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Original Research Article

Early outcome of distally based C-ring cross finger flap for the reconstruction of degloved amputation stumps and volar and dorsal defects of the fingers

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ABSTRACT

Background: Degloved amputation stumps and volar or dorsal finger defects are challenging to reconstruct. The distally based C-ring cross finger flap offers larger size and wider rotation than conventional flaps, but prospective outcome data are limited.
Methods: This prospective observational study included 40 patients undergoing reconstruction of degloved amputation stumps or volar/dorsal finger defects using the distally based C-ring cross finger flap at Dhaka Medical College Hospital (December 2022-January 2024). Outcomes assessed included flap dimensions, viability (necrosis: marginal <10%, partial 10-20%, significant>20%, complete), flap-related complications (venous congestion, infection, wound dehiscence), donor site morbidity (infection, re-skin grafting) and range of motion (ROM) of proximal (PIP) and distal (DIP) interphalangeal joints. Overall functional outcome was classified as good, satisfactory or poor.
Results: Mean flap area was 6.46 cm² (wound area 5.11 cm²). No necrosis occurred in 57.5%; marginal necrosis in 22.5%, partial in 10%, significant in 7.5%, complete loss in 2.5%. Venous congestion occurred in 25%, infection in 10%, wound dehiscence in 10%; 55% had no complications. Donor site morbidity was absent in 65%; infection and re-skin grafting each occurred in 17.5%. Full ROM was achieved in 100% of PIP joints and 97.5% of DIP joints. Overall outcome was good in 70%, satisfactory in 22.5%, and poor in 7.5%.
Conclusions: The distally based C-ring cross finger flap is a reliable technique for reconstructing degloved amputation stumps and finger defects, providing adequate coverage, acceptable flap survival, manageable complications, low donor site morbidity and excellent joint mobility with 70% achieving good functional outcomes.

Keywords: C-ring cross finger flap, Degloved amputation, Finger defect, Hand reconstruction

INTRODUCTION

The hand is a complex organ vital for many daily activities. Hand injuries are common, often leading to functional problems, disability, and socioeconomic impacts.[1] In Bangladesh, they contribute significantly to trauma morbidity, affecting the working population and incurring high healthcare costs.[2] Fingers, being highly exposed and active are especially prone to injury, and soft tissue defects pose reconstruction challenges for surgeons. Finger injuries often cause extensive soft tissue loss, exposing bones, tendons, joints and neurovascular

structures. Reconstruction aims to: cover exposed structures, restore a sensate fingertip for function and minimize donor-site morbidity.[3] Stable, durable soft tissue cover with proper thickness, texture, and color, while preserving length and motion is essential.[4] The principle of replacing "like with like"—restoring tissue of comparable appearance and function is vital in hand surgery, where even minor imperfections can impair function.[5] The cross-finger flap (CFF), first described by Gurdin and Pangman in 1950, is a trans-digital technique for finger defect reconstruction.[6] Cronin later named it, and it became a key procedure in hand surgery. The typical two-stage process involves elevating a pedicled fasciocutaneous flap from an adjacent finger's dorsum to cover a defect on the injured finger's volar side with the donor site usually covered with a full-thickness skin graft. After about 14 days to allow neovascularization, the flap is divided and inset.[7] Developing finger injuries are challenging in hand surgery.[8] They often involve circumferential soft tissue avulsion, exposing bone, tendons, and compromised blood flow.

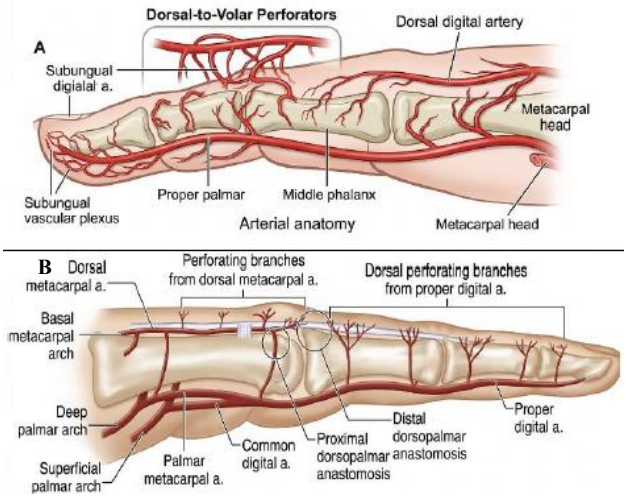

Figure 1: (A) vascular anatomy of finger and (B) dorsal metacarpal artery perforator of finger.[13,14]

Replantation is often unfeasible due to extensive damage or non-viable tissue. Primary amputation, though sometimes necessary, leads to functional loss and deformity. Managing these injuries requires innovative reconstructive strategies to cover soft tissue and preserve digital length.[9] The standard cross-finger flap has limitations in complex finger defects, like degloving injuries and dorsal defects, prompting various modifications.[10] These include reverse cross-finger flaps, laterally based flaps, adipofascial flaps, innervated flaps, and double cross-finger flaps.[11] The C-ring cross-finger flap, described by Mutaf et al in 1993, is a notable advancement.[12] This axial pattern flap, based on one digital vascular bundle, can be designed proximally or distally and surrounds the middle phalanx dorsal and volar surfaces as an open ring, incorporating the digital artery and venae comitantes while preserving the digital nerve. It covers the entire dorsal surface but is limited to half the finger's width volarly to maintain venous and lymphatic drainage of the donor finger's distal part.[12] The C-ring cross-finger flap has advantages over conventional flaps, including a wider, multidirectional arc of rotation that reaches more defects. It's nearly twice as large, suitable for bigger soft tissue gaps. The distally based flap covers stumps without shortening fingers, even with degloved amputation stumps, thanks to its strong blood supply.[12] It can be shaped into a "skin cap' for circumferential defects, and its fasciocutaneous structure offers durable, flexible, and well-vascularized tissue.[13] Despite the advantages and initial reports of the C-ring cross-finger flap, few prospective studies evaluate its outcomes systematically. This study assesses early results of using the distally based C-ring cross-finger flap for reconstructing degloved amputation stumps and finger defects. It focuses on flap viability, complications, donor site morbidity and joint motion in patients undergoing this procedure.

General objective

To evaluate the early outcome of the distally based C-ring cross finger flap for the reconstruction of degloved amputation stumps and volar and dorsal defects of the fingers.

Specific objectives

The study aims to assess flap viability and dimensions, along with related complications such as flap necrosis, infection, venous congestion, and wound dehiscence. It also evaluates donor site morbidity, including wound infection and the need for re-skin grafting. In addition, the range of motion of the proximal and distal interphalangeal joints (or the interphalangeal joint of the thumb) will be measured using a goniometric scale, and the overall functional outcome will be classified as good, satisfactory, or poor.

METHODS

This prospective observational study was conducted in the Department of Plastic and Burn Surgery, Dhaka Medical College Hospital, Dhaka, Bangladesh, from 1st December 2022 to 31st January 2024. A total of 40 patients with soft tissue defects distal to the proximal interphalangeal joint of the index, middle, ring, or little finger, or distal to the interphalangeal joint of the thumb, with exposed degloved amputation stumps, tendons, or neurovascular structures requiring flap coverage, were enrolled using purposive sampling. Patients were included if the donor digit had two patent digital arteries confirmed by Allen test or doppler examination, regardless of age or sex, and if the defect resulted from trauma, electric burn, tumor or post-burn contracture release. Exclusion criteria included potential injury to the pedicle or donor site from previous trauma or surgery, uncontrolled diabetes mellitus, Raynaud's disease, Buerger's disease, rheumatoid arthritis, or Dupuytren's

contracture. All procedures were performed under regional or general anesthesia with a tourniquet. The distally based C-ring cross finger flap was designed around the dorsal and volar surfaces of the middle phalanx as an open ring, including the entire dorsal surface but limited to half the volar width to preserve venous and lymphatic drainage. The flap was elevated superficial to the paratenon, incorporating the digital artery and venae comitantes while preserving the digital nerve, then transposed to the recipient defect. The donor site was covered with a full-thickness skin graft, and the fingers were immobilized with a light plaster cast. Flap division and final inset were performed at 14 days, with suture removal 10 days later.

Outcome measures included flap dimensions (length, width, area), wound dimensions, flap necrosis (classified as marginal <10%, partial 10-20%, significant >20%, or complete), flap-related complications (venous congestion, infection, wound dehiscence), donor site morbidity (infection, need for re-skin grafting), and range of motion of proximal and distal interphalangeal joints measured using a goniometric scale at 30 days after flap division. Overall functional outcome was classified as good, satisfactory, or poor based on composite criteria. Follow-up assessments were conducted on postoperative day 1, day 5, day 14, day 24, and at 30 days after flap division (day 45). Data were collected using a semi-structured questionnaire, compiled, and analyzed using SPSS version 26, with descriptive statistics expressed as mean, standard deviation, range, frequency, and percentage. Ethical approval was obtained from the institutional review boards, and informed written consent was obtained from all patients prior to inclusion.

Operative procedure

Marking technique

Before beginning of marking, vascularity of donor finger was ensured. The donor digit must have two patent digital arteries confirmed by doppler examination before surgery.

Flap selection

The flap includes the whole dorsal surface but it must be limited to half the width of the finger on the volar aspect. It is very important to reserve the skin of the contralateral side and half the volar width of the donor finger to preserve venous and lymphatic drainage of the distal part of the finger. Digital nerve was not included in the flap. For a degloving injury flap were sewn to itself to create a cap over the degloved segment defect.

Surgical technique

It was done under general anesthesia or regional anesthesia with the use of a tourniquet without exsanguination. The flap was designed around the dorsal and volar surface of the middle phalanx as an open ring. As with many of these flaps, dissection plane was just superficial to the paratenon with care taken to leave the paratenon intact. Following the skin incision, the digital artery and the venae comitantes were ligated proximally. Flap was raised in the plane deep to subcutaneous fat, keeping the digital artery and venae comitantes with the flap. Digital nerve was preserved, while the digital artery and venae comitantes were included the flap. Skin was usually kept over the digital bundle intact to protect the vascular pedicle.

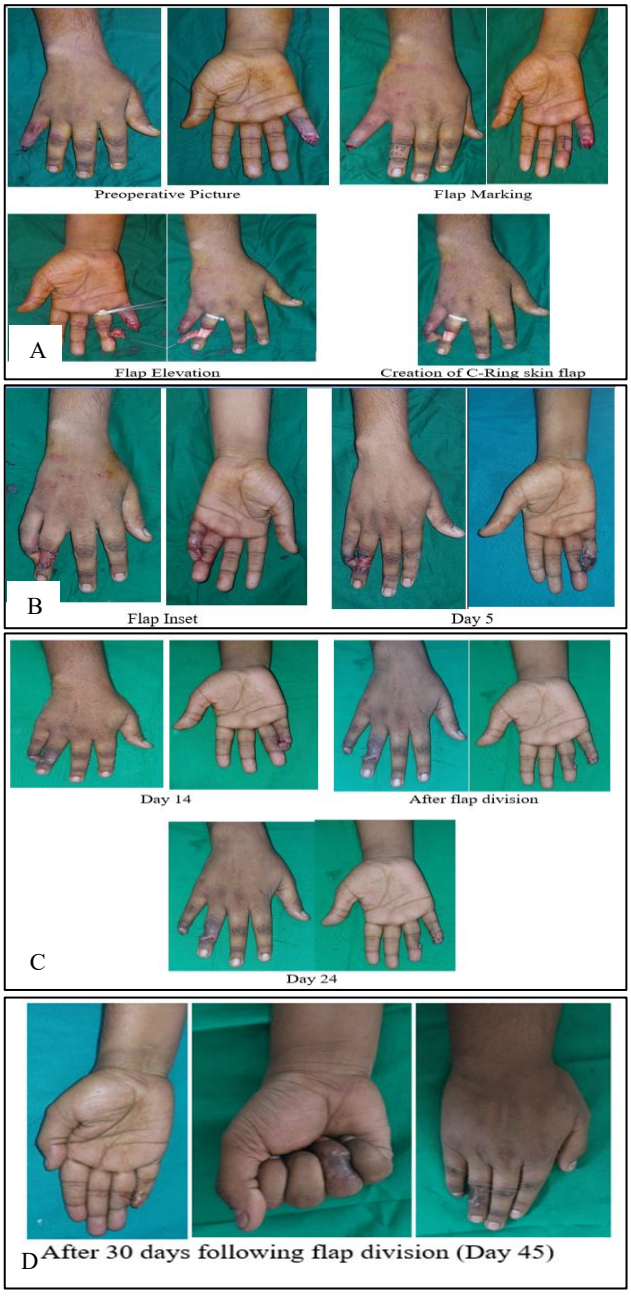

Figure 3 (A-D): Preoperative condition, flap marking, flap elevation and creation of the C-ring skin flap; showing the flap inset and division, with them resting in the follow-up and final condition after surgery, shows the results clearly and confidently.

The whole dorsum surface was limited to half the width of the finger on the volar aspect. It is very important to reserve the skin of the contralateral side and half the volar width of the donor finger to preserve venous and lymphatic drainage of the distal part of the finger. Small skin bridge was left intact to protect the digital artery. The flap could made into an island flap to allow for more flap mobility. After complete elevation of the flap the tourniquet was released, the circulation was checked and hemostasis obtained. Flap was sutured into the defect and the donor area was closed with a full thickness skin graft.

RESULTS

A total of 40 patients underwent reconstruction of degloved amputation stumps and volar or dorsal finger defects using the distally based C-ring cross-finger flap. The results are presented according to the specific objectives.

Table 1: Dimensions of flap and wound (n=40).

Parameters	Mean±SD	Minimum	Maximum
Flap length (cm)	3.12±0.274	2.4	3.8
Flap width (cm)	2.07±0.199	1.5	2.4
Flap area (cm²)	6.46±0.689	4.8	7.92
Wound area (cm²)	5.11±0.725	3.12	6.3

Table 1 shows the dimensions of the harvested flaps were measured intraoperatively. The mean flap length was 3.12±0.274 cm (range: 2.4-3.8 cm), and the mean flap width was 2.07±0.199 cm (range: 1.5-2.4 cm). The mean flap area was 6.46±0.689 cm² (range: 4.8-7.92 cm²). The corresponding wound dimensions after debridement showed a mean defect area of 5.11±0.725 cm² (range: 3.12-6.3 cm²).

Table 2: Distribution of flap necrosis (n=40).

Type of flap necrosis	Number of patients	Percentage (%)
No necrosis	23	57.5
Marginal necrosis (<10%)	9	22.5
Partial necrosis (10-20%)	4	10
Significant necrosis (>20%)	3	7.5
Complete flap loss	1	2.5

Table 2 shows the Flap necrosis was classified as marginal (<10% loss), partial (10-20% loss), significant (>20% loss), or complete. No flap necrosis was observed in the majority of cases (23 patients, 57.5%). Marginal necrosis occurred in 9 patients (22.5%), partial necrosis in 4 patients (10%), significant necrosis in 3 patients (7.5%), and complete flap loss in 1 patient (2.5%).

Table 3: Flap-related complications (n=40).

Complications	Number of patients	Percentage (%)
No complication	22	55
Venous congestion	10	25
Infection	4	10
Wound dehiscence	4	10

Note: Some patients had multiple complications.

Table 3 shows that venous congestion was the most common complication, observed in 10 patients (25%), which was managed with suture removal, hand elevation, and low-dose subcutaneous heparin. Infection occurred in 4 patients (10%) and wound dehiscence in 4 patients (10%). No flap-related complications were seen in 22 patients (55%).

Table 4: Donor site morbidity (n=40).

Donor site complications	Number of patients	Percentage (%)
No morbidity	26	65
Infection	7	17.5
Re-skin graft required	7	17.5

Note: Some patients had both infection and required re-skin grafting.

Table 4 about donor site morbidity was assessed in terms of wound infection and the need for re-skin grafting. No donor site morbidity was observed in 26 patients (65%). Donor site infection occurred in 7 patients (17.5%) and was managed conservatively. Re-skin grafting over the donor site was required in 7 patients (17.5%).

Table 5: Range of motion of interphalangeal joints (n=40).

Joints	Full range of motion	Restricted (5-10°)	Percentage full (%)
Pip joint	40	0	100
Dip joint	39	1	97.50

Table 5 shows the range of motion was assessed using a goniometric scale at 30 days following flap division (45 days after flap inset). All 40 patients (100%) achieved full range of motion at the proximal interphalangeal (PIP) joint. At the distal interphalangeal (DIP) joint, full range of motion was achieved in 39 patients (97.5%), while 1 patient (2.5%) had mild restriction of 5–10 degrees.

Table 6 shows that the overall outcome was classified as good, satisfactory, or poor based on a composite

assessment of flap viability, complications, donor site morbidity, and joint mobility. Good outcome was achieved in 28 patients (70%), satisfactory outcome in 9 patients (22.5%), and poor outcome in no joint movement.

Table 6: Overall functional outcome (n=40).

Outcomes	Number of patients	Percentage (%)
Good	28	70
Satisfactory	9	22.5
Poor	3	7.5

DISCUSSION

This study examined early results of using the distally based C-ring cross-finger flap for reconstructing degloved amputation stumps and finger defects in 40 patients. It shows this flap offers reliable soft tissue coverage, manageable complications, minimal donor site issues and good functional recovery in most cases.

The mean flap area was 6.46±0.689 cm², about 26% larger than the wound area of 5.11±0.725 cm², reflecting standard practice of designing flaps 2-5 mm larger for tension-free inset and postoperative shrinkage. Max flap dimensions were 3.8 cm long and 2.4 cm wide, comparable to Mutaf et al 4 cm×2.4 cm.[12] Patil and Chavre reported smaller mean flap sizes of 2.1 cm×1.6 cm.[13] Larger flaps in this study are due to the C-ring design, which harvests nearly twice the tissue by including dorsal and limited volar skin, allowing coverage of defects up to 6.3 cm² while preserving digital length.[12] This is vital in degloving injuries and amputations to maintain hand function, especially for thumb and border digits, as the C-ring flap's robust blood supply from the contralateral digital artery enables stump coverage without skeletal shortening.

Flap survival is the key to successful reconstruction. In this study, 57.5% of flaps had complete survival, and 22.5% had minor necrosis (<10%) that healed conservatively. Overall, 80% achieved complete survival or minimal necrosis that didn't affect outcomes. Partial necrosis (10-20%) occurred in 10%, significant necrosis (>20%) in 7.5%, and one flap (2.5%) was lost. These results compare well with other series; Mutaf et al reported all 12 flaps survived, though their sample was smaller and they didn't report minor complications.[12] Patil and Chavre also reported no flap loss in 27 cases, and Al-Qattan's series of 15 adipofascial flaps had complete survival in all cases.[15,16] The slightly higher complication rate in our study might be due to larger defects, more complex injuries, and comprehensive reporting of all complications, unlike earlier studies that may have underreported minor necrosis. The single flap loss occurred in a severe crush-degloving injury case, showing the importance of thorough preoperative and intraoperative assessment of vascularity. Venous congestion affected 25% of patients, managed with suture removal, hand elevation, and low-dose heparin, gradually resolving. It's common in distally based flaps due to reliance on venae comitantes and valvular incompetence. Koshima et al noted higher congestion in reverse-flow flaps, advising preservation of subcutaneous tissue and minimal manipulation to improve outflow.[17] Infection and wound dehiscence occurred in 10% each, all managed conservatively. These rates align with other studies; Rabarin et al reported no infections or dehiscence, while Prabhakar et al found 21% infection in dorsal flaps.[18,19] Our 10% infection rate is acceptable. Notably, 55% of patients had no flap complications, highlighting the reliability of the distally based C-ring flap with good patient selection and surgical skill.

Donor site morbidity is a key consideration in flap procedures. In this study, no donor-site morbidity was observed in 65% of patients. Infection occurred in 7 patients (17.5%) and was treated with dressings and antibiotics. Re-skinning was needed in 7 patients (17.5%) due to partial graft loss or delayed healing, aligning with prior reports. Koch et al reported 20% of cross-finger flaps had complications, mainly graft loss.[20] Buehrer et al observed minimal donor-site issues with no secondary grafts required.[21] The low morbidity rate in our series may result from: preserving paratenon during flap elevation, meticulous hemostasis before grafting, using full-thickness skin grafts for better contour and durability and effective postoperative immobilization.[21]

Functional recovery is the main goal of hand reconstruction. In this study, all 40 patients (100%) achieved full PIP joint motion and 39 (97.5%) achieved full DIP joint motion at 30 days after flap division. Only one patient (2.5%) had mild restriction of 5-10 degrees at the DIP joint. These excellent results compare well with published outcomes. Rabarin et al in long-term follow-up, cold sensitivity was found in 7 of 28 patients but joint stiffness was not significant.[18]

A composite assessment showed that 70% of patients had good outcomes, 22.5% satisfactory outcomes, and 7.5% poor outcomes, mainly due to flap necrosis or loss. The distally based C-ring cross-finger flap proves effective for complex finger defects, especially degloved stumps and volar/dorsal defects. The 70% good outcome rate compares favorably with other techniques for similar injuries.

Limitations

This study has limitations. The sample of 40 patients, while enough for a prospective study, is small for firm conclusions. The follow-up was only 30 days post-flap division, potentially missing long-term outcomes such as cold intolerance, neuroma, and aesthetic results. Sensation and two-point discrimination, key to fingertip function, were not assessed. Conducted at a single center, the findings may not be widely applicable. Also, there

was no control group to compare the C-ring flap with other options.

CONCLUSION

The distally based C-ring cross finger flap is a reliable, versatile technique for reconstructing degloved amputation stumps and finger defects. In 40 patients, the flap covered an average of 3.12 cm×2.07 cm, with an 80% survival rate, 25% venous congestion managed conservatively, and full or near-full motion in 97.5-100% of joints. Overall, 70% of patients had good functional results, supporting continued use in selected cases.

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

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