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Original Research Article

Versatility and modifications of the cross-finger flap in reconstruction of digital soft tissue defect

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ABSTRACT

Background: Hand injuries can cause major functional and cosmetic concerns. The cross-finger flap (CFF) is an effective treatment for complex finger defects. While CFF has typically been employed to treat volar aspect abnormalities, new versions now address a larger variety of digital soft tissue defects. The aim of the study was to evaluate the clinical outcome of various modified techniques of cross-finger flap which are used to reconstruct different soft tissue defect of fingers.
Methods: This was a prospective observational study carried out in the department of Burn and Plastic Surgery at Dhaka Medical College Hospital, Dhaka from September 2018 to February 2020. Forty (40) patients who presented with different soft tissue defect of fingers included in this study according to inclusion and exclusion criteria.
Results: The study involved predominantly male participants (80%), with a mean age of 31.70±14.28 years. The most common soft tissue defect site was the volar area (47.5%), and various modified cross-finger flap techniques were employed. The majority of patients achieved excellent functional outcomes, with 82.5% classified as good, 12.5% as satisfactory, and 5.0% as poor.
Conclusions: The modifications of the cross-finger flap are versatile and useful for different sites of digital injuries with good functional outcome.

Keywords: Cross-finger flap, Finger reconstruction, Soft tissue defects

INTRODUCTION

The soft tissue envelope of the hand is uniquely designed to provide tactile input from our environment and must also withstand substantial wear over a lifetime. Today 1/3rd of all injuries consists of hand injuries and they are quite often sufficient enough to restrict daily activities accounting for days lost from work.[1] As finger injuries account for potential morbidity, so there are principles on which a surgeon can base his or her sound management plan. A stable, durable, preferably sensate cover is a deciding factor for a functional finger. Treatment should be expeditious, simple, reliable and cost-effective, taking into consideration the age, gender, occupation, hobbies, hand dominance, health and needs of the patient. A thorough understanding of the various limitations, possible complications and likely outcomes of the various treatment modalities is a must. Therefore, a thorough knowledge, along with a sound judgement, can transform a potentially debilitating injury into a functional finger.[2] The goals of finger defect reconstruction can generally be thought of as threefold: (1) to provide adequate tissue coverage of underlying bone and soft-tissue structures, (2) to provide a sensate digit for functional activities, and

(3) to minimize donor-site morbidity.[3] Defect on the fingers over the proximal, middle and distal phalangeal regions can arise after various conditions like trauma, burns or after the release of contractures and excision of tumors.[4] The repair of finger wounds has evolved from the simple, such as allowing primary closure to the complex, such as free tissue transfer. Numerous local hand flaps that have stood the test of time to cover complex digital defects. Though lower on the reconstructive ladder, these flaps continue to aid the surgeon in dealing with soft tissue losses of the hand and finger. There are three main factors that influence the choice of the most appropriate flap for the coverage of digital soft tissue defects: the size of the defect, its location (fingertip, proximal, dorsal or volar) and the functional demands of the patient. When there is a loss of greater than one third of the volar tissue of the fingertip especially with exposed flexor tendon, joint or bone-more tissue is required than with advancement-type flaps. The cross-finger flap is a popular option under these circumstances. The cross-finger flap was first described by Gurdin and Pangman (1950). Classically, defects on the volar aspect of the finger, in the position of the middle phalanx or the distal phalanx are covered with the cross-finger flap harvested from the dorsal aspect of the adjoining finger. The cross-finger flap has gained wide acceptance in reconstructive hand surgery, due to its ease of dissection, its anatomical security and the provision of soft and pliable tissue very well suited for reconstruction of finger defects. Although the cross- finger flap is a very robust and safe flap, it cannot be used in certain situations the way it was originally described such as defects on the dorsum of the fingers, radial or ulnar borders, stumps of fingers or proximal defects on fingers. Hence, modifications in the flap were necessary to cover different types of defects on the fingers. These modifications have been classified according to the alterations in design, alterations in technique, and alterations in the donor finger. A significant number of studies have testified its superiority in terms of sensibility, durability, efficiency and reliability in terms of patient's return to his or her previous occupation.[2,4-7]

The aim of this study was to overcome the limitations of classical cross finger flap and to use this popular technique in repairing digital defect of various site; not for volar aspect only. The flap is comparatively durable, pliable. It provides protective coverage for exposed vital structures along with good functional outcome. Besides, donor site morbidity can be reduced by full thickness skin grafting and sometimes by primary closure. The objective of this study was to evaluate the clinical outcome of various modified techniques of cross-finger flap which were used to reconstruct different soft tissue defect of fingers.

METHODS

This was a prospective observational study and was conducted in the Department of Burn & Plastic Surgery, Dhaka Medical College & Hospital, Dhaka, Bangladesh during the period from September, 2018 to February, 2020.

Inclusion criteria

Wounds in the fingers caused by trauma, electric burn, machinery injury, and post-burn contracture release, exposing neurovascular tissue and bone required for flap covering.

Exclusion criteria

Patients with potential injuries of donor site due to previous trauma or surgery, patients with significant major co-morbid medical conditions (diabetes mellitus, Raynaud's disease, Buerger's disease), patients with pre-existing disabling problems (rheumatoid arthritis, Dupuytren's contracture), and patients with poly trauma and other life-threatening injury that causes delayed resuscitation were excluded.

This research included 40 male and female patients in total. The study population included patients with wounds on different digits, including those on the volar, dorsal, stumps of finger, and radial border requiring flap coverage, who attended the emergency or outpatient department. All the patients were carefully assessed by history taking, examination and doing relevant investigations to assess the pathology and fitness for surgery.

Surgical technique

Anesthesia- General or wrist block or regional anesthesia and finger tourniquet were preferred, based on patient's condition.

Selection of donor site- Donor site selection was based on injured digit and availability of donor finger.

Flap dissection- Once donor digit had been selected; the recipient finger was debrided. The flap was usually designed as a rectangular flap, which was raised on 3 sides and was classically planned on the dorsal aspect of the middle phalangeal region of donor finger to cover defects on the volar aspect of the distal or meddle phalangeal region of recipient finger. In case of different modification of the technique, flap might be quadrangular in shape instead of rectangular and taken from any aspect of donor finger according to the size and site of injury respectively. The base of the flap was designed on the neutral line of the donor finger, and was usually on the side adjacent to the injured finger. In folded cross finger flap back-cut was given at distal portion of the base. In distally based cross finger flap, base was placed just proximal to distal interphalangeal region. In extended lateral based cross-finger flap, base placed on lateral aspect of finger near the proximal interphalangeal region. In case of adipofascial cross-finger flap, initially dermal

flap was raised, at a plane just deep to the dermis, preserving the subdermal plexus opposite to the site of the defect and opened like a book. The soft tissues covering the extensor paratenon are raised as an adipofascial flap in the same way that a classical cross-finger flap was raised and turned over to cover the defect on the injured finger. This base act such as a hinge, which provides the vascularity of the flap. The flap was raised superficial to the extensor paratenon taking care to preserve this delicate, filmy tissue over the extensor tendon, to ensure a good take of skin graft applied over the donor site.

Flap in setting and donor site- The donor site was covered with full-thickness skin graft in most cases or primary closure in extended lateral based cross finger flap. Adipofascial cross-finger flap also covered by full thickness skin graft and flap was sutured to the recipient site.

Second stage- Usually done 2 to 3 weeks later. It was imperative to ensure good dermal healing at the recipient site before flap division.

The procedure was done under a wrist or digital block. After cleaning the operative site, the base of the flap was divided, ensuring adequate skin for coverage of the defect. The cut edge of the flap was shaped, defatted to ensure good contour, and closed primarily. The cut edge of the flap at the donor site was also trimmed and closed primarily.

Postoperative management and follow-up

Light dressing was applied on the flap and the hand was elevated. To allow for skin graft take, the splint was maintained for 1 week. Following flap division, dressing was given again without any splint. The passive and active range of motion exercise was started shortly after the procedure (flap division) to avoid joint stiffness. All operative areas were observed up to 45 days following flap division. The range of movement of the PIP and DIP joints were evaluated by goniometric scale**.**

Statistical analysis

All data was compiled in a master table first. Standard formula was used and statistical analysis of the result was obtained by using window-based computer software devised with Statistical package for Social Science (SPSS-20). Ethical clearance was obtained from the ethical committee to perform the investigation and study.

RESULTS

Table 1 shows that majority (52.5%) of our patients were aged 21-40 years old, followed by 27.567%, 17.5% and 2.5% were aged between 41-60, ≤20 and >60 years old respectively. The mean age was found 31.70±14.28 years. As for the gender distribution of the patients where most of the patients (80%) were male and (20%) were female. In this study we found that trauma is the leading cause of injuries, accounting for 52.5% of cases. Electric burns and machinery injuries follow at 25% and 20%, respectively. Contracture release procedures contribute to a minimal 2.5% of injuries. As for site of injury in 28 (70.0%) patients, injury was found in right hand and 12 (30.0%) were in left hand. We found more than one third (37.5%) of the patients (15 out of 40) were found injury of index finger followed by 8 (20.0%) in middle finger, 6 (15.0%) in ring finger, 3 (7.5%) in little finger and 1 (2.5%) in thumb. Both middle and ring finger involvement were 4 (10.0%) cases followed by middle and index finger were 3 (7.5%) cases. We found that the location of digital soft tissue defects. The majority of defects occur on the volar aspect, constituting 47.5% of cases, followed by the dorsum at 27.5%. Defects located on the stumps of fingers comprise 22.5% of occurrences, while radial defects represent a minimal proportion of 2.5%.

Table 1: Demographic profile of the study subjects.

Variables		Frequency	Percentage
Age	≤20	7	17.5
	21-40	21	52.5
	41-60	11	27.5
	>60	1	2.5
Gender	Male	32	80
	Female	8	20
Causes of injury	Trauma	21	52.5
	Electric burn	10	25
	Machinery injury	8	20
	Contracture release	1	2.5
Site of injury	Right	28	70
	Left	12	30
Involvement of digit	Index	15	37.5
	Middle finger	8	20.0
	Ring finger	6	15.0
	Middle+ring finger	4	10.0
	Middle+ index	3	7.5
	Little	3	7.5
	Thumb	1	2.5
Location of digital soft tissue	Volar	19	47.5
	Dorsum	11	27.5
	Stumps of finger	9	22.5
	Radial	1	2.5

Table 2 shows that the various modifications were employed, including distally based CFF, large CFF, adipofascial CFF, multiple CFF, folded CFF, extended

lateral based CFF, and jumping CFF. Distally based CFF had 9 cases (22.5%), mostly resulting in good outcomes. Large CFF, with 8 cases (20%), also had predominantly good outcomes. Adipofascial CFF and multiple CFF, both with 7 cases (17.5%), showed varied outcomes. Folded CFF, with 6 cases (15%), uniformly resulted in good outcomes. Extended lateral based CFF had 2 cases (5%), both with good outcomes. Jumping CFF, with 1 case (2.5%), resulted in a good outcome.

Table 2: Types of modification and outcome of the cross-finger flap of the study subjects.

Type of modification	Total case (%)	Outcome		
		Good	Satis-factory	Poor
Distally based CFF	9 (22.5)	7	1	1
Large CFF	8 (20)	6	1	1
Adipofascial CFI	7 (17.5)	5	2	
Multiple CFF	7 (17.5)	6	1	
Folded CFF	6 (15)	6		
Extended lateral based CFF	2 (5)	2		
Jumping CFF	1 (2.5)	1		

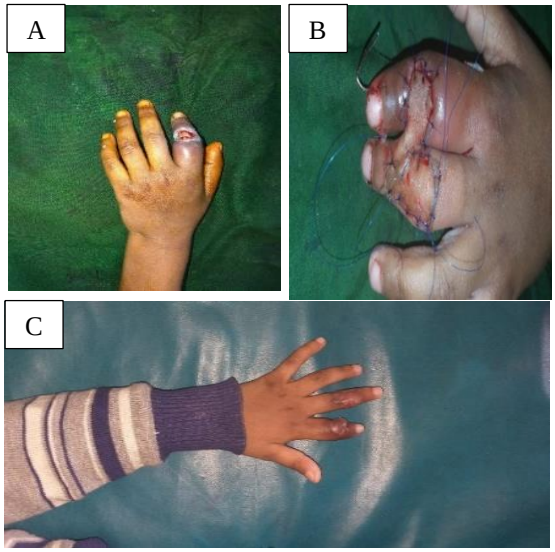

Figure 1: Distally Based CFF: A) Pre-operative-wound over dorsum of middle phalanx), B) Immediate post-operative, C) 14th POD- After flap division.

Table 3 shows that the range of movement in the (DIP) and (PIP) joints among the subjects. For the DIP joint, the majority (64.2%) demonstrate a full range of movement, while 15.3% exhibit a 5-10º restriction, 12.8% show a 10-20º restriction, and 7.7% display no movement. In the PIP joint, a higher (84.6%) cases a full range of movement, with 7.6% experiencing a 5-10º restriction, 5.1% having a 10-20º restriction, and 2.7% demonstrating no movement.

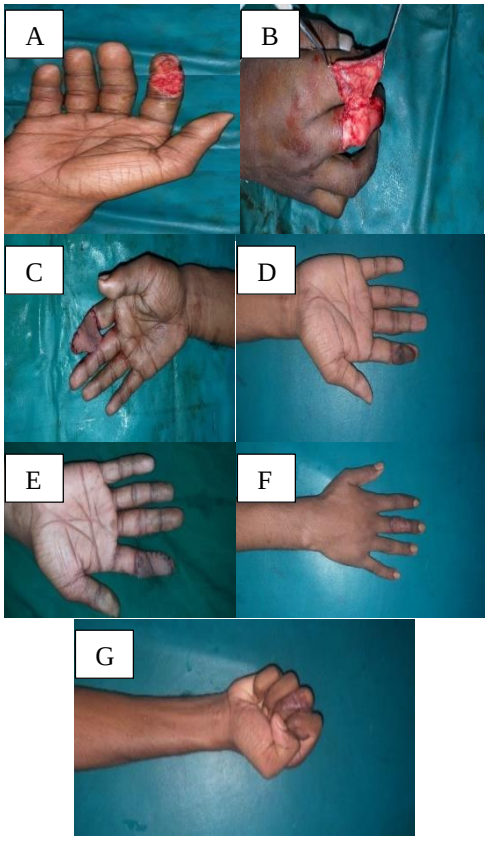

Figure 2: Large cross finger flap: A) Pre-operative, B) After flap elevation, C) Immediate post -operative, D) After flap division- at 17th POD, E) Well settled flap at 45th POD), F) Donor site at 45th POD, G) Good function at 45th POD.

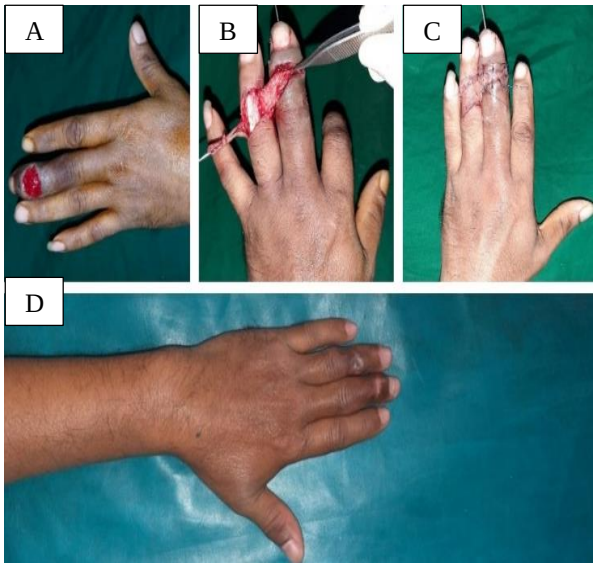

Figure 3: Adipofascial cross finger flap: A) Pre-operative, B) Elevation of Adipofascial CFF, C) Immediate post-operative day, D) 42nd post-operative day.

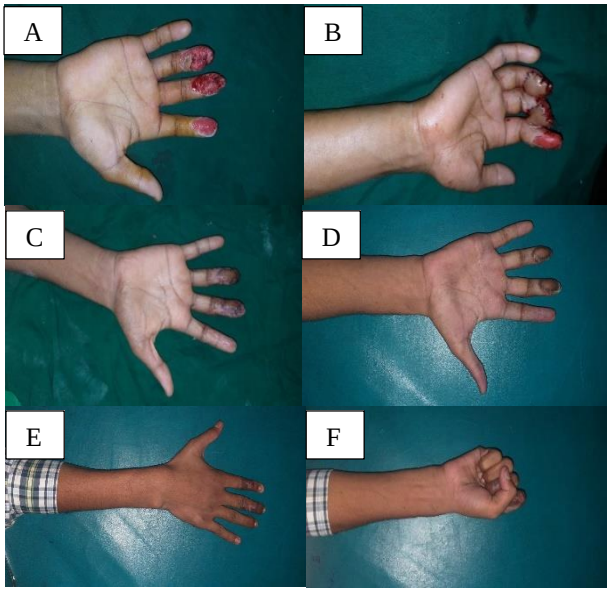

Figure 4: Multiple cross finger flap: A) Pre-operative, B) Immediate post -operative, C) 21st POD after flap division, D) Well settled flap at 45th POD, E) Donor sites at 45th POD, F) Good functional outcome at 45th POD.

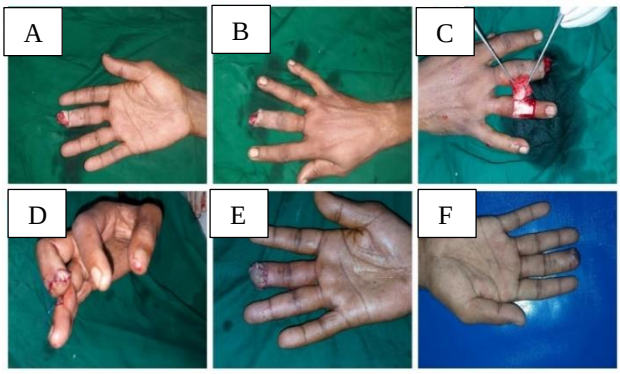

Figure 5: Folded cross finger flap: A) Pre-operative-volar view, B) Pre-operative- dorsal view, C) After flap elevation, D) Flap inset to cover both volar and dorsal surface of finger tip, E) After flap division- 19th POD, F) Well cover tip of finger at 45th POD.

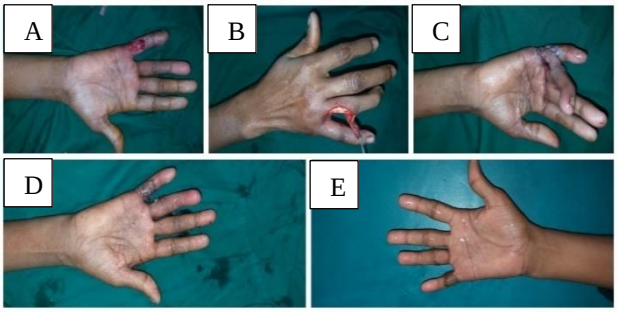

Figure 6: Extended lateral based cross finger flap: A) Pre-operative, B) Elevation of extended lateral based CFF, C) Immediate Post-operative, D) After flap division and donor site closed primarily at 19th POD, E) 45th POD after flap division.

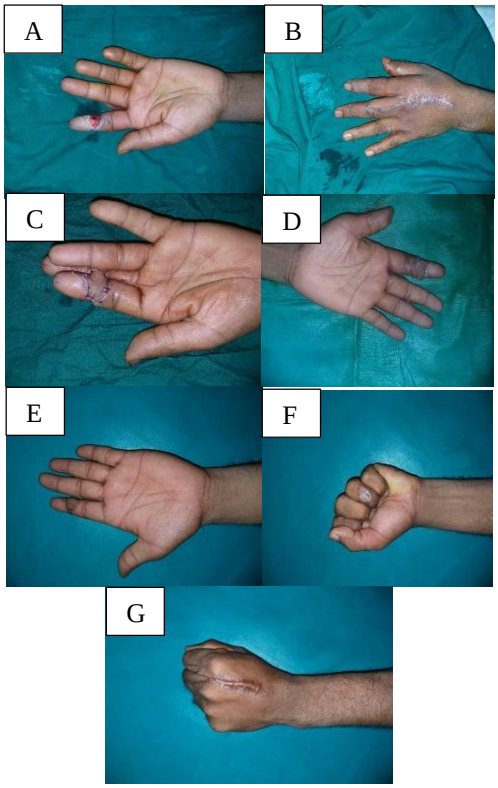

Figure 7: Jumping cross finger flap: A) Pre-operative-volar view, B) Pre-operative-dorsal view, DMAF for proximal phalangeal injury, C) Immediate post-operative, D) After flap division- at 17th POD, E) 45th post-operative day, F) Good flexion of figure at 45th POD, G) 45th post-operative day.

Table 3: Range of movement of DIP and PIP joint of the study subjects.

Range of movement of the joint	PIP		DIP	
	Frequency	%	Frequency	%
Full range of movement	33	84.6	25	64.2
5-10º restricted	3	7.6	6	15.3
10-20º restricted	2	5.1	5	12.8
No movement	1	2.7	3	7.7
Not applicable	1		1	

DISCUSSION

The cross-finger flap is a reliable method in soft tissue reconstruction of the fingers. The provision of soft and pliable tissue very well suited for defects on the fingers, the anatomical security and the ease of flap harvest make the cross-finger flap a widely used reconstructive option. However, it cannot be used in certain situations the way it was originally described. Hence, different modifications in the flap were necessary to cover different types of defects on the fingers. This prospective observational study was done to evaluate the clinical outcome of

various modified techniques of cross-finger flap which are used to reconstruct different soft tissue defect of fingers. The study was conducted in Department of Burn and Plastic Surgery, Dhaka Medical College Hospital, Dhaka during the period from September 2018 to February 2020. Total 40 patients who were presented with different type of digital injury were included in this study. This study showed that majority (52.5 %) of patients were belongs to age range between 21 and 40 years. The mean age was found 31.70±14.28 years with the range of 3.0 to 70.0 years (Table 1). This finding indicates that active age group people are most sufferer of digital injury. It may be due to involvement of this age group in different works which exposed them to this sort of injury. This finding consistent with Karthikeyan et al. (2017) where they found most of the patients were in the age group of 20-40 years. The youngest patient was 2 years of age. The oldest in the group was a 75 years old male. Chen et al (2015) conducted a study where the mean age was 33 (age range was 21-56 years). The present research work was a male predominant study, the percentage of male patient was 80.0% (32 out of 40) and female patient was 20.0% (8 out of 40) (Table 1). The cause may be that the male people of this country are most active member of the family and thus they were more exposed to outdoor activities and are more prone to trauma, machinery and other types of injury. Karthikeyan et al studied on 59 patients; 47 were male and 12 were female among them. There were 66 men (81%) and 15 women (19%) out of 81 patients of the study conducted by Mutlu et al (2019).[4,8,9] In this study, trauma was found as the commonest cause of digital soft tissue defect. Among 40 cases, 21 (52.5%) had digital soft tissue defects due to trauma, 10 (25.0%) cases due to electric burn, 8 (20.0%) cases due to machinery injury and 1 (2.5%) case was after contracture release (Table 1). A study conducted by Jeyakumar and Kumar found trauma (118 out of total 121 cases) was the commonest cause of digital soft tissue defects. Another study done by Bista et al found the most common cause of defects in their study group was machinery injury which consist of 12 cases and 8 cases due to trauma (5 by door crush injury and 3 by road traffic accident), 1 post electrical injury defect and 1 post infective raw area. In this study, in 28 (70.0%) patients, injury was found in right hand and 12 (30.0%) were in left hand (Table 1). This is probably due to right hand dominance in most of the people. Panda (2017) reported that out of 72 patients of his study, 53 (73.61%) patients had injury in the right hand and 19 (26.39%) had in the left hand. Jeyakumar and Kumar (2019) also found similar finding where right hand digital injury occurred in 86 (71.08%) patients and only 35 (28.92%) patients had injury in the left hand, with a total 121 cases.[10-12] Those findings were similar to present study. Among the current study subjects, more than one third (37.5%) of the patients (15 out of 40) were found injury of index finger followed by 8 (20.0%) in middle finger, 6 (15.0%) in ring finger, 3 (7.5%) in little finger and 1 (2.5%) in thumb. Both middle and ring finger involvement were 4 (10.0%) cases followed by middle and index finger were 3 (7.5%) cases (Table 1). Chong et al reported that index finger was the commonest site of injury (7 out of 12 cases), followed by ring and middle finger (3 and 2 cases respectively). Another study conducted by Kim et al also found the most commonly injured finger was little finger and index finger. Most common site of soft tissue defect requiring a modified cross-finger flap coverage of the study was volar area 19 (47.5%) followed by dorsum of the finger 11 (27.5%), stumps 9 (22.5%) and radial side of the finger 1 (2.5%) (Figure-1). Jeyakumar and Kumar observed that most of their study subject required modified CFF to cover volar defect (116 out of 121 patients) which is very much similar to the present study. Karthikeyan et al (2017) found that the most common site of CFF coverage in their study was dorsum of the finger (56.9%) followed by volar defects (21.6%).[4,10,13,14] Another study about distally based CFF done on 27 patients, where 23 flaps were used for covering amputation stumps whereas 2 each were used for dorsal and large volar defects.[15] From all these studies including the present one, it could be said that the modifications of CFF can be used in different sites of digital injury.

This study showed application of different types of modified CFF in various cases (Table 2). These variations that were performed in this study was: 1. modifications in design (distally based, adipofascial CFF, large CFF), 2. modifications in technique (folded CFF, extended lateral based CFF) and 3. modifications in the donor finger (multiple CFF, jumping CFF). Karthikeyan et al. (2017) conducted a similar study with a total of 59 patients who underwent modified cross-finger flap. Among them, 4 had distally based, 3 had adipofascial CFF (modification in design); 10 had folded CFF (modification in technique); 6 had multiple and 3 had jumping CFF (modification in the donor finger). Now, the individual modification used in the present study are discussed below: The most common type of modified cross-finger flaps done were distally based CFF. Total 9 (22.5%) out of 40 patients underwent this modification (Figure 1); 7 patients with good outcome, 1 with satisfactory due to development of marginal flap necrosis and 1 with poor outcome as there was total flap los. Patil and Chavre (2012) conducted a study on distally based cross finger flaps for amputation stumps where 27 patients were included with a satisfactory outcome. Next common modification in this study was modified large cross-finger flap, 8 (20.0%) out of 40 patients (Figure 2); 6 patients had good outcome, 1 with satisfactory due to wound infection and 1 with poor outcome due to significant flap loss. Similar observation was found in a retrospective study conducted with 22 patients who had a large defect in the single finger providing satisfactory outcome.[4,8,15] Adipofascial cross finger flap (Figure 3) was another modification of CFF of the present study with good outcome on 5 cases and with satisfactory outcome on 2 cases (total 7 out of 40 patients). Kumar and Segu (2013) found that cross-finger adipofascial flap was an aesthetically better flap when they used it on 15 patients with complex defects on finger and needed a flap

coverage.[16] Similar outcome also observed by Al-Qattan (2008) who performed the above said procedure on 14 patients with complex dorsal digital defects. Next common modification in the present study was multiple cross-finger flap (Figure 4), done on 7 (17.5%) out of 40 with good outcome in 6 cases and satisfactory outcome in 1 case. Moosa (2010) reported good outcome by using double cross finger flap on 22 cases of ring avulsion injuries. Similar outcome was also found in a case series of 4 patients performed by Al-Qattan et al. (2018) where they used double cross finger flap to repair the injuries.[17,18] In the present study, folded cross finger flap (Figure 5) was done in 6 (15.0%) patients with a good outcome. Karthikeyan et al performed folded cross finger flap in 10 patients. They also found this technique was both functionally and aesthetically better. Extended Lateral based CFF (Figure 6) was used in 2 (5.0%) cases in this study with good outcome. Similarly, a total of 12 patients underwent soft tissue reconstruction of the fingers with a laterally based cross-finger flap by Chong et al and they also observed that this procedure was versatile with less donor site morbidity and better aesthetics than a conventional CFF. In this study jumping cross finger flap (Figure 7) was done in 1 (2.5%) patient with good outcome. Similar study (Sabapathy, Mohan and Bharathi, 2000) found 5 cases with mutilating hand injury where jumping CFF were performed with satisfactory outcome.[19]

In majority of the cases of the current study, no complication had occurred. In 2 (5.0%) patient who had infection managed by dressing and antibiotic. Flap loss occurred in 2 (5.0%) cases, 1 was managed by skin graft and another one by filet flap. 3 cases (7.5%) developed marginal flap necrosis; all of these were managed conservatively with dressing. Karthikeyan et al found no major complications in their study such as total flap loss. In total of 59 patients, 3 patients (5%) had a marginal necrosis; all these flaps were managed with dressings.[4]

This study found that majority (64.2%) of the patients had excellent functional outcome as they preserved full Range of Movement (ROM) of DIP joint (Table 3), measured by goniometer. 6 (15.3%) patients had good and 5 (12.8%) had satisfactory functional outcome as they developed 5-10º and 10-20° restriction of movement of DIP joint respectively. In 3 (7.7%) cases, there was no movement of DIP joint because of flexor tendon (FDP) injury in one case, stiffness of DIP joint in two cases as those patients presented one month after injury with joint involvement, so they found to have poor functional outcome. On the other hand, majority 33 (84.6%) of patients were found in full range of movement of PIP joint (Table 3) in the present study which indicated excellent functional outcome. Only 3 (7.6%) patients had 5-10º restriction and 2 (5.1%) patients had 10-20º restricted movement, which means they had good and satisfactory functional outcome respectively. 1 (2.7%) patient had poor functional outcome as no movement of PIP joint occurred due to injury to the flexor tendons (both FDP and FDS). Both DIP and PIP joint movement was found to be not applicable in 1 case (as that patient was needed ray amputation as a salvage procedure due to infection of flexor tendon sheath subsequently). A study done by Rajappa and Prashant with 40 patients and they found that full range of motion was obtained in 87% of patients where mean total active motion was 260 degrees. Full ROM of both PIP and DIP joint were preserved in all the donor fingers in the current study. Chen et al observed that, of the donor fingers, the ROM of the PIP and DIP joints were 99 degrees (range, 85-110) and 72 degrees (range, 40-90), respectively. The measurements of the contralateral side were 101 degrees (range, 90-110) and 73 degrees (range, 45-90), respectively. They found no significant difference between the donor finger and the contralateral side. In the present study, overall outcome of the flaps (Table 2) was good in 33 (82.5%) cases in terms of no flap loss or infection; followed by satisfactory in 5 (12.5%) cases in terms of marginal flap necrosis and infection managed by secondary healing. In 2 (5.0%) cases the outcome was poor in terms of need of skin grafting in one case and filet flap coverage in another. This finding was consistent with Chen et al where with 22 cases, full flap survival was observed in 20 fingers, partial distal flap necrosis occurred in 2 fingers which was healed without any surgical intervention. So, Modifications of cross finger flaps provide reliable coverage for digital soft tissue defects with good outcomes.[4,8,20]

This study has few limitations. Our study was a single centre study. The sample size of the study was small. Sensation and aesthetic outcome were not evaluated.

CONCLUSION

The various modifications applied to the cross-finger flap in this study not only ensure enduring coverage but also tailor the dimensions to the specific needs of the affected area. This approach proves effective in safeguarding exposed vital structures with minimal associated morbidity, highlighting its utility in providing optimal outcomes for patients.

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

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