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Pattern of Flap Selection According to the Level and Angle of Fingertip Amputation in Patients Undergoing Fingertip Reconstruction

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ABSTRACT

Background: Amputations of the fingertips affect sensation, gripping and pinching, nail growth, and the appearance of the hand. In case of reconstruction, the focus is to maintain the length of the finger with effective sensation and adequate padding without causing any damage to the donor area.

Methods: This randomised controlled trial included 100 patients with acute fingertip injuries requiring reconstruction at Medical Trust Hospital, Kochi. Eligible patients aged 5–75 years underwent clinical assessment, flap selection, and surgical reconstruction based on injury level and angle. Functional, aesthetic, complication, and satisfaction outcomes were evaluated during follow-up. Data were analysed in SPSS version 27 using t-tests, chi-square tests, and ANOVA, with statistical significance set at $p<0.05$.

Results: Among 115 fingers reconstructed, road traffic accidents were the major injury mode (44.4%), whereas Allen type II injuries formed the majority (45.2%). The most common flap types were cross finger flaps (67.8%), V-Y flaps (19.1%), and thenar flaps (8.7%). The use of flaps was associated with middle finger injuries for the thenar flaps ($p=0.002$), dorsal oblique injuries in case of V-Y flaps ($p=0.047$), lateral oblique injuries in case of Venkataswami flaps ($p<0.00001$).

Conclusion: The study concluded that the flap selection was mostly effected by the pattern of injury, finger involved, and amputation level. Individualized selection was conducted on the basis of the defect characteristics, which helps to optimize the reconstruction of the fingertip and the functional preservation.

Key-words: Fingertip amputation; Flap reconstruction; V-Y advancement flap; Amputation level; Reconstructive surgery

INTRODUCTION

Fingertip amputation is one of the most commonly encountered and functionally important injuries of the hand. Despite the small area of injury, the loss of fingertip tissue significantly affects tactile sensation, pinching and gripping capacity, nail growth, cosmetic appearance, and functional capacity [1]. Therefore, the purpose of the reconstruction is not only to provide skin cover but also to preserve as much finger length as possible and provide sensate, durable, and well-padded tissue, causing minimum donor-site morbidity. Current evidence suggests that the level, size, and configuration of the tissue defect should be systematically assessed to select the appropriate reconstructive technique [2]. The main parameters that influence the choice of a flap are the direction and angle of amputation [2, 3].

The extent of amputation is an important factor in the selection of a flap. Distal defects with the presence of sufficient pulp and minimal bone exposure can be treated either conservatively or by local advancement techniques [4]. V-Y advancement flaps can be used for transverse or dorsal-oblique defects because the flaps provide sensate volar covering without changing finger length. Comparative studies of the Atasoy and Kutler V-Y methods show that the results are generally satisfactory in terms of sensory and functional outcomes, although

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nail deformities, pain, and cold intolerance may occur [5,6].

The angle of amputation is an important determinant of flap selection in the case of oblique injuries. Volar-oblique defects result in pulp loss and require tissue advancement from volar or side areas of the residual tissue [7]. Volar-oblique, circumferential, and side defects may require modification of homodigital flaps, such as neurovascular island or digital artery perforator flaps. Recent reviews state that such approaches are effective if coverage with simple advancement does not provide sufficient coverage [6,7].

During flap selection, it is necessary to consider digit involvement, the size of the defect, bone or tendon exposure, the nail bed involvement, the vascular state, sensitivity, and required functional demands. Current evidence shows that an anatomical approach to flap selection is generally better than using a specific flap algorithm [8]. For example, homodigital neurovascular island flaps preserve finger length and provide sensate coverage; recently reported outcomes demonstrate successful complete survival of the flaps along with good long-term functional outcomes [9]. Thus, it is clinically relevant to assess the pattern of flap selection with respect to the level and angle of the fingertip amputation [10].

MATERIALS AND METHODS

Research design- The study was a prospective, randomized controlled trial to assess the pattern of the flap selection on the basis of the level and the angle of Fingertip amputation among patients who underwent surgical reconstruction for acute fingertip injuries. The study was conducted among 100 patients in the Department of Plastic and Reconstructive Surgery, Medical Trust Hospital, Kochi, Kerala. The study evaluated the outcomes of reconstructive surgery of the fingertips, including the type of flaps used and clinical outcomes. Patients were selected on the basis of the predefined inclusion and the exclusion criteria. Both verbal and written consent were obtained for the study from all patients.

Inclusion criteria

- Patients of age >5 and <75 years were included.
- Those who had undergone acute fingertip injury with exposed bone were included.
- Patients with thumb-tip amputation with exposed bone or tendon were included,
- Patients with various injuries in the fingertip of the same hand that needed soft-tissue reconstruction were included.

Exclusion criteria

- Patients with tendon fractures or injuries which required repair were excluded.
- Patients with mangled extremity, crush injury, or early injury were excluded
- Stiff finger joints were included.
- Patients with other systemic illness or comorbid conditions were not allowed.

Sample Size Calculation

The formula for sample size in a prospective study is given as $\mathbf{n= Z^2pq/d^2}$

Where n= sample size

Z= standard deviation from normal= 2

p= maximum expected prevalence=0.5

q= 1-p= 0.5

d= maximum allowable error of p= 20% X0.5= 0.1

From the simple calculation,

n=100

Procedure- The study approval was obtained from the Institutional Ethics Committee. Only eligible patients who had experienced injuries to the fingertips were included in the study based on the predefined inclusion and exclusion criteria. Both verbal and written informed consent were obtained for the study. The patients underwent comprehensive clinical evaluation, including their age, sex, the mode of injury, and the extent of the injury in terms of how many fingers were injured. Subsequently, the injury was assessed to determine the appropriate reconstructive modality before implementing the treatment procedure per the study protocol. Follow-up was done to evaluate the outcomes of the reconstruction, both in terms of functionality and aesthetics, and regarding any complications. The patient satisfaction was measured and recorded.

Statistical Analysis- Data were analyzed using SPSS version 27. The results were represented by the use of tables, bar diagrams and pie charts. The continuous variables were represented in the form of mean ±

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standard deviation. Also, the independent two-tailed Student's t-test, chi-square test, and ANOVA were used. A p-value <0.05 was considered statistically significant.

RESULTS

Table 1 stated that the highest frequency of injuries was associated with road traffic accidents (44.4%), which were followed by injuries at the workplace (21.7%) and chain of bicycle injuries (17.4%). In terms of the level of amputation, the highest number of amputations belonged to Allen type II (45.2%), followed by type III (33.9%), suggesting that the level of injuries was mostly intermediate. Reconstructive treatment showed the cross-finger flap as the most common procedure (67.8%), followed by V-Y flaps (19.1%) and thenar flaps (8.7%).

Table 1: The mode of injury distribution, level of amputation distribution, and flap used distribution

Category	Variable	Number of fingers (n)	Percentage (%)
Mode of injury	Bike chain	20	17.4
	Door trap	7	6.1
	Road traffic accident (RTA)	51	44.4
	Worksite injury	25	21.7
	Mixi grinder	12	10.4
	Total	115	100
Level of amputation (Allen classification)	Allen type I	9	7.8
	Allen type II	52	45.2
	Allen type III	39	33.9
	Allen type IV	15	13.1
	Total	115	100
Type of flap	V-Y flap	22	19.1
	Lateral V-Y flap	1	0.9
	Cross-finger flap (CFF)	78	67.8
	FDMA flap	1	0.9
	Venkataswami flap	4	3.5
	Thenar flap	10	8.7
	Total	115	100

Table 2 demonstrated the substantial variability regarding the reconstructive flaps among the digits. The V-Y flap was most commonly observed in the index finger (10 instances); however, no statistical correlation was found for all studied fingers ($p > 0.05$). The cross-finger flap was most commonly applied to the index finger (27 instances), middle finger (22), and ring finger (18) and was significant for the reconstruction of the digits. Venkataswami flaps were used in the reconstruction process, with the highest recorded for the middle finger with 2 instances. Also, a statistically significant correlation between thenar flaps and middle-finger injury was noted, with 8 instances; $p = 0.002$.

Table 2: Relation of flap used with finger involved with the VY flap, Cross Finger flap, Venkataswami flap, and Thenar flap

Finger	V-Y flap	Others	*p*-value	Cross-finger flap	Others	*p*-value	Venkataswami flap	Others	*p*-value	Thenar flap	Others	*p*-value
Thumb	4	7	0.261	6	5	0.514	0	11	NA	0	11	NA
Index	10	30	0.358	27	13	0.699	1	39	0.908	2	38	0.497

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Middle	4	32	0.222	22	14	0.877	2	34	0.786	8	28	0.002
Ring	4	18	0.861	18	4	0.409	0	22	NA	0	22	NA
Little	0	6	NA	5	1	0.191	1	5	0.505	0	6	NA

Table 3 showed the correlation between the angle of injury and the flap used. The V-Y flap was the most commonly used in transverse injuries observed among 10 patients and dorsal oblique injuries noted among 8 patients, with a statistically significant correlation observed in dorsal oblique injuries (p = 0.047). The cross-finger flap was used in 40 cases of transverse injuries and 22 cases of volar oblique injuries. However, the correlation was not statistically significant. Venkataswami flap usage was minimal, with the highest number observed among 2 patients with lateral oblique injuries and a very high level of statistical significance (p < 0.00001). The thenar flap was mostly used for volar oblique injuries in 5 patients, with no statistical significance.

Table 3: Relationship of flap used with the plane or angle of injury

Angle of injury	V-Y flap	Others	*p*- value	Cross-finger flap	Others	*p*-value	Venkataswami flap	Others	*p*-value	Thenar flap	Others	*p*-value
Dorsal oblique	8	14	0.047	12	10	0.219	1	21	NA	1	21	0.728
Transverse	10	44	0.936	40	14	0.25	0	54	0.732	3	51	0.428
Volar oblique	2	27	0.096	22	7	0.4	0	29	NA	5	24	0.132
Oblique	1	5	0.707	3	3	0.609	1	5	NA	1	5	0.974
Lateral oblique	1	3	0.732	1	3	0.186	2	2	<0.00001	0	4	NA

Table 4 demonstrated that the statistical analysis in accordance with the Allen injury level showed a significant correlation between the severity of injury and usage of particular reconstructive flaps. The V-Y flap was most common with Allen level II injuries among 18 patients, while the non-use of this procedure in Allen level III showed a significant correlation (p = 0.0003). The cross-finger flap was common with Allen level III injuries among 36 patients and even in Allen level IV injuries with 14 patients, resulting in significant correlations of p = 0.00009 in Allen level III injuries and p = 0.0001 in Allen level IV injuries. Venkataswami and thenar flaps were least common and did not show any significant correlations.

Table 4: Relation of flap used with a level of injury

Level of injury	V-Y flap	Others	*p*-value	Cross-finger flap	Others	*p*-value	Venkataswami flap	Others	*p*-value	Thenar flap	Others	*p*-value
Allen type I	4	5	NA	3	6	0.049	0	9	NA	2	7	NA
Allen type II	18	34	0.117	25	27	0.053	3	49	0.48	4	48	0.233
Allen type III	0	39	0.0003	36	3	0.00009	1	38	0.877	2	37	0.931
Allen type IV	0	15	NA	14	1	0.0001	0	15	NA	0	15	NA

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DISCUSSION

The current approach to flap selection for the reconstruction of the fingertip defect is based mainly on the site of amputation of the finger in relation to the defect and the availability of local tissue. The surgeon should take into account not only the size but also the type of wounds (transverse, dorsal-oblique, volar-oblique, or lateral-oblique) and the potential for advancement of sensate tissue to cover these wounds [11]. This method still serves as a guideline today, and the final aim is the preservation of the length of the fingers as well as the sensory and pulp function.

For distal, small amputations, with limited bone or tendon exposure**,** conservative management or a simple local advancement flap is indicated [12]. This is especially the case for the selected dorsal-oblique deformity, for which secondary healing can provide optimal coverage with no need to sacrifice additional local skin to create a flap. However, it appears that in certain instances where the defect in the fingertip is small, the reconstruction of the flap is not the most appropriate treatment [13].

A V-Y advancement flap is still one of the best options for reconstruction of a transverse amputation. If the volar pulp is adequate and the defect can be distally advanced, then V-Y advancement of volar skin is indicated. If adequate lateral tissue is available, it is possible to perform a bilateral V-Y advancement (Kutler) [14]. Based on the literature review, this method in general showed good results in terms of sensory recovery and functional outcomes.

In the case of oblique defects, the orientation plays an important role. The dorsal oblique amputation is associated with a good opportunity to advance the remaining volar pulp, and thus V-Y advancement might be indicated [15]. The volar-oblique type is often complicated by loss of volar tissue; therefore, this type is not suitable for this approach, and other options (e.g., Neurovascular Island) should be considered. A large defect where the defect is of the volar-oblique type may require the use of a neurovascular island or flap to obtain satisfactory functional and cosmetic results. The Qatari flap and its variations are recommended for the volar-oblique, circumferential, and extensive lateral defects, according to the literature.

Neurovascular and digital artery perforator homodigital flaps are valuable options in the case of lateral defects. Both methods can be performed with local tissue and avoid donor site morbidity, and improve the quality of the reconstructed fingertip. The homodigital digital artery perforator flaps demonstrated in the 2022 review have proved to be very versatile in the reconstruction of fingertips and reliable and safe options for soft tissue defect correction in fingers. In particular, the latest evidence from Uzel et al. suggests that all the antegrade homodigital neurovascular island flaps that were used in 5 cases survived with a favourable functional and sensory outcome [12,13].

A simple advancement flap may not be sufficient to restore the integrity of the fingertip in extensive amputations or those that extend up to the proximal level. More complex techniques (e.g., cross-finger, regional, free tissue transfer) should be used depending on the specific needs of the patient. For more extensive defects, the free toe-to-pulp transfer is available, not only because of its quality of tissue but also because of a study carried out in 2026, which showed favourable outcomes and a high survival rate.

The overall evidence indicates a need to take factors that would be unique to each patient into consideration when selecting a flap for a fingertip reconstruction. The severity, direction, size of the defect, extent of the involved tissues, presence of bone exposure, nails, and pulp loss must be considered [15]. So, there is no standard size of a flap for every fingertip amputation. A small transverse defect can be reconstructed with a V-Y advancement, while larger defects such as a large lateral or volar-oblique defect would be better served with a homodigital neurovascular or perforator flap, and a proximal defect may be addressed with a regional tissue transfer. All of the recent articles emphasise the need for proper evaluation of the level and geometry of the amputation so that the surgeon can choose the best type of soft tissue defect for optimal healing and favourable function and aesthetic results [16].

The selection of the flaps is also affected by the amount of pulp left and the location of the neurovascular bundles. One of the most important aspects of preservation is the preservation of sensate tissue due to the large contribution of sensate tissue to fine tactile discrimination, precision grip and object manipulation of the fingertip [13]. Thus, it is preferable to use tissue from the same digit whenever possible for reconstruction. Homo-digital flaps have favorable color, tissue thickness, and sensory matching without the morbidity of tissue

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transfer from another finger. Homo-digital neurovascular island flap reconstruction has been shown to have satisfactory sensory recovery and functional outcomes in recent studies [16].

The amputation should also be taken down to the distal interphalangeal joint, and the nail bed should be taken off. If the matrix of the nail is maintained, then sufficient distal support and pulp length can be achieved to result in a better final aesthetic and functional outcome. On the other hand, injuries with significant loss of nail bed or matrix may result in nail deformity, even if the soft tissues over it are covered. So, the selection of flap should be done in conjunction with the appropriate management of the nail complex rather than as an independent soft tissue procedure. Treatment should be selected to take into account patient-related factors including occupation, hand dominance, age, smoking status, vascular condition and expectations. In general, the higher the amputation level, the more the amputation is angled, the larger the defect size and the less amount of local tissue that is available to the limb, the greater the risk of impaired healing, and the greater the potential functional impairment.

CONCLUSIONS

The study concluded that the flap choice for fingertip reconstruction depended on the anatomy of the injured area and the degree of the injury. Road traffic injuries were the most common cause of injury (44.4%), and the most common type of amputation was Allen type II (45.2%). The injuries of moderate complexity were noted in the study. Cross-finger flaps prevailed among the types of flaps used (67.8%), and their prevalence was associated with higher levels of injury and included such groups as Allen type III (36 cases; p=0.00009) and Allen type IV (14 cases; p=0.0001). V-Y flaps were applied most often in Allen type II injuries and were significantly associated with dorsal oblique defects (p=0.047). Thenar flap application was significantly associated with middle finger reconstruction (8 cases; p=0.002), and the use of Venkataswami flap was significantly associated with lateral oblique injuries (p<0.00001).

CONTRIBUTION OF AUTHORS

One author has only contributed to this article.

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