

Dorsal Hand Reconstruction; Comparative Study Between Regional and Distant Pedicled Flaps Following Traumatic Injuries in Developing Countries

Adel Michel Wilson, MD¹, FRCS; Mohamed Abdelmoneim Amin, MD¹; Ahmed Taher Ismail, MD¹; Mariam Mohamed Shoukry^{*1}, MD; Dina Mostafa Badawi, MD¹

¹Department of Plastic and Reconstructive Surgery, Faculty of Medicine, Cairo University, Cairo, Egypt

***Corresponding Author:**

Mariam Mohamed Shoukry,

Email ID: mariam Mohamed Shoukry@hotmail.com

Cite this paper as: Adel Michel Wilson, MD, FRCS; Mohamed Abdelmoneim Amin, MD; Ahmed Taher Ismail, MD; Mariam Mohamed Shoukry, MD; Dina Mostafa Badawi, MD, (2025) Dorsal Hand Reconstruction; Comparative Study Between Regional and Distant Pedicled Flaps Following Traumatic Injuries in Developing Countries. *Journal of Neonatal Surgery*, 14 (19s), 944-951.

ABSTRACT

Background: Hand is a complex anatomical and functional structure in human body that's why special attention is provided to approach different hand injuries to achieve a good aesthetic and functional outcome. Non microsurgical regional or distant flap options tend to be more robust than free tissue transfer especially in developing countries, but require careful planning to choose the most appropriate coverage while being aware of potential complications and future management options. Dorsal hand injuries resulting from a traumatic event are associated with other systematic injuries that preclude lengthy procedures and the lack of microsurgical expertise make the non-microsurgical options from the reconstructive ladder more suitable for those patients.

Patients and methods: This study was conducted on 20 patients presented with full thickness dorsal hand injuries and post traumatic soft tissue defects. Primary survey was done to exclude any life threatening condition. The patients were assorted into 2 groups according to their general condition, comorbidities, donor site morbidity and reliability of the flap coverage technique. Group A included patients who underwent regional pedicled flap and group B included patients who underwent distant pedicled flap. Vigorous irrigation, debridement, hardware fixation, tendon repair and finally coverage were done for all patients. Postoperatively aggressive rehabilitation in the form of relative motion extension program (RME) was done.

Results: The study population included 15 males (75%) and 5 females (25%). The mean age of patients was 30.4 years. The mean size of the defects was 67.6 cm². Bone fracture was present in 17 patients (85%). Postoperative complications percentage was (20%). The functional outcome improved after surgical repair of the injured tendons and by rehabilitation programs.

Conclusion: Distant pedicled flap option shows comparable results to regional pedicled flap option in dorsal hand injuries reconstruction in countries with limited resources. The functional outcome can be improved by proper extensor tendon repair, reconstruction and aggressive postoperative rehabilitation programs.

Keywords: Hand dorsum trauma, Post traumatic injuries, Tendon injury, Dorsal hand reconstruction, surgical flaps.

1. INTRODUCTION

Soft tissue defects of the hand are commonly encountered by the Plastic and Reconstructive hand surgeons in the context of traumatic events, infection, post tumor extirpation and post burn injuries. ^[1] Hand dorsum is a special area characterized by thin, fragile skin and scanty subcutaneous tissue making it a very liable region for different types of injuries. ^[2] Both small and large complex open hand wounds represent a reconstructive challenge. Reconstructive surgeons always focus on maintaining and preservation of the natural state of the patient by putting into consideration to try to avoid donor site complications and achieving optimal results in the recipient site. Aside from the need for soft tissue covering of hand defects, particularly post-traumatic soft tissue defects (PTSTDs), surgeons should identify the complicated functional considerations related to the zone of damage and work to incorporate these goals into their operating strategy. The unique character of the human hand in terms of sensory function and joint mobility raises higher-level functional considerations. ^[3] The most fundamental methods on the reconstructive ladder are local flaps and direct closure, although they are insufficient for big or intricate abnormalities. Granulating wounds with a vascularized tissue bed can benefit from split thickness skin grafts; but, if a joint or bone is exposed (bare), there won't be enough neovascularization, and the graft will be lost.

Reconstructive surgeons have tried to find a workhorse flap that is effective in many defect sites and dimensions. A workhorse flap is defined by its dependable anatomy, simple harvesting, multiple uses, and ease of learning curve. ^[4]

Nowadays with the establishment of the concept of reconstructive elevator rather than the reconstructive ladder, it is possible to use more complex techniques for the best functional and aesthetic outcomes. However, the choice is multifactorial dependent as the available resources, experience, knowledge and patient related factors. ^[5]

The aim of this study was to compare between and evaluate the results of regional pedicled and distant pedicled options of flap coverage for PTSTDs of the dorsum of the hand in developing and low budget countries that lack the facilities of microsurgical flap coverage options.

2. PATIENTS AND METHODS

This descriptive cross sectional study was conducted on 20 patients between March 2021 and June 2023. Patients with post traumatic injuries to the dorsum of the hand between 18 to 60 years old were included in this study after obtaining the ethical committee approval. Patients were divided into two groups (A and B), patients chosen for regional pedicled (reversed radial forearm) flap were allocated in group A while patients for distant pedicled (groin) flap were allocated in group B. Preoperatively, patients with post traumatic injuries to dorsum of the hand resulting in a soft tissue loss were assessed generally for associated injuries using the advanced trauma life support survey (ATLS). Investigations were ordered for all patients in the form of full labs and x-rays, written informed consent and preoperative photos were taken. In the initial (1st look) operative assessment (case 1; Fig. 1); vigorous irrigation was done in the operation room for all patients. All devitalized, necrotic tissues and injured tendons were surgically debrided and when there was no tendon gapping; 1^{ry} repair was done in the same setting. When there was tendon substance loss; marking of both proximal and distal ends was done to allow tendon reconstruction in the next sessions. Injury to important vascular structures warranted thorough assessment. Dislocations and fractures were assessed through the wound if it was full thickness injury and K-wire fixation was done intraoperatively. The size of the defect was measured in centimeters, depth of the defect, affected layers were assessed and the presence of exposed vital structures (vessels, nerves, tendons and/or bone) were important criteria to notice because those factors affected the decision making. [Fig. 1 (Case 1)].

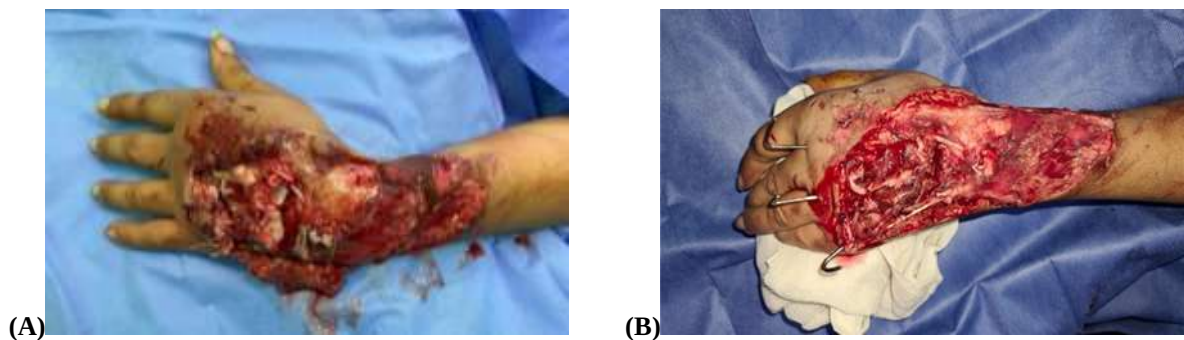


Fig. (1): A, B: Intra-operative photos of left dorsal hand defect after irrigation, debridement, marking of the extensor tendons and K- wire fixation of the associated fractures.

Regarding the definitive management (2nd look); hardware stability and bone viability was rechecked if the extensor tendons and bony framework were intact. If the extensor tendons were lost, tendon reconstruction by autograft (by interweaving Pulvertaft technique) or synthetic rods was done and finally soft tissue coverage; using pedicled flaps was performed.

Regional pedicled flap used in this study for patients in group A was radial forearm flap in the form of fascial and fasciocutaneous types as per Chang and Jin et al., (Case 2 and 3; Fig. 2 and 3 respectively). Distant pedicled flap used for patients in group B was groin flap according to McGreogor (Case 4; Fig. 4) that was done for patients who had dominant radial artery (detected by Allen's test and the AV duplex) so there was a contraindication to perform reversed radial forearm or for patients who refused the poor aesthetic outcome of the donor site resulting from reversed radial forearm flap.



Fig. (2): (Case 2), For a dorsal hand defect measuring 9x7 cm fascial radial forearm flap was done.



Fig. (3): (Case 3), For a dorsal hand defect measuring 11x10 cm fasciocutaneous radial forearm flap was done.



Fig. (4): (Case 4), For a dorsal hand defect measuring 5x3 cm groin flap was done.

Regarding postoperative management; for all patients included in this study pain assessment using the Numerical Rating Scale (NRS), prescribing medications (antibiotics, pain killers and anticoagulants when needed), daily dressings (to detect flap and graft viability), splinting and rehabilitation was performed. Hand elevation was done using arm sling in order to limit incidence of edema. Regarding regional flaps; the patients were dressed once daily. Graft check protocol was done in the form of 1st check after 3 days. Regarding distant pedicled flaps; Groin flap; the patients were transferred in the same

flexion position of the thigh. They were dressed twice daily. Flap separation was done after 3 weeks. Patient rehabilitation and physiotherapy care was an integral part of this study so the relative motion extension (RME) program was applied to them after extensor tendon repair or reconstruction and after bony fractures fixation as well. In phase 1 (1st 4 weeks postop.) of this program; the goal was to protect the repaired tendons while allowing early motion within the protective orthosis customized with 15-20° finger extension and 30° wrist extension. Phase 2 (4-8 weeks postop.) goal was to restore full range of motion (FROM) with minimal to no extension lag, orthosis was discarded during the day but was worn at night. Phase 3 (10-12 weeks postop.) goal was to address return to work so orthosis was discarded completely and progressive resistive exercises were started.

In this study the quick Disability of Arm, Shoulder and Hand (DASH) score (Fig. 5) was used instead of the original DASH score to assess the functional outcome in the form of 11 item questionnaire using a 5 point scale from which the patient selected an appropriate number corresponding to the severity and the functional difficulty. Different tasks were asked by the physician to be attempted by the patient, some of these tasks were:

- Open a jar.
- Do heavy household chores.
- Carry a shopping bag or briefcase.
- Wash your back.
- Use a knife to cut food.
- Recreational activities involving impact or force applied to the hand, shoulder, or arm.
- How much has your arm, shoulder, or hand condition impacted your typical social activities with family, friends, neighbors, or organizations in the last week?
- During the past week, were you limited in your work on other regular daily activities as a result of your arm, shoulder or hand problem?
- Severity of Arm, shoulder or hand pain last week.
- Severity of tingling last week.
- How much has the discomfort in your arm, shoulder, or hand interfered with your ability to sleep during the last week?

QuickDASH-9

INSTRUCTIONS: This questionnaire asks about your symptoms as well as your ability to perform certain activities. Please answer every question, based on your condition in the last week, by circling the appropriate number. If you did not have the opportunity to perform an activity in the past week, please make your best estimate of which response would be the most accurate. It doesn't matter which hand or arm you use to perform the activity; please answer based on your ability regardless of how you perform the task.

Rate your ability to do the following activities in the last week by circling the number below the appropriate response.

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. Open a tight or new jar.	0	1	2	3	4
2. Do heavy household chores (e.g., wash walls, floors).	0	1	2	3	4
3. Carry a shopping bag or briefcase.	0	1	2	3	4
4. Wash your back.	0	1	2	3	4
5. Use a knife to cut food.	0	1	2	3	4
6. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g., golf, hammering, tennis, etc.).	0	1	2	3	4

	NOT AT ALL	SLIGHTLY	MODERATELY	QUITE EXTREMELY A BIT
7. During the past week, to what extent has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours or groups?	0	1	2	3

	NOT AT ALL	SLIGHTLY LIMITED	MODERATELY LIMITED	VERY LIMITED	UNABLE
8. During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder or hand problem?	0	1	2	3	

	NONE	MILD	MODERATE	SEVERE	EXTREME
9. Arm, shoulder or hand pain.	0	1	2	3	4

A QuickDASH-9 score may not be calculated if there is greater than 1 missing item.
 QuickDASH-9 SCORE = $\left(\frac{\text{sum}}{9}\right) \times 1.1 \times 5/2$, a missing response is added as the average of the remaining.

Fig. (5): Quick DASH score.

Ethical approval:

This study was authorized by the ethics committee and carried out in compliance with the Declaration of Helsinki's criteria. Following receipt of all information, signed consent was provided by each participant.

Statistical analysis:

The statistical program for the social sciences (SPSS), version 28, was used to code and input the data. Mean $\pm$ SD, median, minimum, and maximum were used to represent quantitative data, while frequency (count) and relative frequency (%) were used to summarize categorical data. The non-parametric Kruskal-Wallis and Mann-Whitney tests were used to compare quantitative variables. Categorical data were compared using the χ^2 -test. When anticipated frequency was less than 5, the exact test was employed instead. P-values below 0.05 were regarded as statistically significant.

3. RESULTS

In this study 20 cases underwent reconstruction of their dorsal hand injuries in the form of hardware fixation, extensor tendon repair and soft tissue coverage by pedicled flaps; all of which were done in Kasr Al-Ainy Cairo University hospitals in the period from March 2021 till June 2023.

The study population included 15 males (75%) and 5 females (25%). The mean age of patients was 30.4 years. The mean size of the defects was 67.6 cm². Bone fracture was present in 17 patients (85%) affecting the metacarpal bones and phalanges as well; all of which were fixated by K-wires (there was no place for internal fixation due to the contaminated field and the high risk of infection). Methods of reconstruction were regional pedicled flap in group A with total number of 10 patients (50%); distributed in the form of 9 patients (45%) underwent fasciocutaneous type and 1 patient only (5%) underwent fascial type and distant pedicled groin flap in group B which included 10 patients (50%). In this study complications (Table 1) were encountered in 4 patients (20%) all of which in group B; which were managed in a conservative manner.

Table (1): Encountered complications and their percentages.

Complication	Number and percentage of patients
Surgical site infection (SSI) and donor site wound dehiscence.	3 patients (15%)
Distal flap congestion.	1 patient (5%)

All of the patients had stable soft tissue coverage in their follow up period and none of them had long term wound healing problems. Most of the patients in this study had associated injuries in the form of brain concussion, splenic tear, rib fractures, pneumothorax and femur fracture for whom definitive management was done. Regarding the length of operation; the mean was 3.225 hours with statistically significant result for group B. Regarding the need for 2^{ty} procedure; 5 patients (25%) needed further stages distributed in the form of 2 patient (20%) in group A and 3 patients (30%) in group B. The mean duration of rehabilitation was 2.5 months. Regarding the functional outcome using the quick DASH score; the mean disability percentage was 23.85%. Regarding the aesthetic outcome; it was classified into 2 categories in this study which were:

Aesthetic outcome from patient's perspective by 5 point scale:

- Grade 1 (very satisfied): 4 patients were ranked in this grade with total percentage of 20%.
- Grade 2 (satisfied): 8 patients were ranked in this grade with total percentage of 40%.
- Grade 3 (having no opinion): 5 patients were ranked in this grade with total percentage of 25%.
- Grade 4 (not satisfied): 3 patients were ranked in this grade with total percentage of 15%.

Aesthetic outcome from surgeon's perspective (Flap thickness, skin color match and hair distribution):

- Satisfied: 17 patients were ranked in this grade with total percentage of 85%.
- Not satisfied: 3 patients were ranked in this grade with total percentage of 15%.

4. DISCUSSION

The dorsum of the hand is characterized by being fragile due to very thin skin covering and poor subcutaneous tissue rendering it very prone to different types of injuries leading to exposed tendons and bones as well as bony fractures. There are various methods for reconstruction of the PTSTDs of the hand dorsum for which the choice depends on the size of the defect (medium sized <20 cm² and large sized ≥20 cm²) as local, regional, distant pedicled and free flaps. ^[2]

Due to the wide range of dorsal hand wounds, the surgeon must make informed and deliberate decisions for the best coverage of the wound. The vascularity of the wound bed, site, size and desired functional outcome all influence determination of the optimal coverage as well as restoring dorsal hand aesthetics and minimizing donor site morbidity. Fasciocutaneous flaps are the most commonly used flaps to manage medium and large sized defects, the choice of which flap to use depends on the cosmetic match of the skin color, reduction of donor site morbidity and the simultaneous approach to wound debridement and flap harvesting. ^[6]

Distant pedicled flaps (mainly groin flap) are the workhorse flaps for dorsal hand injuries resurfacing because they are relatively safe and show less complication rates than other pedicled, perforator and free flaps. The major drawback of groin flap is the patient's posture postoperatively and the necessity to keep patient's hand attached to the groin for 3 weeks which is considered a sort of discomfort to patients. Another disadvantage of this flap is the need of separation and debulking making it a multistaged procedure. On reviewing the literature many examples of groin flaps were used in post-traumatic reconstruction of hands; in 2018 Naalla et al. ^[7] reported the outcomes in a study of 85 patients with soft tissue defects within the upper limb. Flap healing was achieved in a total of 99% of cases, with total flap necrosis occurring in one case. Most patients were satisfied with the outcome of the treatment and the function of the reconstructed hand. However, complications were relatively common and were encountered in 22 patients (26%). The most common complication was marginal flap necrosis (10 cases, 12%), other encountered complications were partial flap necrosis requiring repair or skin transplant coverage (6 cases, 7%), infection at the surgical site (4 cases, 5%) and flap detachment requiring surgical re-attachment (2 patients, 2.4%). According to the authors, despite the development of new reconstruction techniques, groin flap continues to be a good and safe method of repair of medium and large-sized tissue defects within the upper limb. ^[7] Successful outcomes of the treatment of large hand tissue defects were also reported on by other authors. ^[8-11]

In this study 10 patients underwent coverage by groin flap with a total percentage of 50%, it was a safe flap, relatively easily harvested and dissected, suitable for all sizes of full thickness wounds and offered a durable coverage for the hand dorsum. However; it offered the advantage of a concealed donor site, the main drawback of this flap was the discomfort that the

patients faced in the postoperative period due to the sewn hand position into the groin for at least 3 weeks as described by the authors in the literature. Encountered complications, distal flap congestion for which leeches were applied and surgical site infection for which antibiotics were administered according to the culture and sensitivity. Additional 2nd procedures were needed in the form of debulking and 2nd stage tendon reconstruction in this study.

Yang et al. ^[12] first published the radial forearm fasciocutaneous flap as a free flap in 1981. **Lu et al.** ^[13] then characterized it as a retrograde-flow pedicled flap for hand reconstruction in 1982. The discovery of the nature of retrograde flow in distally pedicled radial forearm flaps was a significant advancement in hand surgery since it allowed for the single-stage transfer of large regions of relatively thin skin and fascia with a strong blood supply without the need for microvascular technique, which aided in early mobilization and postoperative elevation. Although the radial forearm flap may cover the whole dorsal portion of the hand, its use has drawn criticism due to the donor site's unpleasantness and the sacrifice of a major artery in a hand that is already wounded. The retrograde fascial radial forearm flap, which preserves the forearm skin, can help address these issues to some extent. Because they offer a thin, malleable, mobile layer with a dependable circulatory supply, the possibility for sensitivity, and a gliding surface to promote tendon and joint movement, fascial flap repair has well-established benefits for the hand. ^[3]

The distal reach of the fascial flap is similar to the retrograde radial forearm fasciocutaneous variant. Because of its thinness a split-skin grafted fascial flap, however, may provide a less favorable environment for secondary procedures such as staged tendon grafting. ^[1]

In this study 50% of the patients underwent reversed radial forearm flap in the form of fasciocutaneous type (9 patients; 45%) and fascial type (1 patient; 5%). For all of the patients included in this group Allen's test or A-V duplex was done in order not to sacrifice the radial artery if it was the dominant artery supplying the hand. It was a versatile flap allowing durable coverage and tendon reconstruction in the same stage or in later stages; however the major disadvantage was the poor aesthetic outcome of the donor site being covered by skin graft. This disadvantage was overcome by using the fascial variant as described in the literature but unfortunately it was a very thin flap that rendered staged tendon reconstruction a difficult procedure in this study.

Hand surgeons frequently encounter gapping extensor tendon injuries but reconstruction modalities are not extensively reported in the literature. There are two main techniques for reconstruction which are; tendon grafting from the injured tendon or free tendon graft reconstruction. Tendon transfers may be an available option in cases of impaired muscle function or impossible 1st repair or reconstruction. ^[14]

Tendon allograft is an effective method for reconstructing extensor tendon lesions, and it may be suitable for reconstructing numerous extensors. One of the primary benefits of this technique is the lack of donor site morbidity, as no tendon harvesting is required. ^[15] The Pulvertaft (PT) procedure is regarded the gold standard for tendon transplants and repairs. ^[16]

Some researchers discovered that the side to side (STS) repair is stronger than the PT weave with same repair mass. The STS repair may allow surgeons to rehabilitate patients in the same manner as they would when employing PT procedures, and may even help in a faster rehabilitation regimen. ^[17] In this study most of the patients had extensor tendon injuries for which primary repair by core sutures, tendon grafts using the Pulvertaft technique, tendon rods were used as well only in 1 patient to create the tendon pseudo-sheath and after one and half month tendon autograft was done. Tendon reconstruction was done in a later stage in most of the cases in this study after maintaining a stable hardware and durable coverage.

Modern suture procedures and rehabilitation programs have improved outcomes, with good to outstanding results surpassing 90% for proximal injuries. ^[18] Any rehabilitation protocol's primary goal is to avoid adhesions and achieve healing with the least amount of gapping. The conventional postoperative technique was static mobilization; however, there have been reports of problems such as tendon rupture, adhesions, extension lag, loss of flexion, and diminished grip strength. There are two types of early mobilization rehabilitation programs: early controlled mobilization using a dynamic splint and early active mobilization. It has been discovered that using a dynamic extensor splint for early controlled mobility reduces adhesions and the ensuing contractures. In the postoperative phase, the patient must be extremely cooperative, and the hand therapist must keep a close eye on them. ^[19]

In this study the relative motion extension (RME) program was applied as mentioned earlier in patients and methods but it was difficult to be performed in group B patients due to the attachment of the hand to the groin region. In this study, functional outcome was assessed by using the quick DASH questionnaire. High scores indicated higher level of disability and severity. The majority of the patients had a positive functional result and returned to their normal activities and jobs. Comparison of the functional outcome with other studies was difficult because most of the studies concentrated on the durability of the coverage option as a main 1st outcome without assessment of the functional outcome and disability level.

5. LIMITATIONS

Limitations of this study are that it is a retrospective study, the frequent need of 2nd procedures in most of patients, the long

rehabilitation duration, noncompliance of some patients especially in postoperative physiotherapy sessions. As well as refusal of the patients to perform an option that will need long operative time and sacrifice of a donor site (especially fascial flaps and tendon grafts) which had a negative impact on the functional and the aesthetic outcome of the wound as well as the donor site. The use of the quick DASH score only without using the universal goniometer to assess the functional ROM and the integrity of the small joints of the hand is one of the limitations of this study to assess properly the functional outcome.

6. CONCLUSION

Multiple options are available for soft tissue reconstruction of the hand dorsum. Although distant pedicled flap (groin) option shows higher incidence of complications and the need for 2ry procedures but it has comparable results to regional pedicled flap option. The knowledge of different tendon repair techniques is important to allow the surgeons to choose the most appropriate technique according to the zone of injury together with the aggressive physiotherapy programs can improve the functional outcome.

No funding.

No conflict of interest.

REFERENCES

- [1] Page R, Chang J. Reconstruction of hand soft-tissue defects: alternatives to the radial forearm fasciocutaneous flap. *The Journal of Hand Surgery*. 2006; 31(5):847-56.
- [2] Adani R. Dorsal hand coverage. *BMC Proceedings*. 2015; 9(3): A59.
- [3] Carty MJ, Taghinia A, Upton J. Fascial flap reconstruction of the hand: a single surgeon's 30-year experience. *Plastic and Reconstructive Surgery*. 2010; 125(3):953-62.
- [4] Friedrich JB, Pederson WC, Bishop AT, Galaviz P, Chang J. New workhorse flaps in hand reconstruction. *Hand*. 2012; 7(1):45-54.
- [5] Gottlieb LJ, Krieger LM. From the reconstructive ladder to the reconstructive elevator. *Plastic and Reconstructive Surgery*. 1994; 93(7):1503.
- [6] Scheker LR, Ahmed O. Radical debridement, free flap coverage, and immediate reconstruction of the upper extremity. *Hand Clinics*. 2007; 23(1):23-36.
- [7] Naalla R, Chauhan S, Dave A, Singhal M. Reconstruction of post-traumatic upper extremity soft tissue defects with pedicled flaps: An algorithmic approach to clinical decision making. *Chin J Traumatol.*, 2018; 21: 338–351.
- [8] Sabapathy SR, Venkatramani H, Martin Playa P. The use of pedicled abdominal flaps for coverage of acute bilateral circumferential degloving injuries of the hand. *Trauma Case Rep.*, 2015; 29: 25–31.
- [9] Bajantri B, Latheef L, Sabapathy SR. Tips to orient pedicled groin flap for hand defects. *Tech Hand Up Extrem Surg.*, 2013; 17: 68–71.
- [10] Whitehouse H. Comparison of thigh-based versus groin-based versus lateral- -thoracic-based flaps for hand resurfacing: a review article. *World J Plast Surg.*, 2021; 10: 3–8.
- [11] Jokuszies A, Niederbichler AD, Hirsch N et al. The pedicled groin flap for defect closure of the hand *Oper Orthop Traumatol.*, 2010; 22: 440–451.
- [12] Yang G, Chen B, Gao Y. Forearm free skin flap transplantation. *Natl Med J China*. 1981; 61: 139–142.
- [13] Lu KH, Zhong DC, Chen B, Luo JW. The clinical application of the reversed forearm island flap. *Chin J Surg*. 1982; 20:695– 697.
- [14] Gu YP, Zhu SM. A new technique for repair of acute or chronic extensor tendon injuries in zone 1. *The Journal of Bone & Joint Surgery British*. 2012; 94(5):668-70.
- [15] Rockwell BW, Butler PN, Byrne BA. Extensor tendon: anatomy, injury, and reconstruction. *Plastic and Reconstructive Surgery*. 2000; 106(7):1604.
- [16] Crook T, Tawfik J, Bertollo N, Wheen DJ, Scougall PJ, Walsh WR. Biomechanical assessment of a novel tendon junction. *Journal of Hand Surgery*. 2013; 38(7):795-800.
- [17] Brown SH, Hentzen ER, Kwan A, Ward SR, Fridén J, Lieber RL. Mechanical strength of the side-to-side versus Pulvertaft weave tendon repair. *The Journal of Hand Surgery*. 2010; 35(4):540-45.
- [18] Sameem M, Wood T, Ignacy T, Thoma A, Strumas N. A systematic review of rehabilitation protocols after surgical repair of the extensor tendons in Zones V–VIII of the hand. *Journal of Hand Therapy*. 2011; 24(4):365-73.
- [19] Brünner S, Wittemann M, Jester A, Blumenthal K, Germann G. Dynamic splinting after extensor tendon repair in zones V to VII. *Journal of Hand Surgery*. 2003; 28(3):224-27.

..