



Long-term outcome of fingertip reconstruction with the homodigital neurovascular island flap

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Abstract

Introduction Fingertip injuries are frequent and several surgical strategies exist to reconstruct the amputated part and restore function and appearance. Yet, long-term results are rarely published. The purpose of this study was to examine the long-term clinical outcome of neurovascular island flaps for traumatic fingertip amputation of Allen type III/IV injuries.

Materials and methods We retrospectively analysed a cohort of patients with traumatic fingertip amputation that underwent reconstruction with a neurovascular island flap from January 2003 to December 2014. No mandatory splinting was applied after surgery. 28 participants (29 fingers) were available for follow-up at mean 8 years after reconstruction. Activities of daily living were measured with the disabilities of the arm, shoulder and hand questionnaire. Grip strength and finger motion were assessed using a Jamar dynamometer and a goniometer. Two-point discrimination and Semmes–Weinstein monofilaments were used to evaluate sensory recovery.

Results No intraoperative complications occurred and all flaps survived. Mean flap size was $4.7 \pm 0.6 \text{ cm}^2$. Active motion of the fingers was over 95% of the contralateral side at follow-up. Three patients showed mild extension lag of the proximal interphalangeal joint. The grip strength of the affected hand and of each of the affected fingers was over 70% of the contralateral side. In comparison to the contralateral side we did not detect any significant difference for the Semmes–Weinstein monofilament test, but two-point discrimination ($5.1 \pm 1.7 \text{ mm}$) was significantly impaired. According to the Lim classification 1 of 14 nails with hook nail deformity showed grade 3 breaking of the nail. The DASH score was 16.0. All patients returned to their original occupation and patient satisfaction with the procedure was high.

Conclusions The risk for disabling flexion contracture seems to be small even without mandatory splinting. Neurovascular island flaps for fingertip amputation of Allen type III/IV injuries are a reliable tool in fingertip reconstruction in the long term.

Keywords Fingertip defect · Homodigital neurovascular island flap · Homodigital artery flap · Fingertip reconstruction · Direct flow flap

Introduction

Fingertip amputations are frequent injuries in trauma units and require immediate treatment [1, 2]. Several surgical strategies exist to reconstruct the amputated part and restore

function and appearance. The ideal reconstruction aims to replace “like with like” and thus to recreate a near normal fingertip in one operation with immediate sensate skin, minimal donor side morbidity and near normal movement [3].

The homodigital island flap meets most of these criteria as it is a sensate flap from the same finger with glabrous tissue to reconstruct the fingertip. Yet many studies report some extent of proximal interphalangeal (PIP) joint flexion contracture due to bending of the finger for an optimal insertion of the flap. Some authors advocate to include z-plasties [4] or step ladder designs [5] or to implement a mandatory splinting regime [6] to minimize PIP joint contracture. However, most studies reporting clinical outcomes of the homodigital neurovascular island flap for fingertip reconstruction only report short or mid-term follow-up and do not

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specify the type of donor site closure or the postoperative splinting regime [4, 7–10].

In this study, we evaluated the long-term clinical outcome of patients with Allen type III/IV finger amputation injuries [11], focussing on the recovery in range of motion, sensibility and impact on daily life.

Methods

We retrospectively analysed a cohort of 53 consecutive patients with traumatic fingertip amputation that underwent reconstruction with a neurovascular island flap from January 2003 to December 2014.

The contact information of 23 patients (43.9%) was no longer correct or the patients could not be contacted by phone or mail. Two patients (3.8%) did not want to participate in the study due to the long journey but expressed satisfaction with the results. These patients were not included in the study. The study was approved by the ethics committee of the regional State Chamber of Medicine (approval number FF 61/2016) and written informed consent was obtained from the participants indicating their permission to scientific publication of the data obtained from their treatment.

Surgical technique

Contraindications for fingertip reconstruction with a neurovascular island flap were prior injury of the digital vessels and any history of angiopathy affecting the vessels of the hand such as vasospasm, vasculitis or embolism. The flap was only raised if the proximal vessels were well perfused and not in the zone of injury. A digital Allen test or an examination with a handheld Doppler to ensure patency of both digital arteries were carried out before the procedure. Only patients compliant to postoperative rehabilitation were considered for surgery. Smoking and advanced age were not considered contraindications. Allen type I and II injuries were treated conservatively.

Antibiotic prophylaxis (second-generation cephalosporin) was administered intravenously prior to surgery. The operation was performed under regional or general anaesthesia. A pneumatic tourniquet with a pressure of 300 mmHg and magnifying loupes were used.

After debridement of devitalized tissues, the flap was designed using a mid-lateral and a palmar oblique incision. The neurovascular bundle was identified proximal to the flap and the flap was raised above the tendon sheath (Fig. 1a, b). The neurovascular bundle was dissected until the flap did fit into the defect without any tension. Venous and arterial congestion of the neurovascular bundle has to be avoided when fitting the flap into the final position, and temporary artificial skin was used when primary closure

could not be achieved at the time of the initial surgery due to swelling. If necessary, the flap was pinned with a 0.7-mm K-wire to the medullary canal of the distal phalanx to prevent proximal retraction. Z-plasties or step advancements were not used. Reconstruction with an ulnar neurovascular pedicle flap was preferred for the index finger tip and a radial-based flap for the little finger.

Patients were encouraged to perform motion exercises according to the instructions of the Hand Surgeon who performed the procedure and a physiotherapist. To ensure tension free healing of the flap emphasis was laid on motion exercises for the PIP joint with a flexed metacarpophalangeal joint. There was no standard splinting regime applied after surgery.

Follow-up

At follow-up, a patient questionnaire was completed assessing patient characteristics, occupation and satisfaction. Grip strength was measured three times for each hand using a Jamar Hand Dynamometer (Sammons Preston, Rolyan, Bolingbrook, IL, USA) on handle position two with seated participant in a neutral wrist position and the elbow by their side flexed to a right angle. The average grip strength was calculated for the left and right hand. Active range of motion for the injured fingers compared to the contralateral digits was assessed using a hand-held finger goniometer for the distal interphalangeal (DIP), proximal interphalangeal (PIP), and metacarpophalangeal (MP) joint and a standard goniometer for wrist joints. To test the patients' static two-point discrimination test (2PD), the standard protocol of the American Society for Surgery of the Hand and the International Federation of Societies for Surgery of the Hand [12] was used. Semmes–Weinstein monofilament (SWM) threshold was measured with a five-piece hand kit. The results of the SWM test were then converted to a point value that is based on the Rosen and Lundborg Physical Impairment Summary Scale [13, 14] with a maximum point value of 5 and a minimum of 0. The tinell's sign on the finger was assessed. Scars were assessed using the Vancouver scar scale, which consists of four variables: vascularity, pigmentation, pliability and height [15]. The pain at follow-up was recorded by a numeric rating scale (0–10). Activities of daily living were measured with the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire [16]. Hook nail deformity was characterised using the Lim classification [17] (Fig. 2). The patient charts were analysed retrospectively.

The follow-up assessments were completed by an independent examiner (N. B.) who was not involved in the patient's treatment.

Fig. 1 a, b The flap is raised above the tendon sheath and the neurovascular bundle is dissected until the flap fits into the defect without tension

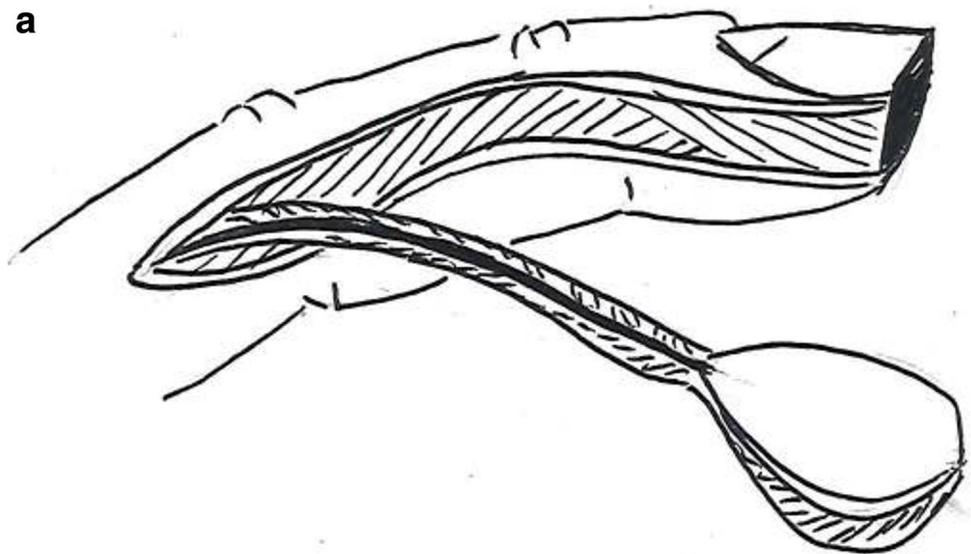


Fig. 2 Lim classification for hook nail deformity. The fingertip is divided into quarters from dorsal to palmar in a lateral view. Grade 0: normal nail appearance with no beak deformity. Grades 1–4: progressively greater downward curvature (beaking) of the nail



Statistical methods

Clinical variables were tabulated according to their distribution with means, range and standard deviation or expressed as percentages. After testing for normal

distribution, differences between injured and contralateral side were tested using unadjusted paired *t* tests to determine significance at the $\alpha = 0.05$ level in normally distributed variables. The Mann–Whitney test was used for asymmetric distributions.

Results

Follow-up was available for 28 patients and 29 fingers. Mean follow-up after the operation was 105 ± 42 months (range 42–169). The mean age of the patients at time of surgery was 42.9 ± 15.0 years (range 11–73). The participants' characteristics are summarized in Table 1.

Treatment and complications

26 patients were operated under brachial plexus block and 2 patients under general anaesthesia. No intraoperative complications occurred. The mean in-hospital stay of all patients was 5.0 ± 3.4 days (range 1–12).

All flaps survived, yet one flap showed partial necrosis, was debrided and closed primarily 22 days after the initial operation. One reoperation was necessary due to bleeding on the fourth postoperative day in a patient with continued perioperative acetylsalicylic acid treatment. In two patients the artificial skin covering the donor side was removed after

swelling had subsided and the wound was either closed primarily or with a skin graft. 3 months after the initial operation, a scar correction was carried out in one patient due to painful scarring of the donor side after failure of conservative treatment. There were no infections during the postoperative course.

Complete healing was achieved after 14.6 ± 9.6 weeks (range 4–48). 16 of 28 patients (57.1%) were treated with physiotherapy (mean 15.3 ± 14.6 sessions, range 2–60) due to scar formation or impaired movement.

Follow-up

Motion and grip strength

Total active motion of the injured finger was $260^\circ \pm 23^\circ$ (unaffected side $268^\circ \pm 15^\circ$, $p=0.021$). The motion in the DIP, PIP and MP joint was over 95% of the contralateral side. Three patients developed an extension lag of 5° , 15° and 20° in the PIP joint (Table 2) and one patient developed an extension lag of 10° in the DIP joint. No patient demonstrated an extension lag in the MP joint. There was no impairment of wrist motion. The grip strength of the affected hand and of each of the affected fingers was over 70% of the contralateral side. Detailed results of hand function are summarized in Table 3.

Patient satisfaction

On a numeric rating scale, pain at rest was mean 1.2 and motion pain was mean 2.4. 21 participants (75%) reported no pain at rest and 15 of 28 (53.6%) no motion pain. 14 of 28 (50%) of participants reported an increased sensitivity to cold temperatures and 5 of 28 (17.9%) tenderness of the reconstructed fingertip. The overall DASH score was 16.0. The score of the DASH work module was 17.2 ($n=20$) and the score of the sport module was 15.5 ($n=19$). Patient satisfaction was 8.7 ± 1.4 on an eleven point rating scale (0 = extremely dissatisfied and 10 extremely satisfied). All participants would have had the same surgical procedure again (as opposed to a qualified amputation) knowing the final outcome.

Table 1 Demographics

Patients available for follow-up	28 (29 fingers)
Gender	24 male, 4 female
Affected hand	25 right, 3 left
Affection of the dominant hand	14 of 28 (50%)
Professional activity as manual worker	17 of 28 (60.7%)
Affected finger	
D1	1 of 29 (3.4%)
D2	10 of 29 (34.5%)
D3	10 of 29 (34.5%)
D4	6 of 29 (20.7%)
D5	2 of 29 (6.9%)
Allen's classification	
Type I	0
Type II	0
Type III	22 (75.9%)
Type IV	7 (24.1%)
Smoker	9 of 28 (32.1%)

Table 2 Demographics and clinical results of patients with a decrease in the proximal interphalangeal (PIP) joint extension angle

Patient	PIP joint extension lag	Age in years ^a	Injured finger	Follow-up in months	Time to heal in weeks	Sessions of physiotherapy	DASH score
1	5°	64	II	45	6	18	5.8
2	15°	34	IV	44	10	24	6.7
3	20°	45	II	169	12	10	29.2

DASH disabilities of the arm, shoulder and hand questionnaire

^aAt the time of injury

Table 3 Hand function

	Average (SD) at follow-up	Comparison to contralateral side (%)
Total active motion in degrees	260 (23)	97
DIP motion in degrees	81 (19)	96
PIP motion in degrees	96 (6)	98
MP motion in degrees	87 (9)	99
Grip strength at wrist in kg	33 (13)	91
Grip strength at injured finger in kg for		
DII	5 (3)	80
DIII	4 (2)	100
DIV	5 (2)	79
DV	1 (1)	73

SD standard deviation

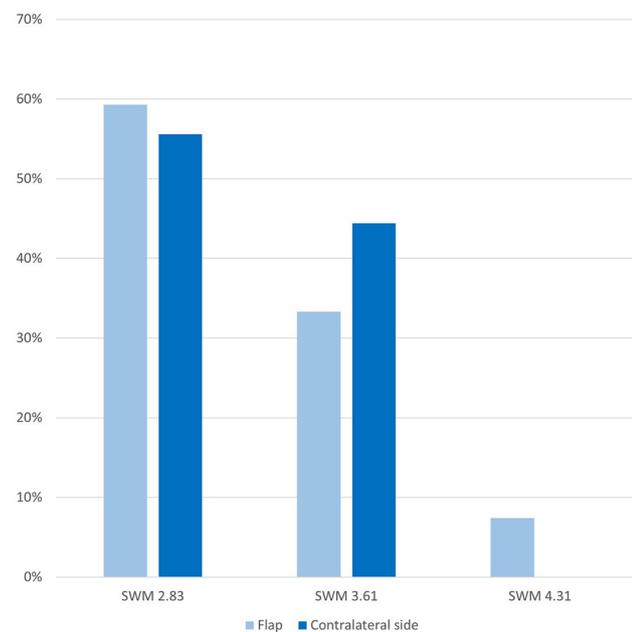


Fig. 3 Distribution of Semmes-Weinstein monofilament (SWM) results of the injured finger (flap) compared with the contralateral finger. There was no statistical significant difference in the Mann-Whitney test between the injured and uninjured side ($p=0.976$)

Neurological assessment

The Semmes-Weinstein monofilament results are shown in Fig. 3. 9 patients were able to feel the 3.61 (diminished light touch) at the reconstructed fingertip and 2 patients feeling 4.31 (diminished protective sensation). The remaining patients were able to feel 2.83 (normal). In 23 patients the results of the injured finger were equal or better compared to the uninjured side. There was no

statistical significant difference in the Mann-Whitney test between the injured and uninjured side ($p=0.976$).

Static two-point discrimination was 5.1 ± 1.7 mm (range 2–8), contralateral side 3.6 ± 1.0 mm (range 2–6, $p=0.005$). In nine patients the results of the injured finger were equal or better compared to the uninjured side.

Four patients reported a tingling sensation over the course of the nerve and seven patients (including the latter 4) showed a mild Tinel's sign after careful examination despite conservative treatment. None of the seven patients described this sensation as disturbing.

Appearance

Mean flap size at follow-up was 4.7 ± 0.6 cm². The scars were rated 0.6 (range 0–3) on the Vancouver scar scale by the independent examiner.

The nail plate could be preserved in 22 of 29 (75.9%) fingers. In 10 of the reconstructed fingertips with preserved nail, the nails were shorter than the contralateral side (mean 1.8 ± 0.6 mm shorter, range 1–3 mm). 14 fingers showed hook nail deformity at follow-up. According to the Lim classification 1 of 14 nails (7.1%) showed grade 3 breaking of the nail and 7 of 14 (50.0%) showed grade 2. The remaining 6 nails (42.9%) were classified as grade 1. All patients with preserved nail were satisfied, that the finger had a nail. No patient reported further treatment due to hook nail development, infections or other complications caused by the nail deformity.

Occupation

27 of 28 patients were working at the time of injury, one participant had retired. The average absence from work was 6.1 ± 3.3 weeks (range 1–12 weeks). In the 18 of 27 patients that received WC, the average sickness leave was 6.9 ± 3.4 weeks (non-WC patients 4.4 ± 2.5 , $p < 0.05$). All 27 patients, including the 17 blue collar workers, returned to their original occupation. All patients returned to the same work schedule, that they had before the injury.

Discussion

Choosing a suitable treatment for an individual patient with fingertip injuries remains challenging despite many options. There is an ongoing discussion among hand surgeons which treatment is best for different types of fingertip injuries [18–20]. The therapeutic armamentarium consists of a variety of conservative and surgical treatments including revision amputation [2, 20–22]. Publications are very heterogeneous regarding mechanism and level of injury, demographic characteristics and treatment technique and

thus results are sometimes hard to compare. Many studies are published describing new surgical techniques for fingertip reconstruction. However, most studies only report short- or mid-term outcomes. The homodigital island flap meets a lot of the criteria for an ideal reconstruction, yet only few studies are published with a longer follow-up. Knowing the long-term outcome would help surgeons and patients to make an informed decision when considering the right option for the individual patient. In this study, we showed that a functional digit can be expected in most patients after homodigital island flap reconstruction of the fingertip at follow-up of more than 8 years.

One main goal of the treatment of fingertip injuries is to restore a near normal active motion without flexion contracture. The present study shows total finger joint movement over 95% of the contralateral side, which is rated “good” according to Kleinert [23]. 14.3% developed an extension lag of the PIP or DIP joints with a maximum of 20°. In a study of 63 fingers [10] 23.8% showed an extension lag in the interphalangeal joints at a mean follow-up at 46 months. In this study, extension exercises and splinting were used, when a flexion contracture persisted, but no further information is given on this topic. In another study [7], 9.5% of the 115 fingers showed impaired motion at a mean follow-up at 41 months. The maximum extension lag in the PIP joint was 25°. Plaster splint immobilization was applied for only 1 week after the operation and an extension lag splint was prescribed in case of an early extension lag. Usami [9] followed 17 patients at mean 12.1 months and found mild PIP joint contractures in 23.5% of fingers. We attribute the overall good outcome in motion in our series mainly to the fact that our study had a longer follow-up than other studies with small improvements of the extension lag over time.

A multivariate analysis of 44 fingers with average 33 months follow-up detected age over 59 years as an independent predictor of flexion contracture of the PIP joint [24]. However, we could not confirm this finding, as in our series only one of the three patients with PIP joint flexion contracture was over 59 years while the other ones were noticeably younger.

Mandatory splinting after surgery remains controversial. As our results are not inferior to the results of other authors that splint every finger, mandatory splinting might not be necessary. Other reconstructive options such as cross-finger flaps or palmar flaps require additional immobilization and bear the risk of PIP flexion contracture, too [3]. The reverse flow island flap with neurotomy can minimize this risk, yet discriminatory sensation seems to be better in the direct flow flap [8].

Reaching the optimal sensation of the reconstructed fingertip is another main goal of treatment [25]. In a study with 115 fingers 87.3% of fingers showed a sensitivity of 4.31 or better in the SWM test after mean follow-up of 41 months

[7]. However, there was a wide variety of 2PD ranging from 2 to 11 mm. 66.4% fingers had a 2PD of 2–4 mm.

In the study published by Varitimidis and colleagues [10] static 2PD was mean 4 mm with 93.7% of fingers having a static two-point discrimination between 3 and 6 mm. In our study, static two-point discrimination was mean 5.1 mm, which is rated as “excellent” according to the Modified American Society for Surgery of the Hand guidelines to stratify 2PD [26]. All patients (100%) showed a sensitivity of 4.31 or better in the SWM results. Our results of static two-point discrimination are comparable to other studies, while the results for SWM seem to be slightly better in our long-term study compared with studies that have less follow-up.

There are only few studies addressing the nail after fingertip reconstruction with a neurovascular island flap, but most authors mention hook nail deformity as possible complication [10]. In a series of 115 fingers hook nails were detected in 8 fingers (7%) at mean 41 months. Three patients underwent flap reconstruction for hook nail deformity and were satisfied with their result [7]. The findings of Lim [17] suggests, that nail breaking might worsen over time in fingertips that were reconstructed with a spiral flap. In our series nearly half of the participants demonstrated varying degrees of hook nail deformity at long-term follow-up, yet no patient complained about it at follow-up or needed treatment. This promotes that patients should be counselled about the possibility of nail deformity before surgery.

There is an ongoing discussion regarding the best treatment for fingertip amputations. Despite the high frequency of this injury no evidence-based standard has been established so far.

One main alternative to flap reconstruction is conservative management [11] e.g. with semi-occlusive dressings [27]. Several studies reported good results with near-normal sensibility and without donor side morbidity not only in distal fingertip amputations but also in patients with Allen's type III/IV injuries [18, 28–30]. The few existing comparative studies indicate, that surgical reconstruction of the fingertip might offer little to no advantage over conservative treatment [31, 32]. Accordingly, our own treatment standard has shifted from flap surgery for most patients with exposed bone until 2014 to a more conservative approach based on the characteristics and mechanism of the amputation and the individual needs of the patient.

There are some limitations to this study. First, it is a single-centre cohort study. Second, follow-up was only available for 28 patients, and thus this is a small sample size. Third, as the Allen classification [11] was used to classify injuries there is no information on the direction of injury or the shape of the defect. Using more complex classifications with more subdivisions to describe the injury would be more exact [33], but these were considered too complicated by

some authors [10] and are thus not commonly used in other studies [9, 8, 7].

Conclusion

A very high patient satisfaction and good long-term function can be achieved with the anterograde homodigital neurovascular island flap in a one-step operation with immediate sensitivity of the reconstructed fingertip without compromising an uninjured adjacent finger. Mandatory splinting or z-plasties to avoid disabling PIP joint flexion contracture might not be necessary. A functional digit with near normal length and good movement can be expected in most of the patients. Further studies are needed to compare the long-term clinical outcome of different therapeutic options.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The study was approved by the ethics committee of the regional State Chamber of Medicine (approval number FF 61/2016) and written informed consent was obtained from the participants indicating their permission to scientific publication of the data.

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