

Comparison between Three Flaps for Reconstruction of Posttraumatic Soft Tissue Hand Defects

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ABSTRACT

Introduction: Mutilating injuries of the hand that occur due to different types of trauma could produce soft tissue defects with, or without bone, tendons, and joint injuries. It is a challenge to reconstructive plastic surgeon.

Patients and Methods: Forty nine patients presented by hand soft tissue defects. The Patients were divided according to the procedure done into three groups: Posterior interosseous artery (PIA) flap (Group I), reversed radial forearm (RRF) flap (group II) and abdominal flap (group III).

Results: Post-operative DASH score and follow up period in abdominal flap operated group were significantly higher than that operated by PIA flap "group I" and "group II". Cosmetic evaluation of patients in group I was significantly higher than that of RRF flap, and abdominal flap. There was a postoperative significant improvement of the angle of first web space in comparison to preoperative angle in six cases operated for contracture of the first web space. The postoperative complications in PIA flap operated group were 21.05%, and 27.78% in RRF flap operated group. In abdominal flap operated group 78.95% of cases showed complications.

In Conclusion: Reconstructive plastic surgeon should have the capability and plasticity in dealing with soft tissue defects of the hands, with best recruitment of the available local forearm flaps, and distant flaps. Each patient should be individually studied and well counseled before the choice of the proper reconstructive method.

Key Words: Soft tissue – Defect – Reconstruction – Flaps – Hand.

INTRODUCTION

Moderate to severe soft tissue defects of the hand represent one of common events in daily scenario. These defects can expose important structures like bone, tendons, vessels, nerve, or even open joints [1]. Machinery injuries and road traffic injuries are the commonest causes [2]. These defects need a flap to prevent vital structures deterioration, to aid in faster healing, and to keep hand function [3,4].

The methods of reconstruction should be versatile, applicable, reliable, associated with minimal donor site morbidity, with better recruitment of blood supply available. Surgeon's experience and preference are determinant of the choice of the reconstruction technique, with two eyes, one interested on functional restoration, and another looking for aesthetic appearance of the recipient and donor areas [5].

Three principle territory of arterial blood supply from the forearm to the hand are apparent, supplying different regions and tissues in the forearm. So the forearm is a rich site for fasciocutaneous perforator flaps [6,7].

Classically speaking, the arterial flow through the reversed radial forearm flap is dependent on the distal backflow from ulnar artery. The drainage of venous blood passes through venae comitantes associating with the radial artery [8].

Reversed radial forearm flap (RRF flap), dependent on the reversed flow, reversed posterior interosseous artery (PIA) flap, and abdominal flap are options for reconstruction of different hand defects [9,10].

Initially, the reconstruction of the defects of the hands by abdominal flap was a valuable method of reconstruction, because of the simplicity, easiness, versatility, and no needs for a lot of expertise [11,12].

The aim of this study is to evaluate the functional and aesthetic results of three models of flap reconstruction of the different soft tissue defects of the hands, including reversed flow radial forearm flap, posterior interosseous artery based forearm flap, and abdominal flap.

PATIENTS AND METHODS

Patients:

In the period from January 2012 to May 2016, Forty nine patients presented by hand soft tissue defects caused by occupational injuries (industrial) in 24 cases, 10 road traffic accident patients, 5 Post burn, 4 post explosion, 3 domestic injuries, 2 post old trauma scarring, and post electric burn in one case.

Patients were divided according to the procedure done into three groups:

PIA flap group (Group I): 19 patients (16 males and 3 females), their age ranged from 10 to 42 years (29.89 ± 8.66), showed defect size ranged from 4x7cm to 12x9cm; right hand was affected in 8 of them, and 11 on left hand. The soft tissue defects were in dorsum of the hand (12 cases), palmer aspect of the wrist (2 cases) thumb (one case), dorsum of the hand with the thenar eminence (one case), palmer aspect of the thumb (one case) and 1st web space (one case).

RRF flap (Group II): 12 patients (10 males and 2 females), their age ranged from 8 to 56 years (28.08 ± 10.97), presented by defect size ranged from 3x8cm to 14x20cm; 7 of them on right hand and 5 on left hand. The soft tissue defects were in: the 1st web space (3 cases), dorsum of the hand (2 cases), palm (3 cases), Palm with 1st web (one case), palmer aspect with lateral side of the hand (one case), Palmer and base of the thumb (one case) and Palmer with dorsum of the hand (one case).

Abdominal flap (Group III): 18 patients (17 males and 1 female), their age ranged from 12 to 40 years (25.83 ± 9.84), presented by defect size ranged from 4x12cm to 16x10cm; 14 of them on right hand and 4 on left hand. The soft tissue defects were in: Dorsum of the hand (9 cases), palmer aspect of the hand (4 cases), the 1st web space (1 case), exposed metacarpals (one case), Exposed metacarpal after amputation (2 case), and Part of palmer and dorsal hand at the ulnar side (one case).

Methods:

This retrospective study design was approved by ethical committee of institutional review board (IRB) of Faculty of Medicine, Zagazig University. Written consents containing the details of operative and postoperative interventions with permission for pre and post-operative photography were taken from all patients included in this study.

Operative procedures:

I- PIA flap:

At the start of drawing of the flap, the upper limb of the patient was kept in elbow flexion 90°, and his wrist in neutral status. Then a straight line was drawn from tip of lateral epicondyle to the distal radio-ulnar junction. This line then divided into 3 thirds. The flap usually designed to be elevated to match the defects centered at the middle third. The hand Doppler can assist in demarcation of the course of the posterior interosseous artery, then application of a tourniquet is done to upper arm. Dealing with the soft tissue defect area by debridement and preparation is to be done meticulously. In dealing with the cases of first web space contracture, an incision to release this contracture from both dorsal side and palmer side is to deepen the web. After that, release the fascial contracture and muscle contracture to attain good web space [13].

The elevation of the flap starts by assuring of the presence of connection between anterior interosseous and posterior interosseous artery at the pivot point (about 2cm proximal to radioulnar joint). Incision of the skin proximal to this point and careful detection of PIA arcade starts, then proximal elevation of the flap is continued with respect of the septum. After identification of the first sized septocutaneous perforator of PIA, the pedicle was legated just proximal to this point. Elevation of the flap with the septum and vascular pedicle as one segment is adopted, then this flap is transposed to its final destination with incision to release bar of skin in between to avoid any kink or congestion. Closure of the donor site by split thickness skin graft is performed. Elevation and splinting of the arm for 7 days is to be ascertained. After that initial period of monitoring of the viability of the flap was done, then later regular follow up is to be done with physical therapy started on second week.

II- RRF Flap:

Clinical Allen test to assess the status of communication between ulnar and radial artery in the hand is essential step before radial forearm flap elevation. General anesthesia or regional supra-clavicular block is to be used according to the need. A pneumatic tourniquet was applied to proximal arm as previous flap. According to the defect dimension and its distance from the expected pivot point (2cm from radial styloid process), the flap was designed centered on the course of the radial artery, with enough length from the designed island to the pivot point. Skin incision was done in a lazy S fashion, and then elevation of the island of the

skin with the fascia, the pedicle for RRF flap was legated at the proximal part of forearm, with preservation of cutaneous nerves, then dissection of the flap from proximal side to distal. Another care should be exerted to avoid superficial radial nerve injury distally. The flap was transported to the defect site, then after grafting of the donor area.

III- Abdominal flap:

The general anesthesia was given to patients, then design of the flap according to the defect and position of upper limb during inseting of the flap. Optimal preparation of the recipient area was achieved, then elevation of the abdominal flap according to the plan, either through its thickness with further times of defatting, or through the plane between thin sub-dermal fat and remaining fatty layers just preserving subdermal vascular plexus. After being sure of the comfortable position of the upper limb, inseting of the flap was done by using Polyglyconic acid 3/0 or 2/0, and 4/0 according to the status. The position of the flap was kept by elastoplast bandage. The flap was separated at 3rd week.

All the patients of the three groups were scheduled for follow up and physical therapy according to the situations of the patients, and associated lesions. Assessment of the results was done by assessing the quick DASH questionnaire, then evaluating the cosmetic results according to thickness of the flap, matching of the color, and donor site status. From 10 degrees scale each parameter of the previous three was evaluated separately, then the mean of the three scores was the final step [14].

Statistical analysis:

Data were analyzed by Statistical Package of Social Science (SPSS), software version 22.0 (SPSS Inc., 2013). Continuous data were expressed as Mean \pm SD, while the nominal data were presented by the frequency and percentage. The one-way analysis of variance (ANOVA) is used to determine whether there are any significant differences between the means of three groups (PIA flap, RRF flap and abdominal flap). Least significance difference (LSD): It is one of the post hoc tests. It is used for multiple comparisons between every two groups. It was calculated at different probability values. p -value <0.05 considered significant.

RESULTS

Regarding the mean value of patient's age (years) among the three operated groups, no significant difference could be detected ($p>0.05$). The flaps size in group III (abdominal flap) ($128.94\pm$

50.98 Cm^2) were significantly larger than that of the other groups; PIA flap "group I" (70.21 ± 18.3 , $p<0.001$) and RRF flap "group II" ($91.0\pm 57.04\text{ Cm}^2$, $p<0.05$), however, no significant difference could be detected between group I and group II regarding flap size ($p>0.05$). The mean value of Post-operative DASH score in abdominal flap operated group "group III" (38.39 ± 12.45) was significantly higher than that operated by PIA flap "group I" (18.17 ± 9.90 , $p<0.001$) and RRF flap "group II" (24.08 ± 12.59 , $p<0.01$), however, no significant difference could be detected between group I and group II ($p>0.05$) as regard post-operative DASH score. Concerning the cosmetic evaluation, While the mean value of group I (PIA flap) was significantly higher than that of RRF flap "group II" (6.42 ± 0.90 , $p<0.001$) and abdominal flap "group III" (5.99 ± 1.01 , $p<0.001$), there was a non-significant difference could be detected between the PIA and RRF flaps ($p>0.05$). The mean value of follow-up period was significantly longer in abdominal flap operated group (18.72 ± 11.12 months) when compared to that of PIA flap (9.68 ± 4.00 , $p<0.001$) and RRF flap operated group (8.25 ± 2.42 , $p<0.001$), in addition the follow-up period showed non-significant deference between PIA flap and RRF flap operated groups ($p>0.05$) (Table 1).

Regarding the six cases of first web space defect (one operated by PIA, four operated with RRF flap and one operated by abdominal flap), there was a postoperative significant improvement of the angle of first web space (51.67 ± 9.31) in comparison to preoperative angle (7.5 ± 2.74 , $p<0.001$).

Concerning the donor sites closure, while the all cases of PIA flap (100%) closed by Split thickness skin graft, 10 cases of RRF flap (83.33%) closed by split thickness skin graft and the other 2 cases closed directly as the size of flaps were smaller. Furthermore, most of the cases of abdominal flaps (16 cases, 88.89%) the donor sites were closed directly and only 2 cases (11.11%) needed split thickness skin graft.

Regarding the postoperative complications, in PIA flap operated group 21.05% of cases showed complications (4 patients) there was a marginal flap loss in 2 cases, a scar at donor site in one case and a bulky flap in one case. In RRF flap operated group, 27.78% of cases showed complications (5 patients) two of them had Partial flap loss, two got bulky flap and one had a keloid scar. In abdominal flap operated group 78.95% of cases showed complications (15 patients), there was a bulky flap in eight cases, donor wound dehiscence in four cases and Partial flap loss in three cases.

Table (1): Statistical analysis of age (years), flap size (Cm²), postoperative DASH score, cosmetic evaluation score and follow-up period (month) between the three operated groups (PIA flap, RRF flap and abdominal flap).

Parameters	Statistical	PIA flap (group I)	RRF flap (group II)	Abdominal flap (group III)
Age (year)	Mean ± SD	29.89±8.66	28.08±10.97	25.83±9.84
	p-value		0.615 ^a	0.209 ^a , 0.537 ^b
Flap size (cm ²)	Mean ± SD	70.21±18.30	91.0±57.04	128.94±50.98
	p-value		0.199	<0.001 ^a , 0.023 ^b
DASH score	Mean ± SD	18.17±9.90	24.08±12.59	38.39±12.45
	p-value		0.17 ^a	<0.001 ^a , 0.002 ^b
Cosmetic evaluation	Mean ± SD	8.11±0.96	6.42±0.90	5.99±1.01
	p-value		< 0.001 ^a	<0.001 ^a , 0.24 ^b
Follow-up	Mean ± SD	9.68±4.00	8.25±2.42	18.72±11.12
	p-value		0.59	<0.001 ^a , <0.001 ^b

a = Versus group I.

b = Versus group II.



Fig. (1): Preoperative soft tissue defects at dorsum of the left hand.



Fig. (3): Post-operative results after PIA flap for soft tissue defects in dorsum of hand.

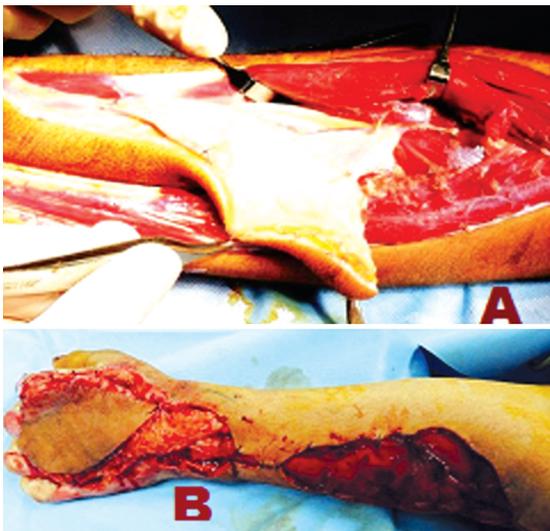


Fig. (2): Intraoperative dissections of the PIA flap to be sure of distal anastomosis (A), inseting of the PIA flap (B).



Fig. (4): Preoperative first web space contracture volar surface and dorsal view.



Fig. (5): Intraoperative dissection and flap elevation of RRF flap (A), inseting of RRF flap dorsal view (B).



Fig. (6): Inseting of RRF flap volar view.



Fig. (7): Preoperative severe contracture post burn volar view.



Fig. (8): Intra-operative severe contracture post burn after excision of the contracted skin.



Fig. (9): Postoperative abdominal flap not separated yet.



Fig. (10): Postoperative abdominal flap after separation.

DISCUSSION

A considerable trauma to the hand can produce mutilating soft tissue defects, which may be associated with bone, tendons, and joints injuries [15]. These conditions represent challenges to reconstructive plastic surgeon. Several surgical techniques used to resurface skin defects of the hand [6].

The available reconstructive methods for soft tissue coverage of the hand are many, ranging from local, retrograde forearm flaps, distant flaps, and free flaps. The choice is usually dependent on local surrounding tissues and wound status, and general health of the patients [16].

As regard the merits of using free tissue transfer in soft tissue reconstruction of the hand are the freedom of size, site, and free flap inseting. In other way, free flaps have disadvantages like the need of a lot of resources needed, and necessity of experienced micro-surgeon [17]. In between local hand flaps, and free flaps, two groups are present. These two groups are reversed forearm flaps, and distant abdominal flap [18].

The flaps based on the reverse flow of blood in vascular arcades to supply forearm skin to be used in the reconstruction technique, represent a cosmetic, color and texture matched flaps with pliable thin skin, with early limb elevation, single stage reconstruction. Others advantages include, early feasibility of hand mobilization, and restricting the surgical trauma to ipsilateral limb [19]. This type of flaps includes, reversed radial forearm flap (RRFF), and posterior interosseous artery flap (PI-AF) [20,21].

RRF flap has a stable, effective, mostly hairless, potent blood flow, reliable, with no need of micro-surgery; and a safe single stage reconstruction of soft tissue hand defects [22,23].

The similarity of the RRF flap as regard quality of skin to that of the hand especially the dorsum is an important factor in selecting this flap. Another factor is the versatility of this flap, as its highly reliable than a lot of distant flap and [15]. The dimension of the RRF flaps used in the present research ranged from 3x8cm to 14x20cm; The mean value of Post-operative DASH score in RRF flap "group II" was favorable, (24.08±12.59). The cosmetic score of the RRF flap was significantly better than that of abdominal flap, but less than that of PIA flap.

The cosmetic problem of the donor area and the sacrificing of the radial artery are two major

disadvantages of the RRF flap reported by Ahn et al. [22] and Zhou et al. [24].

In many times, no harm occurred after this sacrifice of the radial artery; in other instances some cold intolerance may be happened. So in many schools, preserving both ulnar and radial artery is the role [25-27].

PIA flap was presented by Zancolli and Angrigiani in 1988. This flap based on the anastomosis between anterior interosseous artery and posterior interosseous artery. A lot of surgeons depend on this flap to avoid sacrificing one of main arteries of hand [29].

Another merit makes the PIA flap popular is perfect matching to the defects in dorsum of the hand and wrist, palmer aspects of the hand and wrist, and distal up to metacarpal in certain situations [30].

According to opinion of some authors, and after the widespread of PIA flap, the make use of RRF flap, free flaps, and abdominal flap were decreased [31].

The recommendation of using preoperative Duplex to be sure of anastomosis between anterior and posterior interosseous arteries is highly advised by some surgeons. This idea is not recommended by Costa in his work [32].

The dimensions of the PIA flap in literature are variable, certain studies declared a flap with 16x10cm, others presented a smaller dimensions (between 8x5cm, and 3x3cm). Buchler and Frey [33] made a use of flaps from (9x11cm, to 3x3cm). Dap et al. [34] presented in their study a biggest flap was 15x9cm. Costa's cases varied from 4x5cm to maximum 14x9cm [32,35]. Lu et al. [36] had flaps up to 16x10cm. In Balakrishnan's series the biggest PIA flaps were 21x10cm [37]. Another idea, that the dimension of the flap may be the whole skin on back of forearm [38]. In the present work, the flap dimension ranged from 4x7cm to 12x9cm. The cosmetic appearance of PIA flap was significantly higher than that of both RRF flap and abdominal flap; no significant difference could be detected between the PIA and RRF flaps regarding cosmetic evaluation. So PIA flap was represented as a thin esthetic flap [39].

The drawbacks of the PIA flap are the variations in distal anastomosis between the two interosseous arteries, limited flap sizes, and restricted limit of reach of flap. Angrigiani presented one of 80 cases

with no anastomosis distal [25], Büchler and Frey in two of 36 cases [33] and Panteado et al., in four of 70 cadaver specimens [40]. Lu et al. [36] described a case of flap failure from 90 cases, due to absence of distal anastomosis. I did not encounter this problem in this study, may be due to the fewer number of cases (19).

Two complications may occur from this flap radial nerve motor branches palsy, and possibility of venous congestion. In certain literatures, a 34% congestion and edema of the PIA flap may happen [9, 31,37]. Chen et al., [41] suggested to do distal venous anastomosis with intraoperative congestion Tahseen et al., had a reverse idea, as they did not encounter this problem in their cases [9]. As regard the postoperative complications in this series of patients were 21.05% in PIA flap operated group, in RRF flap operated group complications were 27.78% of cases. But in abdominal flap operated group 78.95% of cases showed complications (15 patients), so the PIA flap was the least in complications in comparison with other 2 groups.

Three sites in the anatomy of PIA flap can produce problems in flap elevation. The first one is the possibility of absence of distal anastomosis between anterior and posterior interosseous arteries [43]. The second is the middle part of posterior interosseous artery, which may be absent or very narrow. Some authors consider this part as a choke anastomosis between proximal one third and distal one third [25,33]. The third point is the origin of first septocutaneous perforator from the PIA [25].

The presence of an adequate first web space is essential for normal hand function of pinch, and grip [44,45].

First space contracture may occur after burn contracture or post trauma. This problem is very devastating [46]. Deepening and widening of the web space between thumb and index to restore thumb and hand function is essential. After these surgeries, soft tissue defects on the palmer and dorsal aspects and first web itself, resulting in a long and narrow tissue defect [46,47]. The three types of flap surgery, RRF, abdominal, and PIA flaps can be used to resurface this first space after contracture release [48,49]. In this study, six of cases presented with a first web space defect, after release of this contracture, there was a significant improvement of the angle of first web space.

One of the reconstructive methods of soft tissue defects in the hand and first web space is the random pattern abdominal flap that was very popular for long time. The drawbacks of this flap are

two stage procedure, bulkiness and thickness of the flap necessitating defatting, and long period of immobilization during inseting of the flap [50].

The classic raising of the abdominal flap is through tissue planes to take most of the subcutaneous superficial fascia with the skin and subdermal plexus. With thin patient the resulting flap will be thin, but the problem with obese patients. In obese cases surgeon faces the challenge of taking a thick bulky flap or to raise the flap thin in the plane just preserving skin, subdermal plexus, and little fat under this plexus [51,52].

In conclusion:

In the deal with soft tissue defects of the hands, plastic reconstructive surgeon should have the ability to use all available flaps, with best understanding of the merits and drawbacks. Each patient should be individually studied and well counseled before the proper reconstructive method is chosen.

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