>0.05$).

The results of the postoperative Seddon sensory test in patients who underwent a homodigital flap were measured as S4 in 61.5%, S3 in 23.1%, S3+in 7.7%, and S2 in 7.7%. The postoperative Seddon sensory test in patients who underwent an IDAP flap was measured as S4 in 57.9%, S3+in 21.1%, and S3 in 21.1%.

The postoperative mean Sollerman hand function score was 75.00±2.64 in the homodigital group and 73.89±3.34 in the IDAP group. The average follow-up period was also longer for the IDAP group (9.16±1.97 months) compared to the homodigital group (8.50±1.57 months). However, these findings were not statistically significant ($p>0.05$).

Although not statistically significant, the results numerically suggest that the IDAP flap is superior in terms of sensory recovery and hand function compared to the homodigital flap ($p>0.05$).

Data on the proportions of affected fingers according to flap types are shown in Table 1. In 50% of patients who underwent the IDAP flap, the amputated finger was the second finger; in 21.4%, it was the third finger; and in 14.3%, it was the fourth and fifth fingers. In 33.3% of patients who underwent the homodigital flap, the amputated finger was the third finger; in 27.8%, it was the second and fourth fingers; and in 11.1%, it was the fifth finger (Table 1).

Complications developed in only 5 of the patients. Skin contraction was detected after homodigital flap in 2 patients. Flexion contracture was evaluated as an extension limitation that occurs in the proximal interphalangeal (PIP) joint. 12 degrees of PIP joint contraction developed in two patients. It was 6 degrees in the IDAP group and 10 degrees in the patient in the homodigital direct flow group. Venous insufficiency occurred in 2 patients after the IDAP flap and 1 patient after the homodigital flap. During clinical follow-up, venous return returned to normal without the need for surgical intervention. There was no flap loss or revision flap application in the patients. Cold intolerance developed in the long term after the operation in 3 of the patients,

Table 1 Data of patients who underwent IDAP and direct-flow homodigital flap

	IDAP	Homodigital Flap	*P* value
Patients	14	18	> 0.05
Age	29.0	28.3	> 0.05
Side (R/L)	9/5	10/8	> 0.05
Defect size (cm^2)	2.60 ± 1.17 (min:1; max:4)	2.84 ± 1.66 (min:1; max:6)	> 0.05
Sollerman test score	73.89 ± 3.34 (min:67; max:79)	75.00 ± 2.64 (min:70; max:79)	> 0.05
2-point discrimination (mm)	4.79 ± 1.03 (min:3; max:7)	5.15 ± 1.06 (min:3; max:7)	> 0.05
Follow up time (month)	9.16 ± 1.97 (min:5; max:13)	8.50 ± 1.57 (min:6; max:11)	> 0.05
Affected Finger	7	5	> 0.05
2nd finger	3	6	
3rd finger	2	5	
4th finger	2	2	
5th finger			
Amputation types	2	1	> 0.05
Dorsal oblique	4	2	
Lateral oblique	10	9	
Transverse	2	2	
Volar oblique			

2 of whom had a IDAP and 1 of whom had homodigital flap. It was determined that 4 of the 5 patients who developed complications had a transverse incision and 1 had a dorsal oblique incision. In the IDAP group, the average return to work time for patients over 18 years of age was 52±4 days, and for those who underwent a homodigital artery flap, it was 65±4 days. Long-term follow-up pictures of IDAP flap patients are shown in Fig. 3.

Discussion

This is the first study in the literature to compare the direct-flow homodigital flap with the IDAP flap. Unlike other studies that use different techniques, our study also includes comparisons of sensory and functional outcomes related to return to work. Although not statistically significant, the results suggest that the IDAP flap is numerically superior in terms of sensory recovery and hand function compared to the homodigital flap.

Various methods have been successfully applied in the reconstruction of fingertip injuries. The simplest technique is the V-Y advancement flap, which is used for small-area injuries [10–12]. The cross-finger flap and reverse flap can be used for larger fingertip defects, but flap separation requires a second surgical intervention for these techniques. Local island flaps and homodigital or heterodigital artery flaps are other methods that can be used in fingertip reconstruction.

The innervated digital artery perforator (IDAP) was described by Koshima et al. This technique does not require neurovascular pedicle dissection or transection [5]. The most important advantage of the IDAP flap compared to the homodigital direct flow flap is that it does not require pedicle dissection. For these reasons, it is a simpler, faster, and more reliable application. Another disadvantage of the homodigital direct flow flap is the need for finger flexion to ensure progression. Due to this advancement, the risk of after surgery of the finger flexion contracture is higher compared to the IDAP flap. In our study, two patients developed a 12-degree PIP joint contraction. The advantages of the IDAP flap include shorter surgery time, reliable flap survival, suitability of the donor site for primary closure, potential flap dimensions ranging from 2.5 to 4 cm, and preserved sensitivity at the fingertip. The main advantage of the IDAP flap over the homodigital flap is its ability to provide a wider rotational arc, making it suitable for larger injuries [9, 13–15].

Fig. 3 Long-term follow-up of IDAP flap patients

The flap of the homodigital artery has disadvantages such as need for pedicle dissection, causing finger contracture, cold intolerance, high possibility of venous congestion, necessity of grafting the donor site and longer surgery time [16]. In the literature, there are some publications which describe the bilobed digital artery perforator flap in avoiding this disadvantage [17–19]. In our study, a 12-degree PIP joint contraction developed in two patients who underwent a direct-flow homodigital flap. In the IDAP group, the average return-to-work time for patients over 18 years of age was 52±4 days, while for those who underwent a homodigital artery flap, it was 65±4 days. Özcanlı et al. reported in their study that the return-to-work time for patients who underwent an IDAP flap was shorter than for other flap groups [16].

Mitsunaga et al. applied IDAP flap to 13 traumatic finger amputations and reported partial skin necrosis in 2 cases [20]. In our study, skin necrosis did not develop in any of the patients in either of the two flap groups. Ozcanlı et al. reported s2PD measurements of 3.5 mm (ranging from 2 to 6 mm) in their patients following the IDAP flap procedure [16]. In our study, we found it to be 4.79±1.03 mm (min: 3; max: 7), and this result appears to be consistent with the literature. Although early venous congestion was observed in 5 cases in Özcanlı et al.'s series, secondary intervention was required for these patients [16]. In our IDAP group, early venous congestion was observed in 2 patients and the congestion resolved without the need for secondary intervention.

Cold intolerance was reported in 4 patients of Ozcanli et al. [16], while cold intolerance was observed in 2 of our patients. Foucher et al. reported 2 total flap losses in 64 cases of homodigital flap, partial necrosis in 5 cases, severe cold intolerance in 2 patients, and limitation of extension of the pip joint in 11 cases [21]. In our study, venous insufficiency was detected in 2 patients, cold intolerance in 1 patient, and pip joint flexion contracture was detected in 2 patients. The ideal flap to be used in

fingertip reconstruction should be versatile, reliable, sensitive, single stage and easily applicable with low donor site morbidity.

Our study has some limitations. The limited number of patients in our study, the short follow-up period, the retrospective design of the patterns of study, and the nonhomogeneous injury can be considered among the limitations of our study. Retrospective design and nonrandomized assignment of surgical methods are among potential biases that could introduce selection bias. Additionally, the small sample size and single-surgeon involvement may limit its generalizability. We have recognized these limitations and consider future studies to involve larger, randomized cohorts with multiple surgeons in order to validate our results.

Conclusions

Although there was no statistically significant difference in preoperative defect size, postoperative follow-up time, postoperative static two-point discrimination (s2PD), or postoperative Sollerman hand function scores among the flap groups, the mean postoperative two-point discrimination was better in the IDAP group, while the postoperative Sollerman function score was higher in patients who underwent the homodigital flap.

The practical significance for clinical practice lies in the potential preference for homodigital flaps when prioritizing sensory recovery and hand function, and for IDAP flaps due to their advantages, such as faster recovery times and fewer complications related to donor site morbidity. Future research should include larger sample sizes and randomized controlled trials to confirm these findings and explore any long-term effects. Additionally, examining patients' perceptions of their quality of life after surgery would provide a better understanding of the pros and cons of each technique. Based on our findings, we recommend that the IDAP flap be considered a preferred option for fingertip soft tissue amputations when optimal sensory and functional recovery is the goal.

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Data availability
The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Declarations

Ethical approval and consent to participate
The study protocol was approved by the Harran University Faculty of Medicine Clinical Research Ethics Committee for the 03-row session dated 07.07.2024. Before collecting any data, each participant provided written, informed consent. Every step was carried out in conformity with the Helsinki Declaration.

Consent for publication
Not applicable.

Sponsor's role
None.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Hand Surgery, Private Clinic, Gaziantep 27060, Turkey
[2]Department of Orthopedics and Traumatology, Meram State Hospital, Konya, Turkey

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