Egypt, J. Plast. Reconstr. Surg., Vol. 49, No. 4, October: 263-272, 2025

A Retrospective Comparative Study of Neurocutaneous Flaps versus Regional Perforator Flaps in the Reconstruction of Soft Tissue Defects Around the Elbow Region

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Abstract

Background: Pedicled flaps are good surgical options for reconstruction of soft tissue defects around the elbow region. In this study, we compared the use of neurocutaneous flaps versus regional perforator flaps in reconstruction defects around the elbow region.

Objective: The aim of this study is to select between neurocutaneous flaps versus regional perforator flaps for reconstruction of soft tissues defects around the elbow region regarding their indications, advantages, complications and surgical outcome.

Patients and Methods: The study included fifteen patients who were divided in two groups. Group A where perforator flaps were used and group B where neurocutaneous flaps were used. All patients were followed-up for at least six months. Early complications were recorded, after six months, assessment of the outcome of surgery was done.

Results: We performed nine pedicled perforator flaps and six neurocutaneous flaps in fifteen patients. Follow-up of our cases ranged from 26 to 6 months (mean: 14.4 months). Early postoperative complications included surgical site infection and venous congestion. These complications were managed conservatively. *p*-values for the pain score and the range of motion were 0.5 and 0.69 respectively.

Conclusion: A comprehensive evaluations of soft tissue defects in the elbow region are mandatory for selection of the reconstructive option. When addressing moderate-sized defects, particularly those over the olecranon, neurocutaneous flaps should take priority. Perforator flaps emerge as viable options for reconstruction of moderate to massive soft tissue defects around the elbow region.

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Key Words: *Neurocutaneous flaps – Lateral arm flap – Radial forearm flap.*

Ethical Committee: The study was approved by the Ethics Committee (MFM-IRB) of the Mansoura Faculty of Medicine, Mansoura, Egypt. (Proposal code: MS.19.02. 506.R1.R2) .

Disclosure: Nil.

Introduction

The elbow joint plays a crucial rule in the function of the upper limb. Basic activities like eating, self-cleaning and personal hygiene require adequate range of motion of the elbow joint. Soft tissue injuries around the elbow joint are challenging because they have a disabling outcome and affecting the routine daily activities of the patient **[1-3]**. Numerous reconstructive options are described including skin grafts **[4]**, local flaps **[5]**, distant flaps **[6]** and free tissue transfer **[7]**.

The causes of such injuries are numerous. They include traumatic injuries **[8]**, after burn contracture release **[9]**, following tumor excision **[10]**, or exposed metallic hardware **[11]**. Ideal reconstructive option for such devastating soft tissue injuries requires flap coverage which should be thin, have durable wound healing that can withstand for early smooth repetitive flexion and extension elbow's movements **[12,13]**.

The size of the soft tissue defect around the elbow were categorized into small (less than 10 cm^2), medium (from 10 to 30 cm^2), large (from 30 to 100 cm^2) or massive (more than 100 cm^2). Fasciocutaneous flaps were the most used surgical technique for reconstruction of large defects **[14]**. Perforator flaps and Neurocutaneous flaps belong to fasciocutaneous flaps.

Neurocutaneous flaps are an axial flap based on a nerve and a vein. The arterial vascularization is provided by microvascular plexus of arteries surrounding and within the nerve. These flaps were developed on the fact that any cutaneous nerve is accompanied by a vessel which was named Vasa Nervorum which is running beside or within the nerve and give vascular supply to the overlying skin **[15]**. Neurocutaneous flaps used for elbow reconstruction were based on the perforators accompanying the cutaneous nerves (either medial or lateral antebrachial cutaneous nerves) and superficial veins of the anterior forearm **[16]**.

On the other hand, Perforator flaps are supplied by perforator vessel(s) that pass through the fascia from deep source vessel to supply a cutaneous territory. Radial artery perforator flaps **[17]** or the lateral arm flaps **[18]** were used by many surgeons for reconstruction of complex elbow defects.

Patients and Methods

This retrospective study was conducted in the Plastic and Reconstructive Surgery Department, Mansoura Faculty of Medicine, Mansoura University. We collected data from cases that had flap surgery for reconstruction of complex soft tissue defects in the elbow region from March 2016 and March 2021. The study was approved by the Ethics Committee (MFM-IRB) of the Mansoura Faculty of Medicine, Mansoura, Egypt. (Proposal code: MS.19.02. 506.R1.R2).

There were 15 cases that were admitted to the department and suffered from soft tissue defects around the elbow region. Local pedicled flaps were chosen as the method for reconstruction in fifteen patients who were included in the study. The patients were divided in two groups. Group A where perforator flaps were used and group B where neurocutaneous flaps were used. Table (1) shows patients' demographic data.

Data collected included routine history taking, general and detailed local examination including defect analysis and donor site assessment. Also, data from routine preoperative investigations and radiological evaluation including Doppler ultrasound examination were collected.

Surgical technique:

Patient was positioned supine on the operating table and the traumatized arm was placed over a side table. Surgeries were done under general or regional anesthesia. We performed surgeries under aseptic conditions, loupe magnification and tourniquet control. We used only limb elevation before the start of tourniquet control for better visualization of the perforators.

Table (1): Patients' demographic data.

Serial	Age	Sex	SITE	Operation
1	50	M	Olecranon	- Pedicled radial artery perforator flap
2	30	M	Cubital fossa	- Pedicled radial artery perforator flap
3	25	M	Cubital fossa	- Lateral arm flap
4	28	M	Cubital fossa	- Pedicled radial artery perforator flap
5	33	M	Cubital fossa	- Pedicled radial artery perforator flap
6	12	F	Lateral elbow	- Lateral antebrachial neurocutaneous flap
7	16	M	Lateral elbow	- Lateral antebrachial neurocutaneous flap
8	50	F	Lateral elbow	- Lateral arm flap
9	34	F	Cubital fossa	- Lateral arm flap
10	14	M	Cubital fossa	- Medial antebrachial neurocutaneous flap
11	35	M	Cubital fossa	- Lateral antebrachial neurocutaneous flap
12	33	M	Lateral elbow	- Pedicled radial artery perforator flap
13	17	M	Olecranon	- Lateral antebrachial neurocutaneous flap
14	12	M	Olecranon	- Medial & lateral antebrachial neurocutaneous flap
15	30	M	Lateral elbow	- Pedicled radial artery perforator flap

In group A, we used perforator flaps for reconstruction of elbow defects. Perforator flaps was based on the perforators around the elbow soft tissue defect. By the use of Doppler Ultrasound with an 8-megahertz probe, the perforator with the strongest audible sound was chosen for the flap elevation. The radial perforator flaps or the reverse flow lateral arm flaps were the chosen flaps.

Regarding the Radial artery perforator flaps, we started by identification of the perforators by a Doppler Ultrasound. Then the flap was designed over the chosen perforator. We started flap elevation by taking an incision down to the deep fascia on the ulnar side of the flap. The dissection proceeds towards the radial side and from distal to proximal direction.

We raised the flap in an island fashion Fig. (1C). Later, we released the tourniquet and perforator was examined. Finally, the flap was turned or advanced into the defect and sutured Fig. (1D).

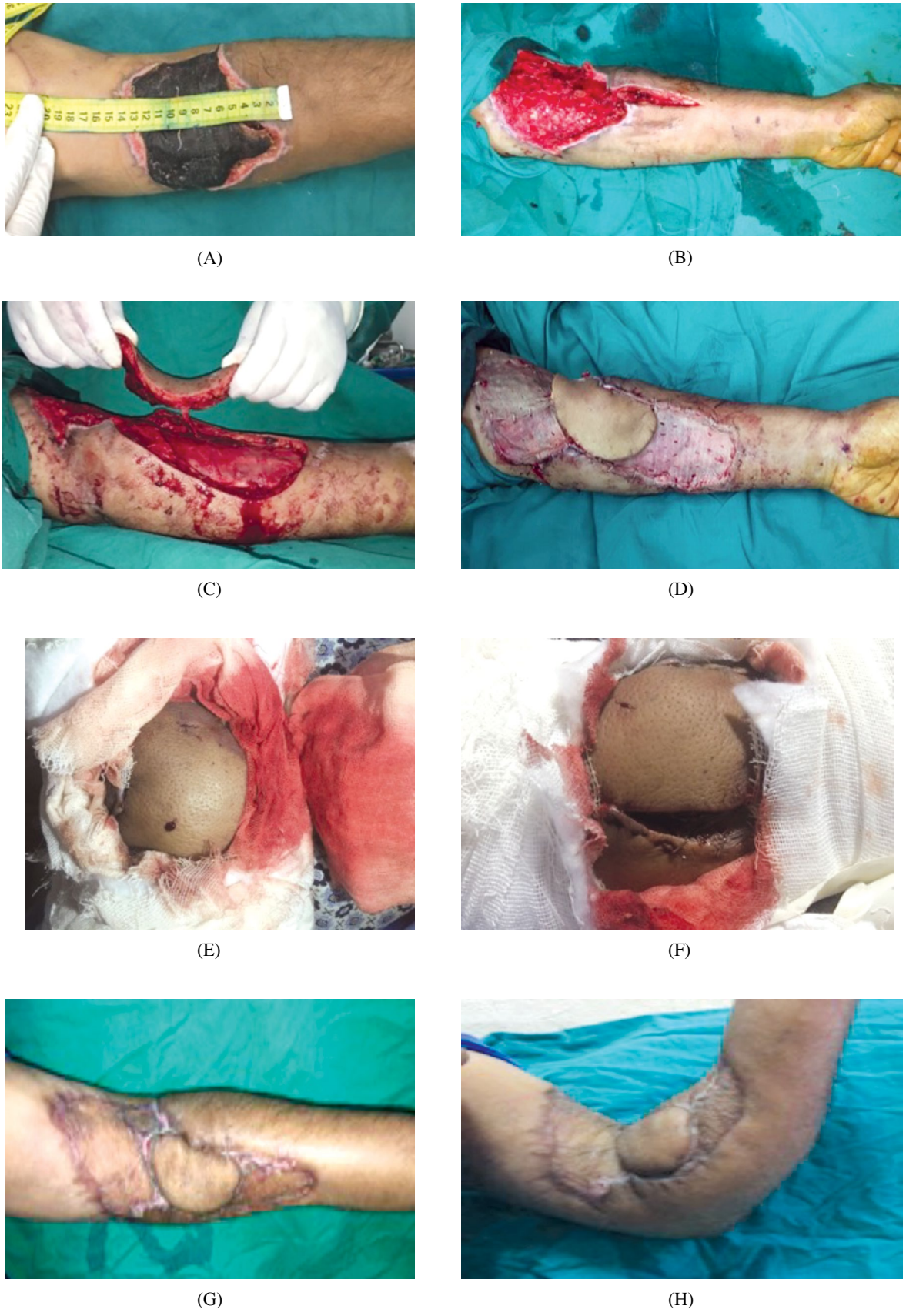

Fig. (1): (A) Ischemic skin flap of the left cubital fossa (B) After wound toilet and debridement, a defect of a size of 11×7 CMs was created (C) Creation of the radial artery perforator flap, (D) Post-operative immediate photo (E) Post-operative flap congestion, (F) Stitches were removed to decrease flap congestion, (G & H) 6 months post-operative photos.

Regarding the reverse Lateral arm flap, the longitudinal axis of the flap was marked over a line from the insertion of the deltoid muscle to the lateral epicondyle (resembling the lateral intramuscular septum of the arm) and a Doppler examination was used to detect the perforator of the radial recurrent artery (1-3cm superior to the lateral epicondyle). We started flap elevation by posterior incision and advance anteriorly till we detect the lateral intramuscular septum with the perforating vessel. Then, we started the anterior dissection towards the lateral intramuscular septum of the arm with preservation of the radial nerve. Finally, we cut the proximal end of the vessel and transpose the flap into the elbow defect Figs. (2E,2F).

Fig. (2): (A) Posttraumatic skin loss over the posterolateral aspect of left elbow, (B) The reverse lateral arm flap (C) The perforator (marked with *) is shown (D) The flap transferred to the elbow, and the forearm is reconstructed with meshed skin graft (E) The flap donor site (F) Six months postoperative view.

In the group B, we used neurocutaneous flaps for reconstruction of elbow defects. Neurocutaneous flaps were based on the perforators accompanying or within the cutaneous nerves including either the medial antebrachial cutaneous nerve or the lateral antebrachial cutaneous nerves and cephalic or superficial veins of forearm.

The proximal limit of the designed flap (usually 2-3cm below the elbow crease) was incised to identify the cutaneous nerves. Flap elevation was continued from proximal to distal direction of the flap in the subcutaneous plane. The axis of the flap was the cutaneous nerve and a cuff of 3-4cm of subcutaneous tissue around it. At the distal end of the flap,

the cutaneous nerve was transected and the flap was rotated in the defect Fig. (3B). The transected distal end of the nerve was buried into a nearby muscle to avoid the occurrence of post-operative neuroma.

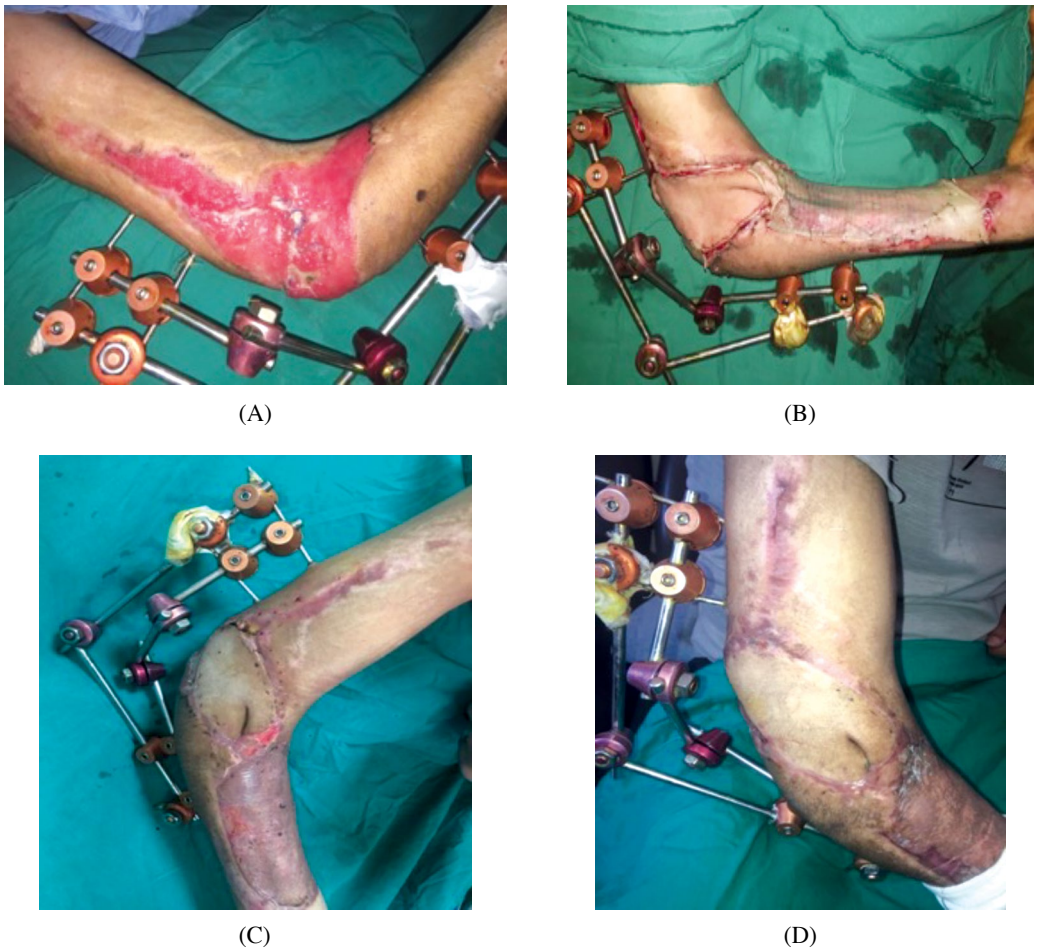

Fig. (3): (A) Post-traumatic granulation tissue over lateral aspect of right elbow and olecranon regions. (B) Lateral antebrachial neuro-cutaneous flap (C & D) Post-operative follow-up photos.

Postoperative antibiotics and analgesics were given. An above elbow splint was applied for 6 weeks. All patients started physiotherapy after complete wound healing. After patients' discharge, they were followed up every week during the first month and every month for the next 6 months. Afterwards, they were followed-up every 3 months for the next year.

Surgical outcome assessment:

At the end of the 6th postoperative month, we performed assessment of the results of surgery using these tests:

- Pain: We used visual analogue scale [score ranging from 0 (no pain) to 10 (worst pain)] **[18]**.
- Elbow range of motion: Cassebaum Classification for Elbow Range of motion **[19]**.
- Overall satisfaction about the surgery.

Data analysis:

Data were analyzed using the SPSS version 26 (Statistical Package for the Social Sciences). The mean values regarding the items of the scoring system were compared between the two groups using Wilcoxon signed rank test. The probability value (*p*-value) was considered significant when it was less than 0.05.

Results

In this retrospective comparative study, we performed nine pedicled perforator flaps and six neurocutaneous flaps in fifteen patients. Twelve cases were male and three cases were female, the mean age was 27.9 years (range from 12 to 50 years).

The cubital area was the most affected site (seven cases), followed by the lateral elbow region (five cases) and the olecranon area (three cases). Table (1).

Table (1): Patients' demographic data.

Serial	Age	Sex	SITE	Operation
1	50	M	Olecranon	- Pedicled radial artery perforator flap
2	30	M	Cubital fossa	- Pedicled radial artery perforator flap
3	25	M	Cubital fossa	- Lateral arm flap
4	28	M	Cubital fossa	- Pedicled radial artery perforator flap
5	33	M	Cubital fossa	- Pedicled radial artery perforator flap
6	12	F	Lateral elbow	- Lateral antebrachial neurocutaneous flap
7	16	M	Lateral elbow	- Lateral antebrachial neurocutaneous flap
8	50	F	Lateral elbow	- Lateral arm flap
9	34	F	Cubital fossa	- Lateral arm flap
10	14	M	Cubital fossa	- Medial antebrachial neurocutaneous flap
11	35	M	Cubital fossa	- Lateral antebrachial neurocutaneous flap
12	33	M	Lateral elbow	- Pedicled radial artery perforator flap
13	17	M	Olecranon	- Lateral antebrachial neurocutaneous flap
14	12	M	Olecranon	- Medial & lateral antebrachial neurocutaneous flap
15	30	M	Lateral elbow	- Pedicled radial artery perforator flap

The mean of the skin defect size is 51.2cm^2 (range from 20cm^2 to 120cm^2). The defect sizes were categorized into medium (26.3%), large (67%) and massive (6.7%). Table (2) shows analysis of the data of the study. Table (2).

Complications included venous congestion and surgical site infection. Venous congestion was observed in 1 case (one case was radial artery perforator flap). Venous congestion improved over days and minimal flap loss was observed. Secondary sutures were done after one week. One lateral arm flap showed surgical site infection and was managed conservatively by dressing changes. Follow-up of cases ranged from 12 to 30 months (mean: 19.7 months). Regarding neurocutaneous flaps, we did not experience any post-operative neuroma or neuropathic pain.

Regarding assessment of the long-term results:

- Pain: 2 cases (13.3%) experienced significant pain during lifting objects. These patients had associated severe bone and joint injuries. Other cases experienced no pain (7 cases 46.7%) or minimal pain (6 cases 40%) during movement as shown in Table (4).
- Elbow range of motion: Results are shown in Table (3).
- All of the patients were satisfied about the outcome of surgery except two cases with significant postoperative pain who were referred for orthopedic surgeon for further management of joint pain and stiffness.

Table (2): Analysis of the data of the study.

1-Number of cases:	15
2- Age:	
A- Mean:	27.9 years
B- Range:	12-50 years
3- Sex:	
A- Male:	12
B- Female:	3
4- Causes:	
A- Machinery injury:	6
B- Road accident:	5
C- Burn scar release:	3
D- Extravasation injury:	1
5- Wound surface area:	
A- Mean:	51.2 Cm^2
B- Range:	(20-120 Cm^2)
C- Defect size categories:	
Medium:	1 (26.3%)
Large:	10 (67%)
Massive:	4 (6.7)
6- Performed flaps:	
A- Pedicled perforator flaps	9
B- Neurocutaneous flaps	6
7- Site:	
A- Cubital fossa:	7
B- Lateral elbow:	5
C- Olecranon:	3
8- Follow-up:	
A- Mean:	19.7 months
B- Range:	12-30 months
9- Complications:	
A- Venous congestion:	1
B- Surgical site infection:	1

Table (3): The result of the elbow range of motion.

Grade	ROM	Group A	Group B	Total
Excellent	Flexion >130°, Extension deficit <15°	3	3	6 (40%)
Good	Flexion >120°, Extension deficit < 40°	3	1	4 (26.7%)
Fair	Flexion >110°, with any extension deficit	2	1	3 (20%)
Poor	Flexion <110°	1	1	2 (13.3%)

Table (4): Analysis of postoperative pain scores and range of motion.

Data	Group A Pain scores	Group B Pain scores	Group A ROM	Group B ROM
	8	2	100	120
	5	4	115	115
	1	1	135	130
	2	1	110	135
	1	9	125	60
	3	1	120	135
	1		130	
	1		130	
	4		125	
p-value	0.5		0.69	

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Video (1): Six Months postoperative view of a case with massive soft tissue defect over the elbow region which was reconstructed pedicled radial artery perforator flap and skin grafting. The case shows a pain free food range of motion of the elbow joint (range from 0º extension to 120º flexion).

Data analysis:

There were no statistically significant differences between the two groups regarding the postoperative pain scores and range of motion of elbow joint as shown in Table (4). The *p*-values for the pain score and the range of motion were 0.5 and 0.69 respectively.

Discussion

In this study, A comparison between the use of neurocutaneous flaps versus pedicled perforator flaps in reconstruction of medium to massive sized soft tissues defects around the elbow region was done with successful surgical outcomes and comparable results.

In this study, the defect sizes were ranging from moderate to massive defects. Ooi and his colleagues reconstructed massive defects around the elbow region by distant flaps **[19]**. However, in this study, the use of pedicled radial artery perforator for reconstruction of a massive defect with the aid of skin grafting without any limitations of range of motion was employed. Skin graft was used to resurface muscular defects and pedicle radial artery perforator flaps for resurfacing exposed tendon and vascular structures.

Numerous muscular flaps were described for reconstruction of small defects around the elbow region including the flexor carpi ulnaris **[20]**, anconeus **[21]**, Brachioradialis **[22]** and triceps brachii muscles **[23]**. Theses flaps were used mainly for coverage of orthopedic hardware exposure, needs skin grafting and used mainly for small anterior defects.

Chui used free flaps for reconstruction of soft tissue defects around the elbow region including free anterolateral thigh flap **[24]**. Ooi and his colleagues used free latissimus dorsi flaps and free rectus abdominis flap **[25]**. However, in this study, free flaps were not used.

Several authors used pedicled distant flaps mainly for reconstruction of massive defects with no local or free flap available or as a salvage option after free flaps failure. Arguello used pedicled latissimus dorsi flaps **[26]**, Turan used pedicled groin flap **[27]**, and Yunchuan used intercostal perforator-based pedicled abdominal flap **[28]**.

Neurocutaneous flap main advantage is providing a sensate flap for reconstruction of the elbow defects. This advantage was of great importance in coverage of posterior elbow defects especially over the olecranon region. Sensation at this pressure point is of great impotence for the patients to protect them from further injuries. The complication rates were comparable to non-sensate perforator flaps.

On the other hand, perforator-based flaps provide a relatively large flaps with robust blood sup-

ply. In addition, it was a rapid and reliable reconstructive option ideal for reconstruction of anterior elbow soft tissue defects with large to massive sizes.

In two cases there was a significant postoperative pain after surgery due to associated skeletal injuries. Further orthopedics interventions were needed to address this condition including either joint arthrodesis or joint replacement. These possible further interventions should be put in mind during the initial flap selection and incision design for the flap.

All patients included in this study needed a standardized post-operative physiotherapy exercises and rehabilitation protocol. Those patients cannot perform any functional exercises before establishment of stable wound coverage. Successful flap coverage followed by a functional exercises and physiotherapy complement each other to achieve the best functional outcome of surgery. The sooner the flap wound healing, the sooner the start of the physiotherapy and the better of functional outcome of surgery.

For evaluating the long-term outcomes of elbow reconstructive surgeries, the predominant indicators are range of motion and pain scores. Various scoring systems, encompassing a multitude of questions and considerations, are commonly employed for this purpose, adding complexity to the assessment **[29,30]**. However, the concept is that a wide range of pain-free elbow motion stands out as the most widely accepted criteria for assessment of elbow function following reconstructive elbow flap surgery. This emphasis on simplicity and prioritizing pain-free motion aligns with the concept that it serves as a practical and meaningful measure of success in evaluating the functional outcome of the surgery.

The limitations of this study are small sample size, absence of independent evaluators during the follow-up period and limited duration of follow-up. Future studies are needed to reconsider these limitations in order to increase the level of evidence of the study.

Conclusion:

In this comparative study, neurocutaneous flaps seems to be an effective method in reconstruction of soft tissue defects in the elbow region as long as the defect size is small to moderate. In contrast to perforator flaps that can reconstruct a wide range of defect sizes up to massive soft tissue defects around the elbow region. Hand held doppler ultrasound plays a critical role in localization of the pedicle of choice.

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