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Original Research Article

Outcome of heterodigital neurovascular island flap for reconstruction of pulp defect of thumb

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ABSTRACT

Background: The reconstruction of thumb pulp defects requires durable coverage and fine sensibility restoration. The heterodigital neurovascular island flap offers glabrous, sensate tissue and is widely used, although local outcome data are limited.
Methods: This prospective observational study was conducted at the National Institute of Burn and Plastic Surgery, Dhaka, from January 2023 to June 2024. Thirty patients with thumb pulp soft-tissue defects underwent reconstruction using a heterodigital neurovascular island flap. Outcomes assessed included flap viability, donor site morbidity, sensory recovery and patient satisfaction. Data were analyzed using SPSS version 26.0.
Results: The mean age was 30.7±12.3 years; most patients were male (83.3%). Trauma was the leading cause (86.7%) and most defects exceeded 5 cm² (53.3%). Flap survival was favorable, with 80% uneventful cases; minor complications included marginal necrosis (10%) and infection (6.7%). Donor site morbidity was low (76.7% uneventful). All patients regained pain sensation by day 5 and 66.7% regained tactile sensation by day 14. Mean static two-point discrimination improved from 4.65±0.46 mm at 3 weeks to 3.70±0.59 mm at 3 months, approaching the contralateral thumb (3.33±0.61 mm; p=0.02). Good outcomes were observed in 80% of cases, with high patient satisfaction (83.3%).
Conclusions: The heterodigital neurovascular island flap is a reliable technique for thumb pulp reconstruction, providing satisfactory sensory recovery, high flap survival and minimal complications.

Keywords: Heterodigital neurovascular island flap, Thumb pulp reconstruction, Soft tissue defect, Sensory recovery

INTRODUCTION

The thumb plays a central role in hand function and is often referred to as the "master digit," contributing to nearly 40% of overall manual performance due to its unique capacity for opposition.[1] This anatomical and functional specialization enables essential activities such as grasping, pinching and fine manipulation. Consequently, soft tissue defects involving the thumb, particularly the pulp, can result in profound functional impairment as well as aesthetic deformity. These defects commonly arise from trauma, thermal or electrical injury, infection, or tumor excision and their impact on hand function is significantly greater compared to injuries affecting other digits.[2] The primary objective of thumb reconstruction is to restore optimal function while

preserving structural integrity. This includes maintaining adequate length, ensuring durable and well-padded soft tissue coverage, restoring mobility and stability, achieving protective sensation, minimizing pain and preventing donor site morbidity while maintaining acceptable cosmetic outcomes.[3]

The selection of an appropriate reconstructive technique depends on several factors, including the size, location and depth of the defect, as well as patient-related considerations. In cases where there is exposure of bone, tendon, or cartilage, flap reconstruction is preferred over secondary healing or skin grafting. Skin grafts, although simple, require a well-vascularized bed and often fail to provide sufficient padding or sensory restoration, especially in the thumb pulp where tactile function is critical.[3]

Over the past decades, numerous reconstructive options have been described, ranging from local and regional flaps to distant pedicle flaps and free tissue transfer. The choice among these techniques depends on the characteristics of the defect, the mechanism of injury, patient age, availability of donor sites and functional demands.

Achieving sensate coverage while preserving the range of motion remains a key determinant of successful reconstruction.[4] Local advancement flaps, such as V-Y flaps, offer good sensory outcomes but are limited by their size and advancement capacity. Cross-finger flaps, although reliable, require a staged procedure, which prolongs recovery and increases patient discomfort.[2]

Distant flaps, while useful for larger defects, necessitate prolonged immobilization of the upper limb, typically for two to three weeks. This can lead to joint stiffness, delayed rehabilitation and patient dissatisfaction. Additionally, these flaps are often bulky and require multiple surgical stages, reducing their overall acceptability.[5]

Free tissue transfer provides an alternative for extensive and complex defects, allowing for the reconstruction of multiple tissue components. However, these procedures are technically demanding, require specialized microsurgical expertise and infrastructure and are associated with longer operative times and potential donor site morbidity.[3]

Among the various reconstructive options, neurovascular island flaps have gained prominence for their ability to provide sensate and durable coverage. The heterodigital neurovascular island flap, initially described by Bunnell and later modified by Littler, Tubiana and Duparc, has become a well-established technique for reconstruction of thumb pulp defects.[6,7]

This flap utilizes tissue from an adjacent digit, preserving its neurovascular supply, thereby enabling transfer of glabrous, sensate skin that closely resembles the native thumb pulp in texture and function. It allows for single-stage reconstruction with reliable vascularity and satisfactory sensory recovery.[2]

Compared to other techniques, the heterodigital neurovascular island flap offers several advantages, including provision of “like-with-like” tissue, restoration of protective sensation, shorter operative time and minimal anesthetic requirements. Furthermore, it can often be performed as a single-stage procedure without the need for prolonged immobilization, facilitating early rehabilitation and return to daily activities.[3] These characteristics make it particularly suitable for reconstruction of larger pulp defects where both durability and sensibility are essential.

Given the critical importance of sensory restoration in thumb function, there is a need to evaluate the outcomes of this technique in different clinical settings. This study, therefore, aims to assess the effectiveness of the heterodigital neurovascular island flap in reconstructing thumb pulp defects, with a focus on flap viability, sensory recovery, donor site morbidity and overall patient satisfaction.

METHODS

This was a prospective observational study conducted in the Department of Plastic Surgery at Dhaka Medical College Hospital, Dhaka, Bangladesh, over a defined study period. A total of 30 patients presenting with thumb pulp defects requiring reconstruction were included in the study.

Selection criteria

Inclusion criteria

Patients were included if they had a soft tissue defect over the pulp of the thumb resulting from trauma or burn (excluding electrical burns) with exposure of bone, tendon, or neurovascular structures. Eligibility also required the presence of an identifiable proper palmar digital artery confirmed using a hand-held doppler examination. Additionally, only patients between 10 and 70 years of age were included in the study.

Exclusion criteria

Patients were excluded from the study if they had polytrauma or any life-threatening condition. Those with a history of injury or prior surgery affecting the donor site were also excluded.

Additional exclusion criteria included the presence of significant comorbid conditions such as uncontrolled diabetes mellitus, hypertension, peripheral vascular disease, arthritis, or Dupuytren's contracture. Furthermore, patients with a proximal nerve injury in the

same hand were not considered eligible for inclusion in the study.

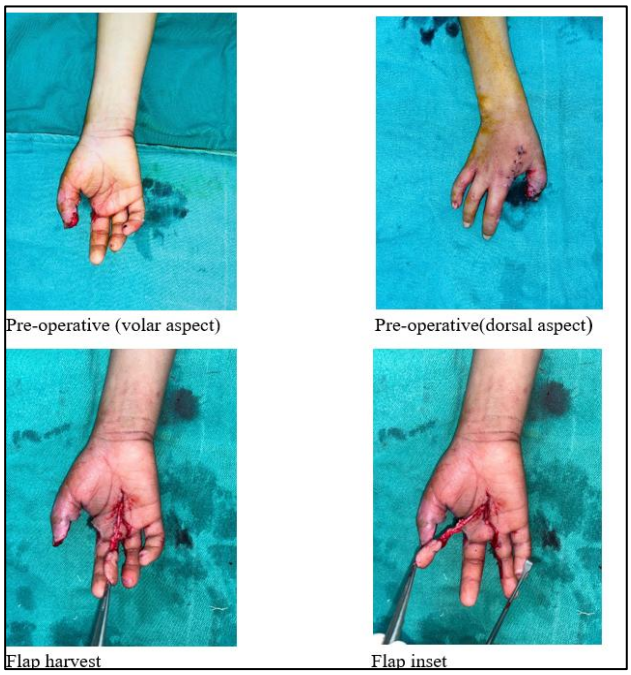

Figure 1: Flap marking and design.

Figure 2: Flap elevation and neurovascular pedicle dissection.

Study procedure

Eligible patients were evaluated through detailed history taking, clinical examination and necessary investigations. Baseline demographic data, cause of injury and characteristics of the defect were recorded. All patients underwent reconstruction using a heterodigital neurovascular island flap.

Operative technique

patient positioning

The patient was placed on supine position with the hand abducted and extended on a hand table.

Anesthesia

Axillary block is given in right upper limb.

Tourniquet

Tourniquet applied for proper hemostasis at the right arm of same side.

Figure 3: Flap transfer to thumb defect and inset.

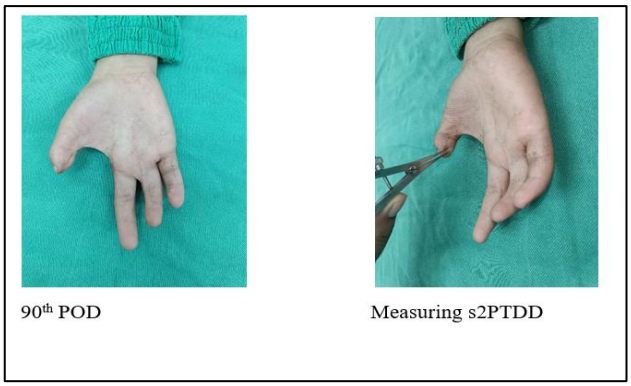

Figure 4: Donor site coverage with full-thickness skin graft and postoperative immobilization.

Flap harvest

Design and markings for standard flap

The doppler study was made with a handheld doppler with an 8 Hz frequency probe around the axis of the digital vessels of radial and ulnar side of the donor digit as well as the thumb. After debridement or excision of wound, the defects were evaluated in terms of dimension, shape and anatomic location. Flap marking was done keeping the neurovascular bundle at middle of the flap along mid axial line at the ulnar side of the middle finger.

This marking extended proximally from PIP joint to distally distal to DIP joint.

Flap dissection

Incisions were made on both the volar and dorsal aspect of the middle finger. The flap is elevated from distal to proximal direction below the plane of neurovascular bundle. Distally at the flap margin neurovascular bundle is dissected and ligated. Subcutaneous tissue including the neurovascular structures then proceed elevating. A zigzag incision was made from distal margins of flexor retinaculum in the palm to the 3rd web space to expose the neurovascular pedicle. Further dissection was then continued till the beginning of the common digital artery from the superficial palmer arch along with common palmar digital nerve. After complete dissection of the flap, transfer of the flap to the defect of thumb is performed by opening the skin bridge to the defect.

Flap inset and donor site coverage

Tourniquet off and proper hemostasis done before the transfer of the flap. Then the flap is transferred to the defect of the thumb and inset is done by gentle traction to avoid any kinking of the pedicle, suturing with the margin by 3/0 cutting body prolene suture. Donor site was closed with a full-thickness skin graft harvested from the inner aspect of the upper arm. Postoperative immobilization is done by mild flexion of IP joint of thumb.

Post-operative management

Postoperative care included drugs (e.g. analgesics and antibiotics). The thumb and the donor finger were immobilized with a protective splint in slight flexion of the interphalangeal joints for two weeks. Check dressing of flap done on 1st POD. Skin graft dressing was opened on the 5th POD. Stiches were removed at the end of the second week on the day of 14th POD. Active-passive joint exercises and sensory rehabilitation were started rom 2nd week under the guidance of a physiotherapist.

Follow-up

The viability of the flap was monitored by tissue color, turgor, capillary refill and temperature. Follow-up data on the flap was obtained by serial clinical examination on the 1st, 5th and 14th postoperative days and photographs were taken during the visit. Static two-point discrimination test was observed on the 3rd week, 6th week and 3rd months.

Data collection procedure

Data were collected using a structured data sheet. Variables included demographic characteristics, cause of injury, side of involvement, flap-related complications, donor site morbidity, overall outcome and patient satisfaction. Sensory and functional outcomes were assessed during follow-up visits using standardized clinical methods.

Ethical consideration

Ethical approval was obtained from the institutional review board. Informed written consent was obtained from all participants before inclusion. Confidentiality of patient information was maintained throughout the study.

Statistical analysis

Data were analyzed using statistical software. Descriptive statistics such as mean, frequency and percentage were used to summarize the data. Outcomes were categorized based on predefined clinical criteria. A p value of less than 0.05 was considered statistically significant where applicable.

RESULTS

Table 1 shows the demographic and baseline characteristics of the study subjects. The largest proportion of participants falls within the 30-39 years' age group, accounting for 30% of the sample, followed by 26.7% in the 20-29 years' age group.

Table 1: Demographic and baseline characteristics of the study subjects (n=30).

Characteristics		Frequency (N)	Percentage (%)
Age group (years)	10-19	6	20
	20-29	8	26.7
	30-39	9	30
	40-49	4	13.3
	>50	3	10
	Mean±SD	30.7±12.3 years	
	Range	13-65 years	
Gender	Male	25	83.3
	Female	5	16.7
Occupation	Businessman	2	6.7
	Housewife	4	13.3
	Labour	9	30.0
	Service	8	26.7
	Student	7	23.3
Cause of defect	Contact burn	4	13.3
	Trauma	26	86.7

A smaller percentage of participants, 20%, were between 10-19 years, while those aged 40-49 years and over 50 years represent 13.3% and 10.0% of the sample, respectively. The mean age of the participants was 30.7±12.3 years. The age range spans from 13 to 65 years. The majority of participants were male, comprising 83.3% of the sample, while females represent 16.7%. So, the male-to-female ratio was 5:1. The highest proportion of participants were labourers (30%), followed by service holders (26.7%) and students (23.3%). Housewives and

businessmen accounted for 13.3% and 6.7%, respectively. Trauma was the predominant cause of defect (86.7%), while contact burn accounted for 13.3%. Table 2 showed the distribution of study subjects based on injured thumb (right or left side). A majority of the participants 73.3% had defects on the right thumb, while 26.7% had defects on the left thumb. This suggests that right thumb involvement was more common among the study subjects.

Table 2: Distribution of the study subjects according to the side of the involved thumb (n=30).

Involved thumb	Frequency (N)	Percentage (%)
Right	22	73.3
Left	8	26.7

Table 3: Distribution of the study subjects by flap morbidity and flap donor site morbidity (n=30).

Flap morbidity		Frequency (N)	Percentage (%)
Flap morbidity	Marginal necrosis	3	10.0
	Infection	2	6.7
	Dehiscence	1	3.3
	Uneventful	24	80.0
Morbidity of flap donor site	Infection	4	13.3
	Partial graft loss	2	6.7
	Total graft loss	1	3.3
	Uneventful	23	76.7

Table 3 showed the distribution of the study subjects based on flap morbidity and flap donor site morbidity. The majority of the participants (80%) experienced no morbidity related to the flap.

However, 10% had marginal necrosis, 6.7% had infections and 3.3% experienced flap dehiscence. The majority of subjects (76.7%) had no morbidity regarding flap donor site. However, 13.3% experienced infections, 6.7% had partial graft loss and 3.3% had complete graft loss. This indicates that while most donor sites healed without complications, a minority faced issues such as infection or graft loss.

Table 4: Distribution of the study subjects according to flap donor site complications management (n=30).

Donor site complications management	Frequency (N)	Percentage (%)
Secondary healing	5	16.7
Re-graft	2	6.7
No management required	23	76.7

Table 4 showed the distribution of study subjects based on the management of the flap donor site complications. A significant number of subjects (76.7%) required no management as they developed no complications. Among those who did have complications, 16.7% underwent secondary healing, while 6.7% required re-grafting.

Table 5: Distribution of the study subjects by outcome of the flap (n=30).

Outcome of the flap	Frequency (N)	Percentage (%)
Good	24	80
Satisfactory	6	20
Poor	0	0

Table 5 showed the distribution of study subjects based on the outcome of the flap. The results indicate that 80% of the subjects experienced a good outcome with their flaps, while 20% had a satisfactory outcome. No patients had a poor outcome. This indicates a high overall success rate for the flap procedures, with the majority achieving favorable results, reflecting effective surgical intervention and management.

Table 6: Distribution of the study subjects by patients' appraisal on sensory recovery (n=30).

Patients' appraisal on sensory recovery	Frequency (N)	Percentage (%)
Good	25	83.3
Satisfactory	5	16.7
Poor	0	0

Table 6 shows the distribution of study subjects based on patients' appraisal of sensory recovery. A majority, 83.3% of patients, reported a good appraisal of their sensory recovery, while 16.7% felt their recovery was satisfactory. No patients were reported as poor outcome. These results suggest that the vast majority of patients perceived their sensory recovery positively, indicating successful surgical outcomes and effective rehabilitation.

DISCUSSION

Thumb injuries significantly impair hand function, particularly due to the thumb's essential role in pinch, grip and fine motor activities. Restoration of thumb pulp defects therefore requires not only durable coverage but also preservation or recovery of sensibility. In the present study, the heterodigital neurovascular island flap was evaluated as a reconstructive option for volar thumb defects, with particular emphasis on functional and sensory outcomes. The findings suggest that this technique offers reliable coverage with favorable sensory recovery and minimal morbidity, aligning with previously published literature. The demographic

distribution observed in this study indicates that the most affected group comprised individuals in their third to fourth decades of life, with a mean age of 30.7 years. This predominance of younger, economically active individuals is consistent with earlier reports by Ayad et al and Uddin et al, who documented similar mean age ranges in populations undergoing thumb reconstruction.[8,9] Comparable findings were also noted by Yıldırım et al and Xarchas et al, although some variation exists across studies, likely reflecting differences in occupational exposure and injury patterns.[5,7] The male predominance (83.33%) observed in this study further supports the notion that occupational hazards contribute significantly to thumb injuries, a trend similarly reported in multiple prior studies.

Occupational distribution in this cohort revealed that day laborers constituted the largest group, followed by service holders and students. This pattern aligns with findings by Uddin et al and Chakraborty SS et al who reported higher injury rates among manual workers.[9,10] The predominance of trauma as the leading cause of defect (86.7%) is also consistent with existing literature, where machinery-related injuries, crush injuries and sharp cuts are commonly implicated.[5,11] Such injury mechanisms often result in complex tissue loss, necessitating reconstructive techniques that provide both coverage and sensory restoration.

In terms of laterality, the majority of defects involved the right thumb, reflecting the dominance of the right hand in most individuals. This observation is comparable to studies by Ayad et al and Wang et al, although some variability exists across different populations.[8,12] The defect characteristics in this study, with a mean size of 5.57 cm², indicate that the heterodigital neurovascular island flap is particularly suitable for moderate to large defects. Previous studies have reported similar defect dimensions, reinforcing the applicability of this technique for extensive pulp loss.[5,13]

Flap dimensions in the present study were proportionate to defect size, with a mean flap area of 6.47 cm². These findings are in agreement with reports by Yıldırım et al and Xarchas et al, who demonstrated comparable flap measurements.[5,7] The ability to tailor flap size to defect requirements while maintaining vascular reliability is a notable advantage of this technique. Furthermore, the use of glabrous skin from a donor digit ensures a close match in texture and color, which is essential for both functional and aesthetic outcomes.[13]

Postoperative complications at the recipient site were minimal, with 80% of cases showing uneventful healing. Minor complications such as marginal necrosis, infection and wound dehiscence were observed in a small proportion of patients and were managed conservatively. These findings are consistent with previous studies, where early venous congestion was occasionally reported but rarely resulted in flap loss.[7,11] The absence of major complications underscores the reliability of the heterodigital neurovascular island flap.

Donor site morbidity was also low, with the majority of patients experiencing no complications. Instances of graft loss and infection were infrequent and manageable. Similar outcomes have been reported by Duygun and Aldemir and Adani et al, who noted minimal donor site issues with appropriate postoperative care.[2,11] The implementation of early mobilization, physiotherapy and scar management likely contributed to the favorable outcomes observed in this study.

Sensory recovery is a critical determinant of success in thumb reconstruction. In the present study, all patients regained protective sensation early, with tactile sensation restored in a majority by the second postoperative week. The progressive improvement in static two-point discrimination distance, reaching a mean of 3.70 mm at three months, indicates satisfactory sensory reinnervation. These results compare favorably with those reported by Xarchas et al and Kumta et al, although some studies have documented slightly higher values, possibly due to longer follow-up periods or variations in surgical technique.[7,14] The statistically significant improvement in sensory function compared to the contralateral thumb further supports the effectiveness of this flap.

Patient satisfaction and overall functional outcomes were also encouraging, with 80% of cases rated as good. This is comparable to findings by Wang et al, as well as Duygun and Aldemir who reported high levels of patient satisfaction following similar procedures.[2,12] The combination of reliable flap survival, adequate sensory recovery and minimal morbidity contributes to the overall success of the heterodigital neurovascular island flap.

In summary, the findings of this study reinforce the role of the heterodigital neurovascular island flap as a dependable and effective option for reconstruction of thumb pulp defects. The technique provides durable coverage, satisfactory sensory recovery and acceptable donor site morbidity, making it a valuable choice in clinical practice. Future studies with larger sample sizes and longer follow-up periods may further elucidate long-term functional outcomes and refine patient selection criteria.

CONCLUSION

The heterodigital neurovascular island flap is a reliable and effective option for reconstruction of thumb pulp defects. It provides sensate, well-matched tissue with favorable functional and aesthetic outcomes. The procedure demonstrated high flap survival with minimal complications and satisfactory sensory recovery, including early return of protective sensation and progressive improvement in two-point discrimination. Donor site morbidity was limited and manageable.

Overall patient satisfaction was high and most patients resumed daily activities within a short period. These findings support the use of this technique as a practical and dependable method for thumb pulp reconstruction.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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