

VOLAR V-Y ADVANCEMENT FLAPS IN RECONSTRUCTING FINGERTIP INJURIES

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1. INTRODUCTION

The fingertip is a highly specialized end-organ that is adapted for touch (Kawaiah et al., 2020). Fingertip injury is mechanical injury distal to the distal interphalangeal joint of the finger and distal to the interphalangeal joint of the thumb (Martin-Playa & Foo, 2019).

Distal amputations of the digits are among the commonest injuries in hand surgery. (Golinvaux et al., 2019) A loss of skin over the pulp of the fingers and thumb creates a problem for its replacement with suitable skin having a sensory nerve supply to restore optimum sensation. (Lim & Chung, 2020)

Fingertip injuries with exposed bones and joints require immediate or early closure for the preservation of function and avoidance of complications. (Koh et al., 2022)

The various procedures of management include conservative management, skin grafts, regional flaps, local flaps and free flaps. (Chakraborty et al., 2021)

The main goals of treatment are the restoration of sensation and durability in the tip, assuring proper bone support to allow for nail growth & restoration of sensation, durability of the tip which is essential for finger motion as well as hand action, and, finally, maintaining appearance. (Tang et al., 2014)

Exposed tendon, bone, or joint surface is best treated by flap coverage. (Rabarin et al., 2016)

Among the flaps used is the flap described by Tranquilli-Leali in 1935, and described again by (Atasoy et al., 1970) (Chakraborty et al., 2021; Franke et al., 2022) is an advancement of palmar skin and pulp tissue to cover exposed bone at the digital tip. (Franke et al., 2022; Waiker et al., 2022)

Because the flap is vascularized by small vessels of the subcutaneous pulp tissue lateral to its edges, its use must be limited to amputations distal to the nail fold (Panattoni et al., 2015). It can only provide adequate bone cover if the amputation is transverse or dorsally-facing. (Waiker et al., 2022) The flap is further restricted in that it is only adequate for transverse amputations at or distal to the mid-nail level. (Waiker et al., 2022)

To overcome these limitations, a larger flap was designed with the flap extending proximal to the proximal interphalangeal (PIP) palmar crease and vascularized directly by the neurovascular bundles and is called the “neurovascular Tranquilli-Leali flap”. (Zook et al., 1980)

The aim of this study is to evaluate the role of the different types of volar V-Y advancement flaps in reconstructing and resurfacing injuries of the fingertips at different levels and angles.

2. MATERIALS & METHODS

The study had been carried out as per the approval of the BAU institutional review board number 2023-H-0126-M-R-0533.

2.1. Sample Selection and Preparation

Thirty patients (N=30) sustaining fingertip injuries of variable aetiology and lost components were selected as per the following inclusion exclusion criteria:

Inclusion criteria:

- ✓ Patients having single/multiple acute traumatic fingertip amputations.
- ✓ Where there is contraindication for replantation of fingertip (age >70 yr, smoker, drug abuse, psychiatric illness, contamination, duration of warm ischemia more than 6 h, avulsion or crush injury).
- ✓ Type III & IV amputation (Allen).

Exclusion criteria:

- ✓ History of trauma more than 3 weeks.
- ✓ Thumb injuries.
- ✓ Any patient with co morbidities like diabetes, collagen vascular diseases, peripheral vascular diseases (Buerger’s disease, Raynaud’s disease), leprosy, pre-existing joint injury, joint stiffness, arthritis, and Dupuytren's contracture.
- ✓ Raw area due to any cause other than trauma.
- ✓ Refusal to give consent to participate in the study.

The following routine has been followed in every one of the thirty patients comprising this work:

2.1.1. Local examination of the injured finger as regards:

- Exposed bone or not, and if exposed: fractured or intact.
- Type of tissue loss: soft, bone or both, i.e. composite
- Level of tissue loss:
 - Loss of part of the terminal phalanx (Allen's type III)
 - Amputation proximal to the lunula (Allen's type IV)
- Direction of tissue loss:
 - Dorsally-directed
 - Volarly-directed
 - Oblique (right or left)
 - Guillotine (perpendicular)

2.2. Grouping

The patients were divided into 2 groups (n=15) according to the extent of tissue loss and the direction of the injury:

Group I (n=15): The injury has been distal to the mid terminal phalanx and slanting dorsally, type III & IV according to Allen's classification. *V-Y Volar flap* has been used in the patients of this group. The flap is of limited size with its apex stopping at the distal interphalangeal joint (DIP) volar crease and its blood supply depends on the terminal trifurcation of the digital arteries.

Group II (n=15): The injury in this group extended more proximally than in group I. The defect has been either volarly-looking or transverse (guillotine), type III & IV according to Allen's classification. Neurovascular V-Y Advancement Flap was used for this group. A much bigger and more proximally based V-Y advancement flap has been utilized based on the actual digital arteries for the blood supply. The apex of the flap could extend to the level of the proximal interphalangeal joint (PIP) volar crease.

All techniques were carried out under tourniquet, good lighting and magnification 3.5 loop (Heine, Germany).

2.3. Surgical Procedure

2.3.1. V-Y Volar flap:

Digital block was administered with 5 ml xylocaine without Epinephrine using a 27-gauge needle.

Blood was exsanguinated from the finger and a tourniquet was placed around the base of the finger and held flat with a hemostat to provide even pressure and a blood-free surgical field.

The entire hand and distal forearm were properly disinfected and draped

The wound thoroughly irrigated with normal saline and inspected before the initiation of treatment.

The proposed palmar skin incisions were marked from the lateral edges of the amputation site proximally and obliquely to meet in the midline of the finger crease, usually at the distal finger crease. This created a triangular flap.

The base of the triangle was the cut edge of skin where the amputation has occurred. This base should be at least the same width as the amputated edge of nail matrix. The oblique incisions were about 1.5 times the width of the flap.

The skin was incised through dermis only. The fibrous septa connecting the flap to the underlying periosteum and tendon sheath were divided under direct vision.

The tip of the dissecting scissors was then used to bluntly dissect and divide the Grayson's and Cleland's ligaments that connected the flap to the surrounding tissues.

After minimum debridement of the stump (smoothing of the sharp edges of the bone end), the flap was advanced over bone and the base of the triangle was sutured to the nail bed with 5-0 prolene sutures.

The V incision on the palmar aspect of the distal phalanx was then closed by converting it to a Y with interrupted sutures.

The sutures were kept close to the skin edge to reduce interference with the vascular supply.

Tension-free closure was mandatory to prevent necrosis or the development of a curved-nail deformity.

The sutures were removed on the 7th postoperative day.

2.3.2. Neurovascular V-Y Advancement Flap:

A larger volar skin flap that extends proximally onto the middle phalanx and the V portion of the flap was planned, with the apex at the PIP-joint flexion crease, has been used in patients in group II.

Repair was carried out under supraclavicular block and arm tourniquet control.

After standard preparation and draping techniques amputation stump was debrided and the flap was outlined bilaterally & the initial skin incisions were made on both the radial and ulnar mid-axial lines, placed along the dorsal aspect of the flexion creases, and remaining dorsal to the neurovascular bundles till the middle of the middle phalanx where both lines were made oblique to meet at the midpoint of the proximal interphalangeal flexion crease (Fig. 1 & 2).



Fig.1: Flap design; lateral view.
Figure made by the Authors



Fig.2: Flap design; volar view.
Figure made by the Authors

The flap was vascularized proximally, and directly by the neurovascular bundles. These were sought and visualized on the underside of the flap as it was turned back from the palmar surface of the distal phalanx and the flexor tendon sheath. The proximal neurovascular bundles could be dissected to increase flap mobility.

The entire volar skin and subcutaneous tissue of the pulp were elevated off the flexor-tendon sheath and therefore the flap was only be attached to the finger by the neurovascular bundle (Fig.3).



Fig. 3: Flap only attached to finger by neurovascular bundles and ready for advancement.
Figure made by the Author.

The flap was advanced distally over the tip defect.

The tip was shaped by excising the corners of the leading edge of the flap.

The end of the flap was sutured to the cut edge of the nail bed and the sides of the digit using 5-0 Prolene interrupted sutures. The donor site was closed in a Y over the middle phalanx using interrupted sutures.

While performing V-Y volar flap after drawing the flap, incision was made only through the skin, attention not to cut fat or subdermal tissues was made, then when dissecting the flap from the underlying periosteum free all connections to distal phalanx.

As for the neurovascular V-Y advancement flap an important point regarding the vertical limb of the Y is that it should not be closed tightly to avoid narrowing of the digit at this level which might jeopardize the potency of the vascular pedicles and consequent vitality of the distal very important and much needed part of the flap.

2.3.3. Assessment:

Subjective assessment:

- Tenderness.
- Cold intolerance.
- Period of disability.
- Patient satisfaction.

Objective assessment: The healed flap has been assessed with regard to:

- Healing and flap survival rate.
- Movement of the PIP & DIP joints and range of movement.
- Nail growth & shape
- Superficial sensation in the flap.

Light touch & Static two-point discrimination test was evaluated

2.3.4. Statistical analysis:

Qualitative variables were expressed as number and percentage while quantitative variables were expressed as mean (\bar{X}) and standard deviation (S).

The following statistical tests were used in the present study:

- 1- The χ^2 -test was used as a non-parametric test of significance for comparison between the distributions of two qualitative variables.
 - 2- The Fisher's exact test was used as a non-parametric test of significance for comparison between the distributions of two qualitative variables whenever the χ^2 -test was not appropriate. It gives a p-value directly.
 - 3- Independent samples t-test was used as a parametric test of significance for comparison between two samples means, after performing the Levene's test for equality of variances.
 - 4- Paired samples t-test was used as a parametric test of significance for comparison between before and after values of a quantitative variable.
- A 5% level is chosen as a level of significance in all statistical significance tests used.

3. RESULTS

This work included 30 patients sustaining various types of fingertip injuries divided into two groups: 15 treated with V-Y volar advancement flap and 15 treated with neurovascular V-Y flap.

Twenty-five were males (83.3%) and 5 were females (16.7%).

Table I shows that the volar V-Y advancement flap was used in 11 cases (73.3%) with Allen type III, and in 4 cases (26.7%) with Allen type IV injury. On the other hand, the neurovascular volar V-Y advancement flap was used in 2 cases (13,3%) with Allen type III and 13 cases (86.7%) with Allen type IV.

Table I. Level according to Allen's classification.

Level	Group I n = 15		Group II n = 15		Total n = 30		Test of Significance:
	N	%	N	%	n	%	
Grade III	11	73.3	2	13.3	13	43.3	χ^2 -test: p = 0.001*
Grade IV	4	26.7	13	86.7	17	56.7	

χ^2 -test: Pearson Chi-Square Test

* Statistically significant difference

Table II shows that the V-Y volar flap was used in 73.3% of cases(11patients) with dorsally directed fingertip injuries, 26.7% of cases with guillotine amputations with slightly slanting dorsally (4 patients). While it indicates that the neurovascular volar V-Y advancement flap was used in 53.3% of cases with guillotine amputations (8 patients), and 46.7% of cases with volarly directed fingertip injuries (7 patients).

Table II. Distribution according to angle of amputation.

Angle of amputation	Group I n = 15		Group II n = 15		Total n = 30	
	N	%	N	%	n	%
Dorsally directed	11	73.3	0	0.0	11	36.7
Guillotine	4	26.7	8	53.3	11	36.7
Volarly directed	0	0.0	7	46.7	8	26.7

The mean operative time taken to perform the volar V-Y advancement flap was 18.27±3.67 minutes (range 14- 25 min), while the mean operative time taken to perform the neurovascular volar V-Y advancement flap was 71.33±14.10 minutes (range 45- 90 min). When checked statistically using the t-test the volar V-Y advancement flap was found to have significantly less operative time.

As regards the time elapsed before return to work the mean value in patients of group I was 15.67±7.01 days, while in group II the mean value was 18.00±5.84 days (Table III).

Table III. Statistical analysis of both groups according to operative time and return to work.

		Group I n = 15	Group II n = 15	Test of Significance:
Operative time	Mean	18.27	71.33	t-test: t =14.1 p = 0.001*
	SD deviation	3.67	14.10	
Time elapsed before return to work	Mean	15.67	7.01	t-test: t = 0.99 p =0.33
	SD deviation	18.0	5.84	

* Statistically significant difference

Table IV shows analysis of the complications that happened in both groups. In group I infection occurred in one case (6.7%), two cases (13.3%) ended up with parrot beak deformity of the nail. In contradistinction to a single case of infection (6.7%), and another of parrot beak deformity of the nail (6.7%) were reported in group II. A single case of partial flap loss (about 10% of the flap) also occurred in group II which did not expose the bone and only required dressings to heal in two weeks' time.

Table IV. Statistical analysis regarding complications.

Complications	Group I n = 15		Group II n = 15		Total n = 30		Test of Significance:
	N	%	N	%	n	%	
Infection	1	6.7	1	6.7	2	6.7	FET: p = 1.00
Parrot beak deformity of the nail	2	13.3	1	6.7	3	10	FET: p = 1.00
Partial flap loss	0	0.0	1	6.7	1	6.7	FET: p = 1.00

Table V shows the results of light touch examination, at 6 months postoperatively.

Table V. Statistical analysis regarding light touch sensation.

Light touch examination	Group I n =15						Group II n = 15					
	Repaired		Contra-lateral		Total		Repaired		Contra-lateral		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Preserved	10	66.7	15	100	25	83.3	14	93.3	15	100	29	96.7
Poor	5	33.3	0	0.0	5	16.7	1	6.7	0	0.0	1	3.3
Test of Significance:	FET: p = 0.0042*						FET: p = 1.00					

* Statistically significant difference

Table VI show the variation in static two-point discrimination test between the injured fingertip and the contra-lateral normal fingertip at 6 months postoperatively.

Table VI: Statistical analysis of static two-point discrimination.

Static 2-point discrimination	Group I n = 15		Group II n = 15		Test of Significance:
	Mean	SD deviation	Mean	SD deviation	
Repaired finger	4.98	0.76	3.50	0.96	t-test: t = 4.666 p < 0.001*
Contra lateral finger	3.06	0.48	3.01	0.58	t-test: t = 0.239 p = 0.813
Paired samples test	t = 16.616 p < 0.001*		t = 2.986 p = 0.01*		

* Statistically significant difference

DISCUSSION

The fingertip is the most important part of the finger. It has been described by Moberg as an organ of sensibility or the third eye. (Moberg, 1964)

Surgical reconstruction is needed to preserve maximum function and to minimize the loss of time from work.

Thousands of people suffer from devastating hand injuries every year, often leading to fingertip amputations. It is estimated that as many as 45,000 finger amputations are performed in the US per year with an incidence rate of 7.5/100,000 people. (Reid et al., 2019)

The traumatic tissue losses of long fingers treated with volar V-Y advancement flaps were the subject of our study in the last 12 months.

The ultimate goal of fingertip reconstructive procedures is to obtain a functional and aesthetically pleasing hand for the injured patient.

Innumerable techniques of digital tissue loss covering have been described and are successfully utilized nowadays. The indication of more complex surgical procedures is dominant when there is osseous exposure. The osseous covering provided by direct suture or cutaneous grafting produces unsatisfactory results and the cutaneous flap is preferable.

The V-Y volar flap has been developed for reconstruction when the distal phalanx is amputated and the bone is exposed. The dorsally oblique amputations are the best indication for this method. Transverse amputations is the second-best indication for the triangular volar skin flap. (Ji et al., 2023; Wang et al., 2022)

Because the volar V-Y flap is vascularized by the small vessels of the subcutaneous pulp tissue lateral to its edges and distal to the trifurcation of the digital arteries, its use must be limited to amputations distal to the DIP palmar crease i.e it is contraindicated for palmar oblique amputations with extensive soft tissue loss. (Scheker & Becker, 2011)

To overcome these limitations, a larger flap has been designed with the flap extending proximal to the DIP palmar crease and vascularized directly by the neurovascular bundles. Such flap has been devised by Elliot et al (1995) and called the "Neurovascular Tranquilli-Leali flap". (Elliot et al., 1995)

For simplicity we referred to this particular flap in this study as the "Neurovascular V-Y advancement flap" and the previous, smaller, more distal V-Y advancement flap mentioned earlier, as "V-Y volar flap".

The neurovascular flap has been used for all three angulations of fingertip amputations (dorsally-directed, volarly-directed and perpendicular guillotine) and also for more proximal finger loss. (Martin-Playa & Foo, 2019) In our work the neurovascular volar V-Y flap was not used for dorsally directed amputations as these injuries were easily dealt with using the V-Y volar flap which was technically much easier to perform.

Because the neurovascular V-Y advancement flap is not based on the small blood vessels beyond the arterial trifurcation but on the actual neurovascular bundles, it can provide tip cover following amputations of the fingertip proximal to the level of the nail fold. It can also be used to achieve stump closure, without shortening, in more proximal amputations at any level of the finger.

Because it is bigger and only attached by the neurovascular bundles, it is capable of greater advancement than the V-Y volar flap. This makes it possible to use this flap not only for transverse and dorsally-facing amputations, but also for volarly-facing amputations up to an angle of 30° to 35°.

Elliot et al (1995) proposed that in order to increase the size of these flaps and so increase their potential for advancement they could be advanced to cover the exposed bone with pulp tissue only, with the tip then re-epithelializing under moist antiseptic dressings, except where suture to the nail or dorsal skin could be achieved easily. This is only usually the case with dorsally-facing amputations, although this technique only achieves a difference of 1mm to 3mm in flap size and advancement, it allows a significant widening of the circumstances in which this flap can be used and allows cover of the fingertip with less tension. Re-epithelialization in this way also appears to achieve more rounded fingertips. The proximal "V" of exposed pulp tissue following flap advancement has not been closed as a "Y" in most cases, but had also been left to re-epithelialize under moist dressing. Elliot feared that closure of the "Y" might narrow the finger proximal to the flap with the risk of post-operative flap congestion. There have been no flap deaths in his series.(Elliot et al., 1995)

Functional evaluation involves objective and subjective criteria, including light touch, two-point discrimination, time elapsed before return to work and patient's complaints of tenderness, cold intolerance. These are the most commonly used tools in evaluation of the outcome. Presence or absence of residual disability, such as permanent joint stiffness or deformity, is perhaps the most objective criterion of assessment.

As regards the functional assessment:

The light touch the results were checked by Fisher's exact test and the difference was found to be statistically not significant, this was consistent with the work of Marouf.(Marouf MF., 1988)

The sensitivity was evaluated with two-point discrimination, and was considered satisfactory in all patients.

The results of 2-point discrimination in the cases managed using neurovascular V-Y flap were checked by t-test for equality of means and were found to have significantly better results than the cases managed by V-Y flap.

The less significant difference in the static two-point discrimination test between the normal contra-lateral finger and the finger reconstructed using the neurovascular V-Y advancement flap than in the cases treated with the V-Y volar flap, is quite plausible. This is because of the inclusion of both digital nerves in the neurovascular V-Y flap. This does not happen in the smaller V-Y volar flap, with apex at the DIP, in which sensation depends on terminal ramifications of the digital nerves rather than the actual nerves.

Complications represented up to 10% of the cases (3 cases);

Infection occurred in 6.7% of our cases (2 cases), one from each group, both were treated by oral antibiotics and topical antibiotic ointment until infection resolved.

In one case (3.3%) of group II there was partial loss of the flap which healed by granulation and epithelialization without exposure of bone. In that case, the extent of the lesion was probably inadequately evaluated, and the vascular pedicle might have been already affected. Or may be due to faulty technique, as the flap requires meticulous dissection, actually this case was our first in the series. That is why an experienced surgeon should perform this flap.

Interphalangeal joint stiffness was not considered as a residual disability as it resolved completely within a few weeks of suture removal and application of extension splint.

Parrot beak deformity of the nail was seen in one case in group II (6.7%) and in 2 cases in group I (13.4%). Walker reported hook nail deformity in 9% of patients treated with neurovascular V-Y flap. (Kumar & Satku, 1993; Walker et al., 1986)

It is known that a flap sutured distally under tension may necrose or pull the distal nail bed volarly, creating a curved nail deformity.(Chakraborty et al., 2021) that is probably what happened with the cases in this study. The two cases in group I were Allen III dorsally directed, tissue loss was not extensive and we assumed volar skin was available to perform volar V-Y flap, the flap was sutured under tension. In those cases, if neurovascular V-Y advancement flap was used we might have prevented this complication. The third case of parrot beak deformity (group II) was Allen type IV, guillotine, with extensive tissue loss. The finger was flexed to help cover the defect, the flap was also sutured under tension, so we ended up with parrot beak deformity.

The advantages of the V-Y volar flap are that it is simple to perform, scar is minimum and less painful since it is not located directly over the end of the finger. Cosmetically, the result is excellent with good fingertip contour and padding. Most important, the procedure preserves normal sensation of the fingertip. Only a simple finger dressing and guard is required without immobilization as in other flaps and grafts, thereby lessening joint stiffness.

The neurovascular V-Y advancement flap is designed so that the proximal part of the “V” extends onto the middle phalangeal segment. It could provide solution for challenging volarly oblique amputations running from palmar-proximal to dorsal-distal. The advantages of neurovascular V-Y advancement flap are evident as compared with other alternatives; it is a single-staged procedure, provides durable full-thickness soft-tissue coverage and restores normal sensation to the skin over the digits permitting the maximum preservation of the finger length. It has low morbidity of the donor site with relatively short rehabilitation. This technique also creates a more normal-looking tip, yet its use requires extensive soft tissue dissection and is often limited by the quantity of skin available for advancement.⁸ It can be used simultaneously in multiple digits.(Martin-Playa & Foo, 2019)

Vascular compromise to the pedicle, digital arteries, can occur from compression tension, or kinking. However, such compression may be prevented with careful dissection and flap advancement without tension.

To achieve maximal coverage without tension on the neurovascular bundle sometimes the digit is flexed and the flap advanced distally to cover the tip, then after suture removal an extension splint is used to regain full extension which is usually achieved in a couple of weeks; still the patient is advised to perform active and passive extension exercises.

The patient can be expected to return to work by 1 month if there are no complications.

SUMMARY

Both groups were similar as regards sex distribution, age or affected hand. Students and manual workers were most commonly affected; the injuries were most commonly caused by a sharp object.

the mean operative time taken to perform cases of GI was 18.27 ± 3.67 minutes (range 14- 25 min in comparison to 71.33 ± 14.10 minutes (range 45- 90min) for cases of GII.

With respect to subjective complaints (tenderness, cold intolerance and incomplete extension) they were all resolved within six months of follow up.

As regards the complications, no significant difference except in light touch examination and 2 points discrimination, they were found to have significantly better results in cases treated with neurovascular V-Y flap.

RECOMMENDATIONS

The simple V-Y volar advancement flap with apex at DIP, and the bigger neurovascular V-Y advancement flap with the apex at PIP are used in Allen III and IV types of fingertip injuries. The choice of either flap depends on the direction of injury. The former is better reserved for the dorsally-directed tissue loss. The latter is preferably used in either the volarly-slanting tissue loss or the perpendicular(guillotine) fingertip amputation.

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