Research Article

Patient satisfaction after innervated digital artery perforator flap for fingertip injuries

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ABSTRACT

Objective: The aim of this study was to evaluate the results of the innervated digital artery perforator (IDAP) flap and to analyze the relationship between patient satisfaction and outcome measures.

Methods: A total of 17 fingertips of 15 patients (14 men and one woman; mean age: 47.2 (26-62) years) were included in this retrospective study. Patients' injured finger and defect type were recorded. At the last follow-up, the static two-point discrimination (s2PD) test, Semmes Weinstein monofilament (SWM) test, and range of motion of the affected finger were analyzed. We interviewed patients to determine hand dominance, cold intolerance, and their satisfaction with the result. We performed correlation and logistic regression analyses between patient satisfaction and outcome measures.

Results: The mean follow-up period was 13.8 (7-18) months. The mean range of motion was 77.3±3.5 (70-80) degrees for the distal interphalangeal joints of affected fingers. The mean s2PD was 6.4 (3-10) mm, and the SWM records ranged from 2.83 to 4.93 monofilament markings. Cold intolerance was noted in seven fingers (41%). Patient satisfaction was negatively correlated with cold intolerance, and cold intolerance decreased as the follow-up period extended.

Conclusion: IDAP flap satisfies both patient and surgeon, with the only significant problem being cold intolerance, regarding which patients must be informed. Although cold intolerance is hard to treat, fortunately, it generally improves with time.

Level of Evidence: Level IV, Therapeutic study

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Fingertip injuries are among the most common traumatic injuries of the hand (1). Generally, the bone, tendon, and neurovascular structures are exposed, thereby requiring flap reconstruction if replantation is unfeasible (2). For optimal functional restoration, the flap must be durable, sensitive, and cosmetically appealing, while preserving finger length (3). Various flaps for fingertip reconstruction have been devised with comparable results, but it is accepted that the best solution depends on patient expectation, defect characteristics, and surgeon experience (1-5). Ultimately, surgeons must rely on the tissue coverage principle of replacing like with like.

The innervated digital artery perforator (IDAP) flap was first described by Ozcanli et al. in 2013 (6). IDAP is a proximally based neurovascular island flap that can be rotated into the defect and has been shown to provide sensate fingertip reconstruction (5, 6). This sensate flap simply replaces the defect with the neighboring tissue of the same finger, adhering to the general rule of replacing like with like. Therefore, it is logical to conclude that patient satisfaction would be higher with such a sensate reconstruction.

In this study, we hypothesized that these innervated flaps would yield favorable outcomes with minimal donor site morbidity and that patients would be satisfied. Aiming to share our experience with the IDAP flap for the reconstruction of fingertip defects, we wanted to analyze the relationship between patient satisfaction and outcome measures.

Materials and Methods

We reconstructed 30 fingertips of 28 patients with IDAP between January 2016 and October 2016. Written informed consent of the participants was obtained, and the study was approved

by Mersin University Clinical Researches Ethical Committee. Patients ≥18 years of age suffering from palmar oblique or transverse fingertip amputations who provided informed consent for the suggested treatment were included. Patients <18 years of age or with dorsal oblique fingertip amputations were excluded. Patients' gender, age, injured finger, and defect types were documented.

There were 10 volar oblique and seven transverse fingertip defects. Injuries included three saw and 14 crush amputations. Specifically, injuries included the thumb in one case, index finger in six cases, middle finger in four cases, ring finger in four cases, and small finger in two cases.

We performed the surgical technique described by Ozcanli et al. under digital block with a finger tourniquet (6). Generally, the flap harvesting area is determined next to the defect area. If possible, donor sites were preferred from the sides of fingers having less contact importance. Ulnar sides were preferred for second and third fingers, while radial sides were preferred for thumbs and fourth and fifth fingers. Following debridement of the defect, the flap area was outlined according to defect size. Flap dissection was initiated on the dorsal side over the extensor paratenon, continuing to the volar side by division of the Cleland's ligament to uncover the neurovascular bundle. The neurovascular bundle was protected, and meticulous deep dissection was performed to the periosteum of the phalanx. The flap pedicle was raised with the surrounding perivascular soft tissue. The neurovascular island flap - including terminal branches of the digital artery and nerve, and the subcutaneous veins - was either rotated or transposed to cover the defect (Figure 1. a-e). We covered the donor site with a full-thickness skin graft. If possible, we acquired the skin graft from the amputated part; otherwise, we acquired it from the medial side of the upper arm. No splint was applied postoperatively. After 1 week, the dressing was thinned to allow full range of motion. Patients were followed weekly for healing progress.

Figure 1. a-e. A transverse fingertip defect of the third finger. a. Amputate skin will be used for full-thickness grafting of the donor site b. Innervated digital artery perforator flap designed at the ulnar site of the third finger c. Immediate postoperative view, the flap is fixed with a tiny needle and the donor site is grafted d, e. The fingertip and the donor site at the postoperative third week

At the final follow-up, 15 patients-representing 17 fingertips-replied to our inquiry and were included in this study. We conducted a static two-point discrimination (s2PD) test and Semmes Weinstein monofilament (SWM) test and analyzed the range of motion of the affected finger. To measure the distance, we used the Dellon 2-Point Disk-Criminator in a longitudinal direction to the autonomous zone of the injured digital nerve. The s2PD distances were recorded in millimeters. A 20-piece full kit of SWM (Touch-Test, North Coast Medical, Inc., Gilroy, CA, USA) was used to evaluate cutaneous pressure threshold. Each monofilament was vertically pressed for 2 seconds onto the skin until it slightly bent while the patients were holding their eyes closed. The monofilament markings were recorded for each patient. We interviewed patients to determine hand dominance, cold intolerance (yes or no), and satisfaction with their fingers. Patient satisfaction was classified per finger as: 1-Highly dissatisfied, 2-Dissatisfied, 3-Moderate, 4-Satisfied, and 5-Highly satisfied.

Statistical analysis
The statistical analyses were performed with the Number Cruncher Statistical System 2007 (Kaysville, UT, USA) program. The correlations between patient satisfaction and age, follow-up period, s2PD records, SWM records, cold intolerance score, hand dominance, and the injured finger were evaluated using Spearman's rho and Pearson correlation coefficients. Patients' fingers were grouped according to satisfaction levels, and univariate and multivariate logistic regression analyses were used to evaluate risk factors affecting patient satisfaction. Statistical significance was accepted at $p<0.05$.

HIGHLIGHTS

- Innervated digital artery perforator (IDAP) flap is a versatile, technically straightforward, reliable one-stage flap for coverage of fingertip defects.

- IDAP flap satisfies both patient and surgeon, with the only significant problem being cold intolerance, regarding which patients must be informed.

- Cold intolerance arose as an important risk factor for patient satisfaction.

- Cold intolerance is commonly encountered after finger amputations and it is hard to remedy, fortunately, it generally improves with time.

- Comparison of the IDAP flap with other fingertip flaps in relation to cold intolerance is an important focus for future research.

Table 1. Correlation analysis of patient satisfaction and cold intolerance with variables

		PS	Age	FU	2PD	SWM	IF	HD	CI
PS	CC	1.00	0.115	0.413	0.058	0.147	0.403	−0.014	−0.575
	Sig. (p<0.05)	-	0.660	0.099	0.825	0.573	0.109	0.958	**0.016**
CI	CC	−0.575	0.025	−0.599	−0.285	−0.038	−0.454	0.029	1.00
	Sig. (p<0.05)	**0.016**	0.925	**0.011**	0.268	0.886	0.067	0.913	-

2PD: two-point discrimination; CC: correlation coefficient; CI: cold intolerance; FU: follow-up; HD: hand dominance; IF: injured finger; p: p value; PS: patient satisfaction; SWM: Semmes-Weinstein monofilament
Significant values are provided as bold characters

Table 2. Univariate and multivariate logistic regression analyses to evaluate factors affecting patient satisfaction

Factors	Univariate			Multivariate		
	p	OR	95% CI	p	OR	95% CI
Age	0.499	1.027	0.950–1.111	-	-	-
Follow-up	0.124	1.306	0.929–1.836	-	-	-
2PD	0.740	1.067	0.727–1.565	-	-	-
SWM	0.382	2.327	0.350–15.463	-	-	-
Cold intolerance (-)	0.039*	14.000	1.135–172.642	0.039*	14.000	1.135–172.642
Hand dominance	0.772	1.333	0.191–9.311	-	-	-

2PD: two-point discrimination; CI: confidence interval; OR: odds ratio; p: p value; SWM: Semmes-Weinstein monofilament *p<0.05
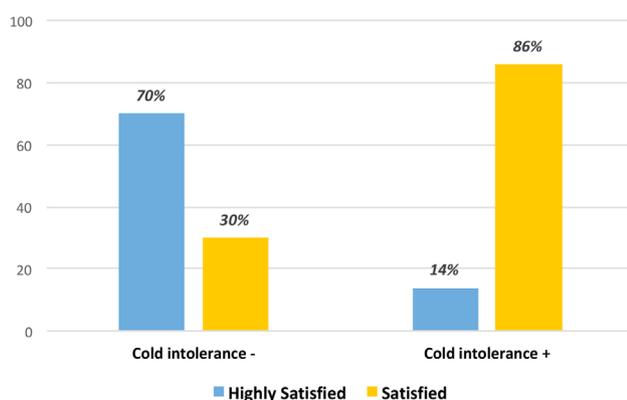
Figure 2. Categorization of patients' satisfaction according to cold intolerance

Results

Of the 30 fingertips reconstructed with IDAP, 17 fingertips of 15 patients (14 men and one woman) were assessed for final follow-up. The mean age was 47.2±12.9 (26-62) years and the mean follow-up period was 13.8±3.3 (7-18) months. During the follow-up period, superficial necrosis was observed in three fingertips of the initial two patients. The defects of these patients healed secondarily after changes in the dressing. Pa-

tients returned to work within a mean period of 22.5 (15-30) days.

At the final follow-up, the mean range of motion was 77.3±3.5 (70-80) degrees for the distal interphalangeal joints of affected fingers. Patients were satisfied with the outcome of nine fingers and highly satisfied with the outcome of eight fingers. The mean s2PD was 6.4±2.5 (3-10) mm, and the SWM records ranged from 2.83 to 4.93 monofilament markings. Cold intolerance was noted in seven fingers (41.2%).

Upon analysis of correlation statistics, patient satisfaction significantly and negatively correlated with cold intolerance (r=-0.575, p=0.016) (Table 1). There was no significant correlation between patient satisfaction and age, follow-up period, hand dominance, injured finger, s2PD records, and SWM records. A significant correlation was found between cold intolerance and the follow-up period (range: 7-18 months); specifically, cold intolerance decreased as the follow-up period extended (r=−0.599, p=0.011).

In univariate logistic regression analyses, significantly more "highly satisfied" patients were grouped in fingers without cold intolerance than in fingers with cold intolerance (Figure 2, Table 2) (p=0.039). Variables with p<0.150 in the univariate logistic regression analysis (follow-up and cold intolerance)

Table 3. Results of similar studies on homodigital flap reconstruction of fingertip injuries

References	Subject	Static 2PD (mean, mm)	SWM (range)	Cold intolerance (%)
Ozcanli et al. (5)	Innervated digital artery perforator flap	3.5	2.83–4.17	7
Ozcanli et al. (6)	Innervated digital artery perforator flap	3.4	3.22–3.84	6
Mitsunaga et al. (9)	Digital artery perforator flap	Not reported	3.61–4.08	Not reported
Ozcanli et al. (10)	Digital artery perforator flap	5.3	3.61–4.56	7
Lanzetta et al. (11)	Homodigital triangular neurovascular island flaps	3–6	Not reported	80
Güleç et al. (12)	Innervated digital artery perforator flap	4.87	Not reported	0
	Homodigital reverse-flow flap	5.17	Not reported	0
Kayalar et al. (13)	Direct-flow neurovascular island flaps	4–5	2.83–4.56	17
Yildirim et al. (15)	Reverse homodigital island flap	6–8	Not reported	41.6
Usami et al. (16)	Oblique triangular neurovascular advancement flap	6.5	Not reported	Not reported
	Reverse digital artery island flap	8.3	Not reported	Not reported
Ozaksar et al. (17)	Homodigital dorsal middle phalangeal neurovascular advancement flap	7	2.83–4.31	100*
Shen et al. (19)	Innervated digital artery perforator propeller flap	5	Not reported	0
Wei et al. (20)	Homodigital anterograde pedicle flap based on the dorsal perforator	4.96	Not reported	0
This study	Innervated digital artery perforator flap	6.4	3.22–4.93	41

*The authors reported that all of the 18 patients had cold intolerance to some extent, but no severe discomfort was reported

were entered as independent variables in the multivariate stepwise (backward elimination) logistic regression analysis. At the end of the second step, only cold intolerance was left in the model as a significant factor on patient satisfaction. The overall percent of cases correctly predicted by the model was 76.5%. Fingers without cold intolerance were significantly more likely to be highly satisfied than fingers with cold intolerance (OR=14.00, 95% CI=1.13, 172.64, p=0.039) (Table 2). The cold intolerance was found to be the only independent risk factor for patient satisfaction.

Discussion

IDAP attracted our attention due to its innervated nature and versatility. Moreover, the defect can be covered using the tissue in the immediate vicinity, representing another advantage of replacing like with like. Therefore, we hypothesized that the results would be favorable and patient satisfaction would be high with this procedure. We observed that IDAP flap was indeed successful for coverage of fingertip defects and the patients were satisfied. Interestingly, patient satisfaction did not correlate with the innervation level, but it did correlate negatively with cold intolerance. Cold intolerance was an independent risk factor for patient satisfaction.

Koshima et al. defined DAP in 2006 and, subsequently, other authors reported promising results with DAP flaps (4, 7-9). In 2013, Ozcanli et al. defined an innervated version of these flaps (IDAP), based on a pedicle containing perforator, with not only the perforator but also the final segment of the proper digital artery and nerve (6). They concluded that isolation of perforators was unnecessary; thus, venous drainage was improved with this technically straightforward flap when compared with the DAP flap. From our experience, we agree with Ozcanli et al. that IDAP is a nearly trouble-free flap (6). While we did observe superficial necrosis in three reconstructed fingertips, these were our initial cases. Overall, our experience demonstrated that IDAP is a technically straightforward flap with a steep learning curve.

Our patients were generally manual laborers with a lower socioeconomic status, and the return-to-work period was around 3 weeks with IDAP flaps. In other studies on one-stage procedures for fingertip reconstructions, return-to-

work periods were reported in the range of 3-9 weeks (10-14). The rapid return-to-work period in our patients may be related to a number of factors. First, we allowed them to return to work after completion of soft tissue healing. Second, our patient cohort was not particularly concerned with altered sensations and desired to return to work as soon as possible. Supporting this, in their global review of reconstruction of fingertip injuries, Tang et al. reported that a mild decrease in sensation usually caused little functional impairment (3). Finally, although sensorial healing takes longer than tissue healing, and sometimes may not even be achievable, the sensorial adaptation of the transferred innervated neighboring tissue was expected to be rapid with this technique.

The mechanism of injury is important to assess possible injured tissues (2). Crush injuries, in particular, pose a risk for accompanying additional fractures. Therefore, we routinely performed direct radiography of fingertip injuries, which confirmed that none of our patients suffered additional fractures. From previous studies, Kayalar et al. reported no association between injury mechanism and cold intolerance, patient satisfaction, and scarring (13).

The one-stage IDAP flap was our first choice for volar oblique and transverse fingertip injuries. Other well-known one-stage fingertip reconstruction procedures include direct-flow neurovascular island flaps and reverse-flow island flaps (11-13, 15-17). These homodigital procedures require meticulous neurovascular bundle dissection, with a higher probability for injury. Moreover, because dissection in both procedures is generally performed through the length of the finger, the reported operating time was longer, and the proximal interphalangeal joint contracture risk increased (3, 15, 16). Additionally, reverse-flow flaps sacrifice the digital artery and are prone to more complications such as flap loss (3, 15, 18). Given these challenges, we preferred the IDAP flap for volar oblique and transverse fingertip defects. We found that the IDAP flap was a rapid one-stage procedure and did not cause finger stiffness (5, 6).

We used the V-Y advancement flap for dorsal oblique amputations and did not face lateral oblique amputations during the 10-month period of this research. However, the IDAP flap was reported to be used both for dorsal and lateral oblique fingertip amputations (5). When versatility is considered, the IDAP flap can reasonably be used for various types of fingertip amputations.

In our study, the quantitative measures of sensorial recovery (s2PD and SWM tests) were slightly inferior to those in most other similar fingertip flap reconstruction studies (Table 3). Tang et al. suggested recovery of sensation to S3+(s2PD= 7-15 mm) or S4 (complete recovery, s2PD=2-6 mm) grades (3). Our patients' mean s2PD of 6.3 mm is comparable for optimal sensation, yet slightly inferior to that in previous

studies. Furthermore, a significant number of our patients (41%) reported cold intolerance. We rated cold intolerance as either "none" or "existing;" therefore, even slight discomfort was assigned a positive value. Accordingly, we believe this led to the high cold intolerance percentage in our study. In previous studies, a wide range of cold intolerance was reported (0-100%), possibly because there was no generally accepted rating scale for cold intolerance (5, 6, 10-13, 15, 17, 19-21). One noteworthy point in our study was that patients without cold intolerance were generally highly satisfied, but sensorial recovery (s2PD and SWM) did not show such a relationship. Supporting this, many studies have reported that cold intolerance is an important negative factor affecting patients' activities of daily living and work (22-26).

Cold intolerance is a well-known phenomenon after replantations and fingertip reconstructions (21, 27-29). However, the pathophysiology of cold intolerance remains controversial and is believed to have both vascular and neurogenic origin (30-32). In the prospective study by Vaksvik et al. the authors studied the natural course and predictors for decreased cold hypersensitivity in 85 patients with severe hand injuries (24). They reported that change in sensibility was not a predictor. Similarly, Collins et al. and Freedlander could not demonstrate any correlation between cold intolerance and sensorial recovery (23, 33). In the well-designed study of Klein-Weigel et al., the authors researched the etiology of cold intolerance in replanted fingers using high-resolution color-coded sonography for assessment of skin vessel density of fingertips, as well as nailfold capillary microscopy and laser Doppler anemometry (30). They found that reduced vessel density pointed toward diminished thermoregulatory capacities in the fingertips of cold-sensitive replanted digits. Finally, Smits et al. found that patients with cold intolerance exhibited a "disordered conditioned pain modulation system," indicating alterations in the central descending inhibitory system (34). Basically, cold intolerance presents as a complex phenomenon with an unclear origin. Regarding our patients, as we could not explain the high incidence of cold intolerance, future research is warranted.

When the pathophysiology is unclear, so is the treatment. To our knowledge, there is no curative method for cold intolerance, although some conditioning methods have been reported (35-37). Promisingly, we found that our patients' cold intolerance negatively correlated with an increase in the follow-up period. Similarly, improvements in cold intolerance symptoms have been reported in several studies (21, 24, 26-28, 31, 38, 39). The findings in our study suggest that patients with finger or fingertip amputation injuries must be informed about the possibility of cold intolerance and possible improvement with time.

Two main limitations of our study include its retrospective nature and the relatively small number of cases (17 fingers of

15 patients) for the last follow-up. However, the 13 patients who declined follow-up declared satisfaction via a telephone interview. Nevertheless, as we were unable to perform sensory measurement tests in this group, we did not consider the telephone interview reliable. Given the relatively small number of patients returning for assessment, our ability to demonstrate other possible correlations was limited. Moreover, patient satisfaction is a broad term, affected by several other parameters. The size of the defect and flap, donor area, and patient psychology were among the parameters not included in our analysis. As a final limitation regarding cold intolerance, our mean patient follow-up was short at just 13.8 (±3.3) months,; therefore, the natural history of their cold intolerance remains uncertain.

In conclusion, IDAP flap satisfies both patients and surgeons, with the only significant problem being cold intolerance, regarding which patients must be informed. Commonly encountered after finger amputations, cold intolerance is hard to remedy; fortunately, it usually improves with time. Comparison of the IDAP flap with other fingertip flaps in relation to cold intolerance is an important focus for future research.

Ethics Committee Approval: Ethics committee approval was received for this study from the Clinical Researches Ethics Committee of Mersin University (Decision number: 2017/74).

Informed Consent: Written informed consent was obtained from the patients.

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Conflict of Interest: The authors have no conflicts of interest to declare.

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