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The outcome of direct-flow neurovascular island flaps in pulp defects

Murat KAYALAR, Emin BAL, Tulgar TOROS, S. Tahir SÜĞÜN, Kemal ÖZAKSAR, Yusuf GÜRBÜZ

Hand and Microsurgery Hospital, İzmir, Turkey

Objective: In this study we aimed to evaluate the results of the direct-flow neurovascular island flap (NIF) transfers in pulp defects.

Methods: We reviewed the records of 96 patients with 115 NIF transfers performed for pulp defect reconstruction. The injury mechanism was crush type injury in 70 patients (72.9%). Ninety-three patients (97%) were emergency cases. Pulp reconstruction was performed by means of pedicled island flap transfer. The results were evaluated with proximal interphalangeal joint range of motion, the Semmes Weinstein monofilament test, static two-point discrimination and cold intolerance assessments. The relations between the injury mechanism, patient satisfaction, cold intolerance and scar problems were analyzed. Also, the association between skin grafting and hook nail deformity was investigated. The level of significance was set at $p<0.05$.

Results: All flaps survived. The mean follow-up time was 41±20.3 (range: 12-108) months. We observed proximal interphalangeal joint flexion contracture in 11 (9.5%) cases. In seven of these, the limitation was less than 10 degrees. Hook nail deformity was seen in 8 fingers (7%). Cold intolerance was found in 16 (17%) cases. Semmes Weinstein monofilament and static-two point discrimination tests of flaps revealed satisfactory results. There was no relation between the injury mechanism and cold intolerance, patient satisfaction and scar problems ($p>0.05$). Among patients, 91.7% were satisfied with their results.

Conclusion: The transfer of direct-flow island flaps, from the same finger, causes minimal morbidity on the donor site and appears to be a safe method, providing satisfactory functional and aesthetic results in the reconstruction of pulp defects.

Key words: Neurovascular island flap; pulp reconstruction.

Reconstruction of the injured fingertip is one of the most challenging problems of hand surgery. Among the reconstructive methods for fingertips, homodigital neurovascular island flap (NIF) is an established procedure in many institutions.[1-8] A general indication of NIF is tangential pulp amputations exceeding 1 centimetre in diameter, with bone exposure. NIF provides glabrous skin for fingertip defects.

The concept of neurovascular skin island was first proposed by Littler.[9,10] The concept of homodigital flaps has evolved considerably since their first introduction. Over time, bipedicular flaps have been replaced by monopedicled flaps and attempts to reduce donor site morbidity have been made.[8,11-18] The first users of this flap were reported to be Venkataswami et Subramanian.[4] Joshi[19] had reported the dorsolateral island flap and Pho[20] had used a similar flap on the thumb. In the following years, large series were reported.[1-8,21-30]

Today, in single fingertip injuries, the aim is to lessen the donor site morbidity and to limit the sur-

Correspondence: Murat Kayalar, MD. El Mikrocerrahi Ortopedi Travmatoloji Hastanesi, 1418 Sok, No.14, 35230 Kahramanlar, İzmir, Turkey
Tel: +90 232 - 441 01 21 e-mail: elmikro2003@yahoo.com

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gery within the injured area.[4,11,13,14,21-23,27] Currently local reconstruction of the original slope and curvature of the pulp with dorsal longitudinal vascular network of the injured finger are being reported.[31-38]

Apart from complications, such as cold intolerance and proximal interphalangeal (PIP) joint flexion contracture, direct-flow NIFs are reliable. In some cases, it's more advantageous when compared with other flaps, such as adiposofascial turn-over flap,[37,38] boomerang flap,[33,34] visor flap,[31] heterodigital island flap and homodigital reverse-flow flap.[14,39-48]

This retrospective cohort study evaluated the results of NIF in terms of reliability, fingertip sensitivity and patients' satisfaction.

Patients and methods

We reviewed our records retrospectively to detect the patients who underwent a NIF reconstruction. A total of 96 patients (mean age, 31.4±12.1 [range: 3 to 65] years; 89 male, 7 female), who had 115 finger NIF reconstructions between 1995 and 2003, were included in the study. The cause of injury was mostly crush type industrial injuries (n=70; 72.9%). The other causative factors were guillotine, saw and knife cuts, and traffic accident, conveyor belt, propeller and surface machinery. The involved digits were the index finger in 42 (36.5%) cases and the third finger in 31 (27%) cases. Ten patients sustained an acute thumb injury (Fig. 1). Nineteen patients, who had multiple finger injuries, were operated using two neurovascular direct-flow flaps (Figs. 2 and 3). There were only 3 elective cases, which were operated for hook nail deformity correction. In this

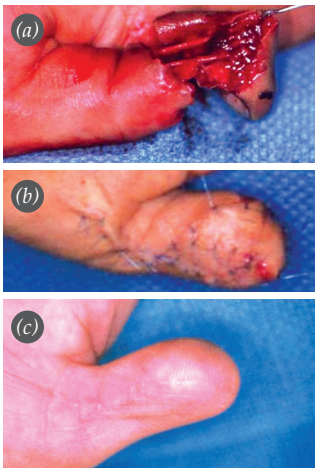


Fig. 1. **(a)** Thumb avulsion injury; **(b)** Primary neurovascular island advancement flap harvested from radial side of finger for pulp reconstruction and preservation of finger length; **(c)** Long term result. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

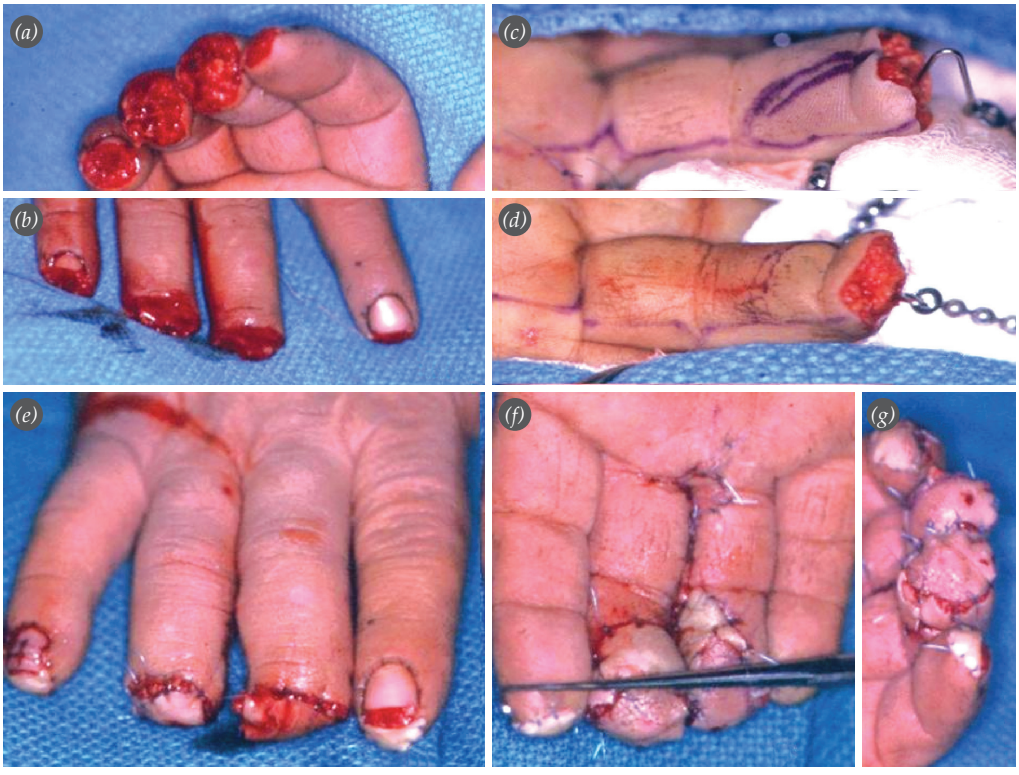


Fig. 2. The use of double finger flaps on the third and fourth fingers; **(a)** Multiple finger amputation; **(b)** Dorsal aspect of finger; **(c)** Large triangle flap island design. **(d)** Square type flap island; **(e-g)** Appearance after insetting the flap. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Fig. 3. **(a-e)** Views of third and fourth fingertips five years later on the same patient. Finger length preserved as much as possible by using flap. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

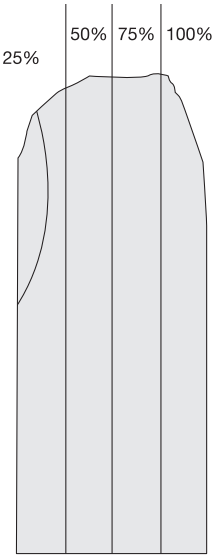
study, NIF indications for fingertip defects were the correction of hook nail deformity, stump closure for the lunula level injury or restitution of the pulp with adequate finger length. The defects that do not exceed the distal interphalangeal (DIP) joint level were convenient for this reconstruction method.

The operation was performed as an outpatient surgery. Plaster splint immobilization was applied for only one week after the operation. The following week, the patients were allowed to initiate limited active movements for ten days. All patients were followed weekly in the first month, then monthly for the next 4 months. An extension lag splint was given when an early flexion contracture was detected. The patients also received desensitization therapy. Return to work was allowed after achieving 90 degrees of flexion with the interphalangeal joints.

Nail beaking (hook nail formation), PIP joint extension lag, cold intolerance, Weber's static two-point discrimination test (s-2PD), and the Semmes Weinstein monofilament (SWM) test results were assessed in postoperative evaluation. Cold intolerance was classified into four stages: A-Severe, B-Disturbing, C-Mild, D-None.

The patients' overall satisfaction was also assessed by self-evaluation of the patients on both the aesthetic and functional state of the finger. The quality of the skin cover, scar appearance and elapsed time to return to work were recorded and a four-grade classification system was used for hook nail deformity (Fig. 4).[17]

Fig. 4. Lim classification for hook nail deformity.



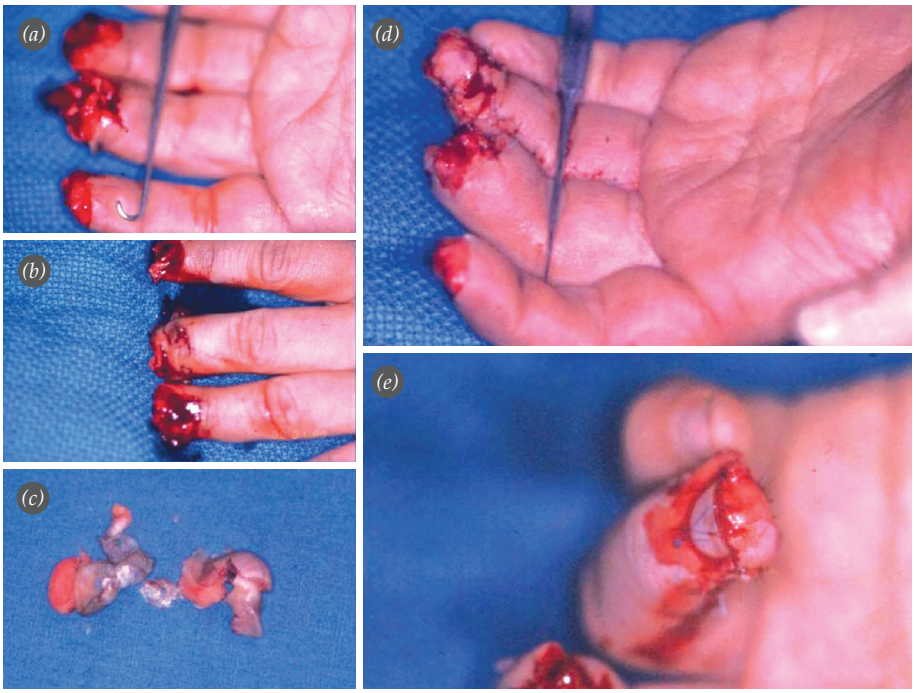


Fig. 5. An example of lateral small triangle flap design. **(a, b)** Crush injury on the fourth finger; **(c)** View of distal amputated part of finger; **(d)** The lateral small triangle neurovascular flap inset; **(e)** Satisfactory aesthetic and functional result. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Surgical procedures

The technique we used in this study contains some similarities to that of Foucher and Lanzetta.[6,24,29,30] The urgent cases were operated within the first 12 hours. The operations were performed with regional anaesthesia, pneumatic tourniquet and loupe magnification.

A midlateral incision is used. The skin flaps is cut into either a small triangle, a large triangle or a square configuration. The small triangle flap does not extend beyond the interphalengeal joint crease (Figs. 5-7). That skin island can be lifted from both the volar and lateral sides. The large triangle skin island extends to

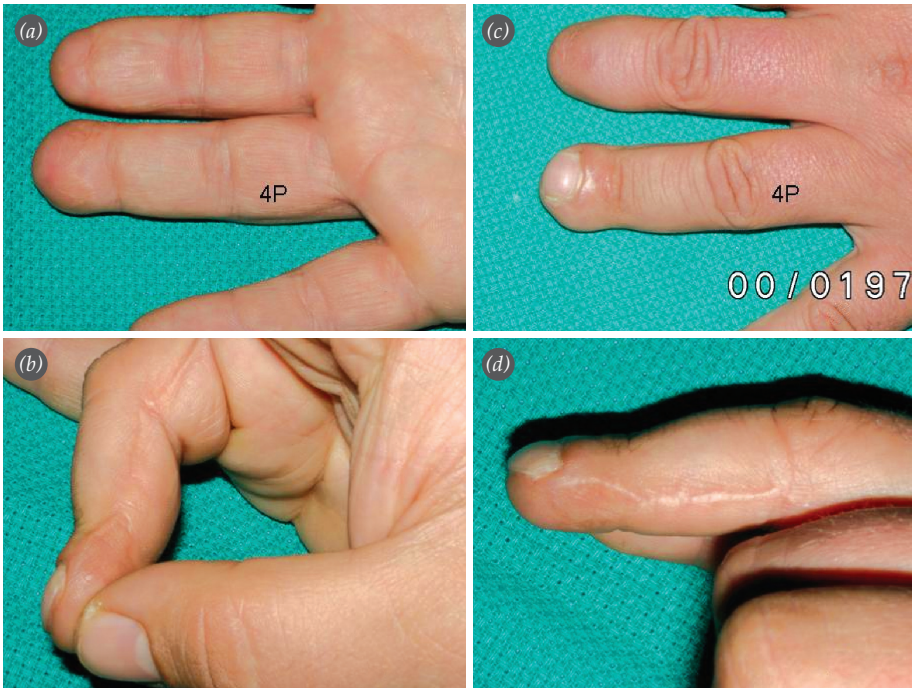


Fig. 6. **(a-d)** Appearence of the same finger after 6 years. Pulp contour has been formed and there isn't any nail deformity. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

the proximal interphalangeal joint. The square skin island is cut up to the contralateral digital artery border (Fig. 2d).

The only known contraindication of NIF is the damage to the opposite digital neurovascular bundle. NIF should be carefully performed in avulsion-type injuries. The damage on the arterial segment may compromise flap circulation in these injuries. Therefore, we begin the dissection of the neurovascular bundle at the proximal phalanx level to control the integrity of the bundle. After dissection, when attaching the flap to the distal tissues, it is advisable not to apply traction towards the volar side. This step can be carried out by either transversely placing it under the nail matrix or attaching it onto the lateral skin folds with fine, non-absorbable sutures (Figs. 5 and 8). It can also be affixed to the bone using a hypodermic needle. While covering the defect, excessive traction of the pedicle is avoided. The donor site can be closed primarily in large triangle skin island flaps. However, if there is pressure on the pedicle due to a tight suture, a full-thickness skin graft is preferred.

Outcome analysis

The statistical analyses were done using the SSPS 15.0 software and chi-square tests. The aetiologies were crush injuries (n=70; 72.9%) and clean cuts (n=26; 27.1%). The relation between the causes of injury and patient satisfaction, cold intolerance, and scar complications were analyzed. The level of significance was set at 0.05.

Results

All flaps survived. Patients were followed up for a period of 12 to 108 (mean: 41±20.3) months. Generally, the soft tissue healed within 2 to 4 weeks, and all patients returned to work within 2±0.8 months. Range of motion was limited in 11 patients (9.5%). The PIP joint extension deficit was less than 10 degrees in 7 of them. The maximum extension loss was 25 degrees.

Hook nails were assessed according to the Lim classification system, which is based on the proportion of the bent part of the nail (beak formation) to the volar to dorsal distance of the fingertip. There were 8 hook nail (7%) deformities varying from severe to mild forms. Three of them were classified as Grade 2 deformity with 25-50% beaking of the whole fingertip. However, only two patients complained of the hook nail deformity and the rest were very mild cases. Upon observation, three patients had some residual short nails without a hook shape,

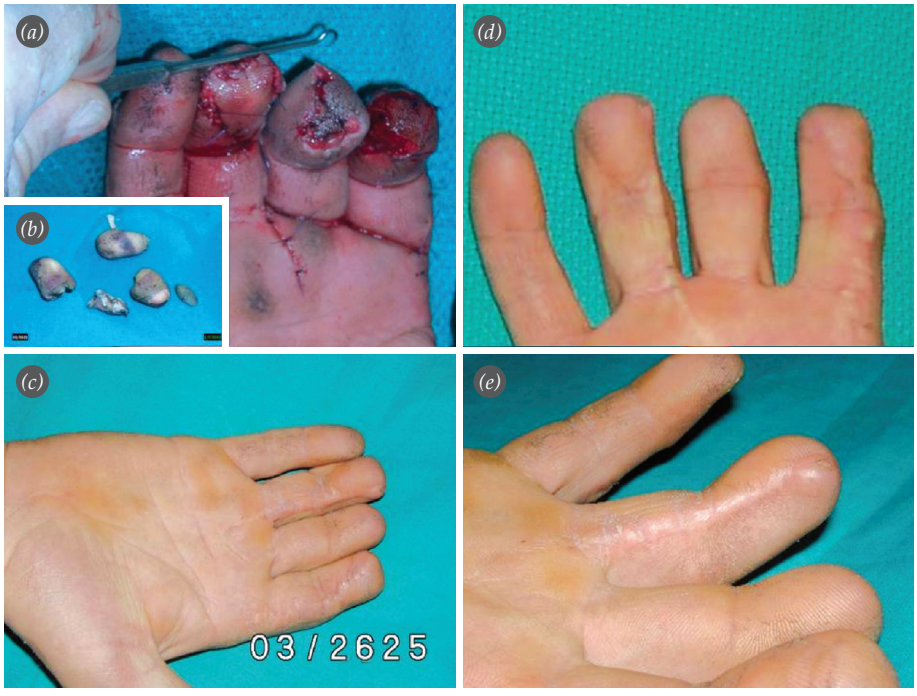


Fig. 7. An example of complications. **(a, b)** Fourth finger neurovascular direct flow flap reconstruction in multipl finger injury; **(c-e)** Skin contracture and proximal interphalangeal joint extension lag was observed in the long term. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

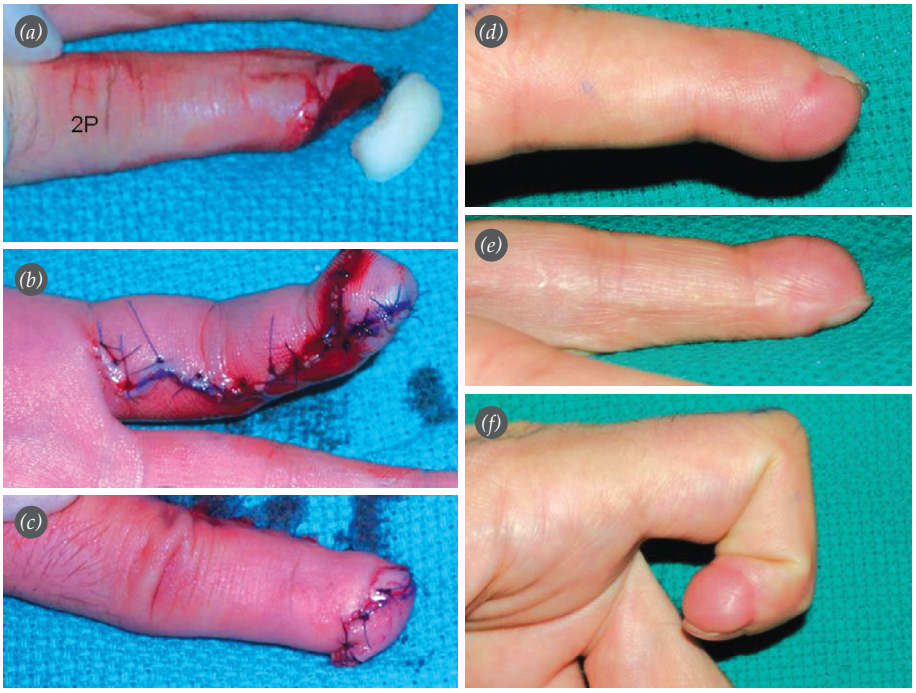


Fig. 8. **(a-f)** Small triangle flap lateral inset for transverse mounting of the distal part of steril matrix, and achievement of satisfactory fingertip form without any nail deformity. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

due to shortening of the distal phalanx and loss of soft tissue. The three patients who had a flap reconstruction for hook nail deformity were satisfied with their results. The hook nail deformity which was 50% according to Lim classification before the operation, decreased below 25% after the operation.

The appearance of the reconstructed tissue was classified as hypertrophic scar or skin contracture by the authors. No significant morbidity were noted in 101 (87.8%) of 115 fingers, with no scar problem. Seven patients (6.1%) had hypertrophic scar which was relieved by silicone gel sheet and topical Contractubex® gel application (Merz Pharma GmbH, Germany) in the early period. Skin contracture with a PIP joint extension limitation of less than 10 degrees, was detected in 7 fingers (6.1%) (Fig. 7).

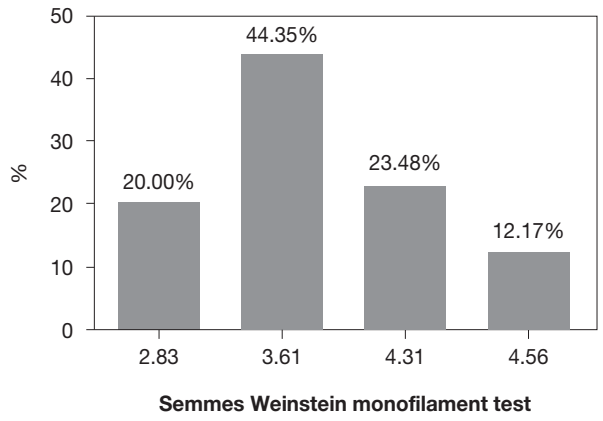


Fig. 9. Distribution of fingers Semmes Weinstein monofilament test results.

Cold intolerance was classified according to the patients' evaluation: 1- "A", indicating a severe intolerance, was present in one (1%) patient; 2- "B", indicating a disturbing intolerance, was present in 15 (15.6%) patients, 3- "C", indicating a mild intolerance, was present in 31 (32.3%) patients, and 4- "D", indicating no intolerance, was present in 49 (51%). Only 2 of 16 patients with severe and disturbing intolerance had discomfort in their daily activities.

In our study most of the cases had a sensitivity at Semmes Weinstein monofilament test with an evaluator size of 4.31 and below (Fig. 9). There were only 14 patients (12.2%), who had sensitivity with an evaluator size 4.56. The two-point static discrimination varied from 2 to 11 mm. It was found over 6 mm in only 5 patients (Fig. 10).

No patient had a postoperative infection. We had a digital arterial injury complication in a 3-year-old patient. This thermal electrocauterization injury was detected after the release of the tourniquet, and repaired. The patient did not have a circulation problem after the operation.

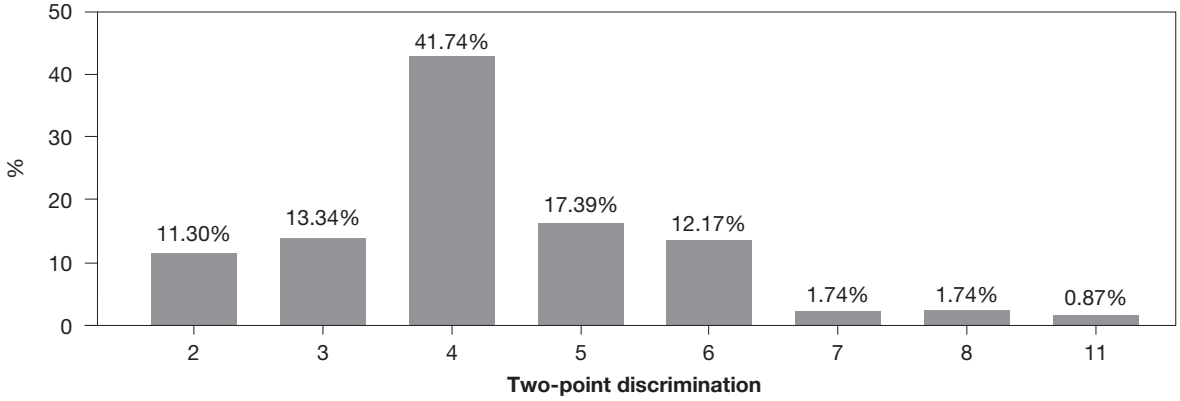


Fig. 10. Distribution of static two-point discrimination test results.

There was no relation between the cause of injury and patient satisfaction (p>0.05). There was also no relation between the cause of injury and cold intolerance (p >0.05) and scar problem (p>0.05). Skin graft was used to cover the donor site in 29 patients (30.2%). There was no significant relation between the presence of skin graft and hook nail deformity (p>0.05).

Eight patients (8.3%) were not satisfied with the result. Two of them had a PIP joint limitation (of 20 degrees and 25 degrees), and another two was complaining of cold intolerance.

Discussion

There are many reports in the literature on homodigital reverse or direct-flow flaps from the adjacent tissues to the defect.[11-14,17,30,32,35,36] Homodigital direct-flow neurovascular island flaps have better results in terms of sensitivity.[1,5-7,11,21,24] Constant and reliable direct blood flow without sacrificing a major artery makes NIF the favourable option in pulp reconstruction. NIF preserves an adequate finger length for a more stable and sensible fingertip. Another advantage of NIF is to allow for early motion. Only 2 of our patients (2.08%) were unsatisfied with their final range of motion.

Foucher et al.[24] reported a mean PIP extension lag of 22.7 degrees, in 17.2% of their patients. Adani et al.[3] detected flexion contracture in 8% of the cases in his series; while Braga Silva and Jaeger[8] detected it in 10% of the cases with volar flap. The mean extension loss in the literature is between 8 to 29 percent.[1] In our series, a mild extension lag of 10 degrees was seen in 9.5 % of the patients.

For large defects extending the level of DIP joint and requiring advancement over 20 mm, other local or distant flap transfers should be considered. Lanzetta et al. reported that NIF can be advanced up to 20 mm.[6] The dorsolateral skin flaps may be larger than the classical NIF. Thus, larger defects may be covered better with those types of homodigital direct-flow flaps.[17,19,21,22,28]

The difference between NIF and reverse-flow homo/heterodigital flaps is that NIF does not necessitate a re-innervation to obtain a sensible island. Reverse-flow flaps get their blood supply from the contralateral digital artery, via transverse palmar arcs, and have higher complication (flow insufficiency) rates.[35,49] They sacrifice the major digital artery and have a higher probability of venous insufficiency.[46-48] However, flap loss is about 15% in Lai's series. In contrast, Ünlü et al. used adiposofascial turn-over flap in 10 patients without any problem.[44] The other advantage of these flaps is that they can be raised

Table 1. Complications.

Complications	
PIP joint ROM limitation	11 fingers (9.5%)
Hook nail deformity	8 fingers (7%)
Skin contracture	7 fingers (6%)
Hypertrophic scar	7 fingers (6%)
Cold intolerance	With a severe and disturbing level in 16 patient (17%)

nearby the defect and include a larger skin island.[46] However, sensorial restoration provided by these flaps is controversial.[11,12,14,33-36] Lai et al. advocated that reverse-flow flap is a good alternative with re-innervation for pulp injuries. The two point discrimination was found between 3.9 and 6.8 mm.[36] Takeishi et al. stated the static TPD values were between 3 and 5 mm in his series. The results revealed that the protective sensation had been recovered.[46,47] These values are close to the average rates of 4-5 mm. in our direct-flow neurovascular flap series (Fig. 4).

Sensorial assessment of the NIF revealed satisfactory results in our series. In 110 (95%) of the reconstructed fingertips, two-point discrimination values were less than 7 mm TPD values were 3 to 9 mm. in 85% of the patients in Adani et al.'s series and 3 to 10 mm in 93.6% of the patients in Varitidimis et al.'s series.[1,3]

Neurovascular island flaps are safe flaps, with a high survival rate. In a previous series flap loss was reported as 10% for the emergency cases and 12.5% for the elective cases[24] and in several studies different failures rates between 3 to 5% were reported.[3,24,26] No patient suffered from flap loss in our series and we had arterial injury complication in only one iatrogenic.

The involvement of thumb pulp reconstructions (n=10) and double-flap reconstructions (n=19) are the distinctive points of our series (Fig. 2-4), as they are not much seen in other publications.[1-8,21-30] The difficulty of NIF dissection in the thumb is related to the arterial anatomy. The pedicle is usually short and may contain some interarterial connections around the interphalangeal joint and the flexor tendon. Thus, the amount of flap advancement in the thumb would always be less than the other fingers.

The rate of cold intolerance was reported between 0% and 38% in previous series.[1,3,5,8,22-24] Cold intolerance was observed in 16 patients (17%) in our series, whereas Varitidimis et al. found a lower rate (6.3%) that they attributed to the regional warm climate.[1] We did not find any association between the injury mechanism and cold intolerance.

Hook nail deformity is a challenging problem after the reconstruction of pulp defects. Although some of our cases resulted in hook nail deformity, none of our patients complained of mild curving. Our hook nail deformity rates were lower than the previous reports (Table 1). We relate this to our surgical technique.

Statistical analysis showed no association between the etiology of the injury (crush/clean cut) and the rate of patient satisfaction, cold intolerance and scar problem. There was also no relation between the donor site skin grafting and nail beaking ($p>0.05$).

As a conclusion, homodigital direct-flow neurovascular flaps generally cause minimal donor site morbidity. Skin islands, lifted off in proportion to the contralateral unaffected pulp, can be safely used in NIF transfers, where the loss of tissue does not extend beyond the DIP joint level.

The satisfaction rate of the patients in our series was as high as 91.7%. The aesthetic and functional results were also good in the long term follow-ups.

In conclusion, homodigital neurovascular direct-flow flaps, with their predictable results, can be used to reconstruct pulp defects that do not extend beyond the DIP joint level. Nail beaking, PIP joint extension lag, and cold intolerance are possible complications of this procedure.

Conflicts of Interest: No conflicts declared.

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