Long-term clinical outcomes of innervated digital artery perforator flap in the treatment of fingertip injuries

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Objective: The aim of this study was to evaluate the long-term clinical outcomes of innervated digital artery perforator (IDAP) flap in the treatment of patients with fingertip injuries.

Methods: Eighty-three patients (93 fingers; 70 male, 13 female; mean age = 35.2 years, age range = 5-65) with fingertip injuries who underwent acute or late reconstruction with IDAP flap between 2011 and 2016 were retrospectively reviewed. The mean age was 35.2 (range = 5-65) years. Reconstructions performed in 85 fingers (91.4%) were acute, and 8 fingers (8.6%) were late. Hypersensitivity, cold intolerance, and patient satisfaction were questioned as subjective evaluation parameters. The objective patient outcome evaluations consisted of static two-point discrimination (s2PD) test, the Semmes-Weinstein monofilament (SWM) test, and range of motion of the reconstructed fingers.

Results: The mean follow-up period was 33.1 (range = 12-62) months. The smallest flap size was 1.6 x 0.7 cm; the largest flap size was 4 x 2 cm. All flaps survived completely. There was no postoperative infection or donor site morbidity. Hypersensitivity was observed in 4 fingers (4.3%), of which 3 were mild and 1 was moderate. Eighteen patients (18 fingers, 19.3%) experienced mild cold intolerance on reconstructed fingertips. 75 patients (90.3%) were highly satisfied, and 8 patients (9.7%) were satisfied with functional and aesthetic results of their fingertip reconstructions. No range of motion limitation was observed in any joints of 90 fingers (96.8%). The s2PD in the flaps ranged from 2 mm to 6 mm (mean = 3.71 ± 0.97 mm), compared with 2 mm to 5 mm (mean = 2.73 ± 0.66 mm) on the contralateral hand. The SWM test results of the flaps ranged from 2.44 to 4.56, compared with 2.44 to 4.31 on the contralateral hand. The difference regarding s2PD and SWM test was statistically significant (P < 0.001).

Conclusion: IDAP flap seems to be a sensitive, reliable, and versatile flap that can be used in acute and late reconstructions of any type of fingertip defects. Satisfactory functional and aesthetic results can be achieved with better sensorial results and lower complication rates compared to other conventional reconstruction techniques.

Level of Evidence: Level IV, Therapeutic Study

Introduction

Fingertip injuries are one of the most common causes of emergency department admissions and frequently encountered by hand surgeons in their daily practices. The main goal in the treatment of such injuries is to achieve painless and aesthetic fingertip with stereognosis and proprioception properties, which sense heat, pain, and pressure. Moreover, type of the injury, patient outcome evaluations consisted of static two-point discrimination (s2PD) test, the Semmes-Weinstein monofilament (SWM) test, and range of motion of the reconstructed fingers.

In 2006, Koshima et al. described the Digital Artery Perforator (DAP) flap, which was designed to be elevated over single perforator closest to the defect.5 Complicated detection of perforators, venous congestion problems, and to be insensate are major shortcomings of the DAP flap.5,7 In 2013, a new reconstruction technique for the treatment of fingertip injuries was described, and it is the “Innervated Digital Artery Perforator” (IDAP) flap.6 The IDAP flap is a proximally based neurovascular island flap that provides sensoate reconstruction for defects of the fingertip. Pedicle of the flap includes perforators and final segment of digital artery and nerve, and there is no need to isolate the perforator. This makes the flap more reliable and less technically demanding than DAP flap.6

Aim of the present study was to evaluate the long-term clinical outcomes of patients who underwent reconstruction with IDAP flap in the treatment of fingertip defects.
Materials and Methods

Approval from the ethics committee was obtained, and informed consent was provided by all patients. One hundred fourteen patients (125 fingers) with fingertip injuries who underwent acute or late reconstruction with IDAP flap between August 2011 and October 2016 were evaluated. IDAP flap was preferred in patients with fingertip injuries and exposed distal phalanges where replantation was not feasible due to severely crushed amputation material or absence of it, and local flap was required for soft-tissue coverage. Eighty-three patients (93 fingers; 10 patients had multiple injuries in the same hand) were followed for more than 1 year postoperatively, and their physical examination and measurements were recorded regularly included in the study. Conditions that negatively affect regional blood flow (diabetes mellitus, vasospastic problems, smoking, etc.) were questioned.

The mean age of the patients was 35.2 years (range: 5-65 years). The mean follow-up period was 33.1 months (range: 12-62 months). Most commonly injured finger was the 3rd finger with a rate of 40.8% (38 fingers), and the most common defect type was transverse (n = 57; 61.3%). Demographics of the patients are summarized in Table 1.

Acute reconstruction was performed to 85 fingers (91.4%), and late reconstruction was performed to 8 fingers (8.6%). In case of late reconstruction, flap was performed in the same session after debridement. Late reconstructions were performed due to pulp necrosis developed after previous fingertip injury in seven patients and diabetic wound in one patient. The mechanisms of acute injuries were sharp and crush in 11 and 74 patients, respectively.

All operations were performed according to the surgical technique described by Ozcanli et al. Flap dissections were performed under digital block anesthesia with loupe magnification, and local anesthesia was performed for the donor site of the skin graft when required. An IDAP flap can be designed from either side of the digit; however, elevation from the ulnar side of the index, middle, and ring fingers is preferred; because this, area does not contact the thumb during hand activities. The flap was designed on the midlateral line proximally. The distal part of the flap started at the lateral line distally, extending slightly dorsal and oblique to the thumb during hand activities. The flap was designed on the midlateral line distally, extending slightly dorsal and oblique to the midlateral line proximally. The distal part of the flap started at the edge of the wound, and the proximal portion can be extended to the dorsal part of the middle phalanx when necessary. The incision can be started from either the dorsal or volar part of the digit; however, dorsal incisions are preferred because of the ease of identifying the neurovascular bundle under the Cleland ligament. The subcutaneous tissue was dissected from the periosteum of the phalanx. The paratenon of the extensor system should be left intact. The Cleland ligament was divided to view the neurovascular bundle.

After identification of the neurovascular bundle, the palmar incision was meticulously dissected to the periosteum. The flap was mobilized as a digital artery island flap. The pedicle included the terminal branches of the digital nerve, the terminal digital artery, the perforators, and the subcutaneous venous system. A 2-3 mm cuff of subcutaneous tissue should be left around the pedicle to improve venous return through the venous plexus. Then, flap was rotated to cover the defect. The donor site of the flap was covered with a full-thickness skin graft. If available, graft was taken from amputation material. However, it was taken from the ulnar side of the wrist crease under local anesthesia when there is no amputation material and in late reconstructions. Neither orthosis nor anticoagulant therapy was used. The patients were encouraged to perform active range of motion exercises beginning 72 hours after the operations.

Subjective–objective parameters and satisfaction of the patients were evaluated, and the results in last examination were included in the study. All examinations were performed by a certified hand surgeon. Hypersensitivity, cold intolerance, and patient satisfaction were questioned with Likert-type scale as subjective evaluation parameters. Cold intolerance and hypersensitivity were classified into the following five grades: none, mild, moderate, disturbing, and severe.

Patient satisfaction was questioned in terms of both functional and aesthetic aspects of the procedure, and the degree of satisfaction was evaluated as “highly satisfied, satisfied, moderate, dissatisfied, and highly dissatisfied”.

HIGHLIGHTS

- IDAP flap is a sensate, reliable, and versatile flap that can be used in acute and late reconstructions.
- Surgical procedure is technically straightforward, less demanding, single-stage, and performed under digital block anesthesia. Additional local anesthesia is performed when skin graft needs to be taken from wrist.
- Any type of defect (volar, dorsal, lateral oblique, transverse, pulp defect, etc.) in any finger can be safely reconstructed with IDAP flap.
- Satisfactory functional and aesthetic results can be achieved with better sensorial results and lower complication rates compared to other conventional reconstruction techniques.

Table 1. Demographics of the Patients

| Affected hand | 70 (84.3%) males, 13 (15.7%) females |
|--------------|-------------------------------------|
| Gender       | 44 (53%) right, 39 (47%) left       |
| Affected finger |                                      |
| 1st          | 12 (12.9%)                          |
| 2nd          | 23 (24.8%)                          |
| 3rd (most-common) | 38 (40.8%)                        |
| 4th          | 16 (17.2%)                          |
| 5th (least-common) | 4 (4.3%)                         |
| Tamai classification |                                          |
| Zone I       | 76 (81.7%)                          |
| Zone II      | 17 (18.3%)                          |
| Defect types |                                      |
| Transverse   | 57 (61.3%)                          |
| Volar oblique | 17 (18.3%)                          |
| Lateral oblique | 9 (9.6%)                            |
| Dorsal oblique | 7 (7.6%)                           |
| Pulp defect  | 3 (3.2%)                            |
| Smokers      | 29 patients (34.9%)                 |
| Mean smoking time | 21.4 pack years                   |
| Diabetics (oral antidiabetics/insulin) | 6 patients (7.2%)         |

Static 2-Point Discrimination (s2PD) and Semmes-Weinstein Monofilament (SWM) test were applied in comparison with contralateral intact fingers of the patients as objective evaluation parameters. 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. Metacarpophalangeal (MP), Proximal Interphalangeal (PIP), and Distal Interphalangeal (DIP) joints’ range of motion of the reconstructed fingers were evaluated, and existing limitations were recorded.
Statistical analyses and descriptive statistics were presented with frequencies and percentages. The difference between operated and contralateral fingertip findings regarding s2PD and SWM tests was evaluated with the paired samples t test and Wilcoxon signed-rank test.

Results

The smallest flap size was 1.6 × 0.7 cm, and the largest flap size was 4 × 2 cm. Seventy-six (81.7%) flaps were designed from the ulnar side of the finger and 17 (18.3%) from the radial side. All flaps survived completely (Figure 14). There was no postoperative infection or donor site morbidity. In the early postoperative period, 6 (6.4%) of 93 fingers had transient venous congestion findings. Congestion regressed in two of the patients after elevation and loosening dressing. Superficial epidermolysis was observed in four fingers (4.3%). However, no secondary intervention was needed.

Mild hyperpigmentation was detected in two fingers (2.15%). Hyperesthesia was observed in four fingers (4.3%): three of these were mild and one was moderate. Eighteen patients (18 fingers, 19.3%) experienced mild cold intolerance on reconstructed fingertips. 55.5% (n = 10) of the patients with cold intolerance were smoking.

All patients were asked to evaluate their surgical procedure both functionally and aesthetically; 75 patients (90.3%) reported being “highly satisfied” and 8 patients (9.7%) reported being “satisfied” with the results of their fingertip reconstructions.

The s2PD in the flaps ranged from 2 to 6 mm (mean, 3.71 ± 0.97 mm), compared with 2 to 5 mm (mean, 2.73 ± 0.66 mm) on the contralateral hand. The SWM test results of the flaps ranged from 2.44 to 4.56, compared with 2.36 to 4.31 on the contralateral hand. The difference regarding s2PD and SWM test was statistically significant (P < 0.001) (Table 2).

No range of motion limitation was observed in any joints of 90 fingers (96.8%). One patient had 20°of flexion limitation in the IP joint of 1st finger, and two patients had 10°and 15°of extension loss, respectively, in the DIP joint of 2nd fingers.

Discussion

The main purpose in the treatment of fingertip injuries is to obtain a painless, firm, aesthetic, and sensory fingertip. Local and regional flaps have become popular in the last decade, with the advances in microsurgical techniques. However, ideal flap for fingertip injuries is still controversial. The ideal flap should be versatile, reliable, sensate, single-staged, and easily performed with few complications and donor site morbidities.

Pulp sensation has been the keystone of successful fingertip reconstruction. A sensate fingertip is important for precise stereognosis object identification and function. This increases efforts to make the

Table 2. Difference between Operated and Contralateral Finger Tip Findings Regarding s2PD and SWM

| Reconstruction Type | Number (Patients/ Fingers) | Mean s2PD (mm) | SWM |
|---------------------|---------------------------|----------------|-----|
| Cohen & Cronin†     | 7/7                       | 4.8            |     |
| Yazar et al.10      | 66/70                     | 5.7            | 2.83-3.61 |
| Lee et al.11        | 21/21                     | 7.2            | 4.08-4.74 |
| Rinker12            | 15/15                     | 5.5            |     |
| Shao et al.13       | 11/11                     | 4.4            | 3.61-6.65 |
| Chen et al.14       | 12/12                     | 8.3            | 3.61-4.56 |
| Acar et al.15       | 11/22                     | 10.3           |     |
| Chen et al.16       | 166/187                   | 10.5           | 3.84-4.56 |
| Ozcanli et al.17    | 15/15                     | 5.9            | 3.84-4.56 |
| Kim et al.18        | 25/30                     | 5.9            | 3.22-4.17 |
| Usami et al.19      | 17/17                     | 6.4            | 2.83-4.56 |
| Aarslan-Werner et al.19 | 28/29                   | 5.1            | 2.83-4.31 |
| Qin et al.20        | 16/16                     | 8              |     |
| Present study       | 81/93                     | 3.7            | 2.44-4.56 |

Table 3. Comparison of the Sensorial Outcomes of Different Local or Regional Flaps for Covering the Fingertip Defects

| Reconstruction Type | Number (Patients/ Fingers) | Mean s2PD (mm) | SWM |
|---------------------|---------------------------|----------------|-----|
| Cohen & Cronin†     | 7/7                       | 4.8            |     |
| Yazar et al.10      | 66/70                     | 5.7            | 2.83-3.61 |
| Lee et al.11        | 21/21                     | 7.2            | 4.08-4.74 |
| Rinker12            | 15/15                     | 5.5            |     |
| Shao et al.13       | 11/11                     | 4.4            | 3.61-6.65 |
| Chen et al.14       | 12/12                     | 8.3            | 3.61-4.56 |
| Acar et al.15       | 11/22                     | 10.3           |     |
| Chen et al.16       | 166/187                   | 10.5           | 3.84-4.56 |
| Ozcanli et al.17    | 15/15                     | 5.9            | 3.84-4.56 |
| Kim et al.18        | 25/30                     | 5.9            | 3.22-4.17 |
| Usami et al.19      | 17/17                     | 6.4            | 2.83-4.56 |
| Aarslan-Werner et al.19 | 28/29                   | 5.1            | 2.83-4.31 |
| Qin et al.20        | 16/16                     | 8              |     |
| Present study       | 81/93                     | 3.7            | 2.44-4.56 |
Patients can experience subjective sensory complaints such as hypoesthesia, dysesthesia, cold intolerance, and hypersensitivity in most of the fingertip reconstruction techniques, especially the advancement flaps. These sensory problems are encountered due to tension of the digital nerve and its branches after advancement. In the present study, hyperesthesia was observed in 4.3%, and cold intolerance was observed in 19.3%. Hyperesthesia rate in our study was significantly lower than similar studies involving other fingertip reconstruction techniques. In a study evaluating volar V-Y advancement flap, 7 out of 10 patients (70%) had hypoesthesia or dysesthesia. The same study reported hypo/hyperesthesia in 10 of 14 patients (71%) whom Kutler flap was performed. Usami et al. reported 10% severe hypersensitivity in patients whom oblique triangular flap was performed. In another study, 78% of the patients experienced hypoesthesia. Sano et al. evaluated the sensory recovery after oblique triangular flap and hyperesthesia were detected in 50%.

In our experience, the reason for this low rate of hyperesthesia is extensive arc of rotation of the IDAP flap. Depending on the size and configuration of the defect, flap can be rotated 90° (especially for volar and dorsal oblique defects) or 180° (especially for lateral oblique and transverse defects). Thus, nerve is not under tension after flap is rotated and defect is covered.

The pathophysiology in cold intolerance is different and remains controversial. Van den Berg et al. evaluated 59 fingertip injuries treated with 3 different techniques (secondary granulation, revision amputation, and reconstruction) and detected cold intolerance in 50 fingers (84.7%). Cold intolerance rates were reported as 41.6%, 17%, and 16.6% in the studies, in which patients were treated with retrograde homodigital island flap, antegrade homodigital island flap, and innervated cross-finger flap, respectively. These high rates even with different reconstruction techniques show that cold intolerance is a complication of injury rather than treatment.

Prolonged immobilization should be avoided in reconstructive surgeries to prevent joint stiffness. Although two-stage flaps like cross-
finger flap and thenar flap are simple, quick, and reliable flaps, patients have a risk of joint stiffness due to prolonged immobilization. A flexion contracture of PIP joint is also a common complication of antegrade homodigital island flaps. In the literature, extension restriction rates in PIP joint were between 8% and 29% on average. Varying rates of flap loss were reported with different techniques of IDAP flap is that it enables early joint motion. Patients were informed to undertake active range of motion exercises beginning 3 days after surgery. In our study, 90.8% of 93 fingers had no restriction in range of motion.

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