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Versatility of the Radial Forearm Free Flap in Facial Reconstruction

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ABSTRACT

Introduction: The Radial forearm free flap (RFF) was considered to be the workhorse flap for facial reconstruction for many years. In this study the authors are going to present their experience in using RFF flaps for facial reconstruction.

Patients and Methods: The RFF flaps were used to reconstruct 18 patients with upper, middle, and lower facial defects. Nine patients with traumatic defects, while tumor ablation was the etiology in 8 patients. In only one patient, the facial defect was due to chronic inflammatory condition. The RFF flaps were used to provide coverage, lining or both. It can also provide facial contouring according to the defect requirements.

Results: The percentage of flap survival in this study was 88.88%, with accepted aesthetic and functional outcomes.

Conclusion: The RFF flap is a versatile flap in reconstruction of different types of facial defects in different facial subunits.

Key Words: *Radial forearm flap – Facial reconstruction – Free flaps.*

INTRODUCTION

In 1978, Yang Guofan and Gae Yuzhi were the 1st surgical team to harvest the Radial forearm free flap (RFF flap) in Shenyang Military Hospital. In 1981 Yang and his colleagues published their successful study of 60 patients having RFF flap for variable indications; including head and neck reconstruction **[1]**.

The radial artery runs in the forearm from proximal to distal between the pronator teres and the brachioradialis muscles. Then it runs between the flexor carpi radialis and the brachioradialis muscles. The radial artery becomes subcutaneous over the distal part of the radius. The forearm volar skin is supplied by multiple septocutaneous perforators arising from the radial artery and passing deeply through the septum between the brachioradialis and the flexor carpi radialis. The radial artery supplies also the surrounding bone, muscles, fascia, tendons, and nerves through segmental perforators system. This makes the radial forearm flap very versatile in composition and true segmentation is feasible **[2]**.

The RFF flap is used to restore form and function in the facial region; giving superior results when compared to other flaps. Our study highlights the versatility of RFF flap in facial reconstruction and demonstrates its advantages over other flaps.

PATIENTS AND METHODS

In a retrospective study, from June 2011 to May 2015, 18 patients had RFF flaps for reconstruction of different facial defects. The patients were 14 males and 4 females; their age ranged from 14 to 65 years old (mean age = 37.2). The facial defects were classified according to the location into upper, middle, and lower facial defects. Five cases were in the upper facial subunit, four were in the middle facial subunit, two cases included both middle and lower facial subunits, and seven cases were in the lower facial subunit (Table 1).

According to the etiology, nine patients had traumatic facial defects, six of them were due to gunshot injuries, and the other three were due to motor car accidents. Eight patients required facial reconstruction with RFF flaps following tumor excision; three cases of them were recurrent BCC, two cases were SCC; one case was Retinoblastoma with history of irradiation, one case was minor salivary gland tumor and the last case was cheek dermato-fibrosarcoma. Chronic inflammatory condition was the etiology in one patient (Table 1).

All patients were assessed preoperatively with the Allen test and color Doppler ultrasonography to investigate the collateral circulation. All flaps were harvested from the non-dominant hand, seventeen flaps were harvested from the left hand, one flap from the right hand. The flaps dimensions ranged from 8 to 16cm in length and 5 to 14 in

width. The RFF flaps were used for coverage of surface defects in 8 patients, and for coverage and lining in through and through facial defects in 8 patients. In two patient, the RFF flap was used for simultaneous coverage and contouring of the facial defects (Table 1).

Table (1): The descriptive data of the patients.

No.	Facial subunit	Age	Sex	Etiology	Risk factors	Dominant hand	Flap dimensions	Indications
1	Upper 1/3 (orbit)	14	Male	Retinoblastoma exenteration + radiation	–	Left	Right forearm 8 X 6	Coverage + contour
2	Upper 1/3 (fronto-temporal area)	29	Male	Motor car accident	Smoker	Right	Left forearm 12 X 8 + Racquet shaped modification	Coverage
3	Upper 1/3 (orbit)	25	Male	Motor car accident	Smoker	Right	Left forearm 14 X 6	Coverage + lining
4	Upper 1/3	65	Female	Recurrent BBC of temporal area	Diabetic	Right	Left forearm 16 X 14	Coverage
5	Upper 1/3	48	Male	Recurrent BBC of forehead	Hypertensive	Right	Left forearm 10X7 + Racquet shaped modification	Coverage
6	Middle 1/3	26	Male	Gun shot	Smoker	Right	Left forearm 10 X 5	Coverage
7	Middle 1/3	33	Female	Minor salivary gland tumor of cheek	–	Right	Left forearm 16 X 6	Coverage + lining
8	Middle 1/3	50	Female	Recurrent BBC of upper lip and nose	–	Right	Left forearm 15 X 12	Coverage + lining
9	Middle 1/3	28	Male	Dermatofibrosarcoma of the cheek	–	Right	Left forearm 10 X 5	Coverage
10	Middle and lower 2/3 thirds	24	Female	SCC of the cheek	–	Right	Left forearm 16 X 10	Coverage + lining
11	Middle and Lower 2/3 thirds	39	Male	Gun shot	Smoker	Right	Left forearm 15 X 9	Coverage
12	Lower 1/3	42	Male	Motor car accident	–	Right	Left forearm 15 X 9	Coverage + lining
13	Lower 1/3	46	Male	Gun shot	Smoker	Right	Left forearm 14 X 7	Coverage + lining
14	Lower 1/3	34	Male	Gun shot	–	Right	Left forearm 12 X 7	Coverage
15	Lower 1/3	44	Male	Gun shot	Hypertensive and smoker	Right	Left forearm 15 X 8	Coverage + lining
16	Lower 1/3	25	Male	Gun shot	Smoker	Right	Left forearm 12 X 7	Coverage
17	Lower 1/3	54	Male	SCC of the lower lip	Smoker	Right	Left forearm 14 X 7	Coverage + lining
18	Lower 1/3	45	Male	Chronic specific infection of the facial skeleton	Smoker	Right	Left forearm 16 X 8	Coverage + contour

BCC: Basal cell carcinoma. SCC: Squamous cell carcinoma.

The operative technique:

Under general anesthesia, the patients were positioned in supine decubitus with the neck extended and turned opposite to the side selected for the anastomosis. In recent traumatic defects the operation started with thorough irrigation and debridement of the wounds. Gunshot injuries needed one or two sessions of debridement before definitive reconstruction. Underlying skeletal fixation and/or reconstruction was done if it is required. In patients with tumors, excision with adequate safety margins was done. The regional lymph nodes were managed according to the oncologic nature and the stage of the tumor. For the patient with the chronic inflammatory condition, debridement and wide local excision were done to insure adequate drainage and eradication of any septic loculi. In patients having contour deficiency, contracture release and skin undermining were done to allow the inset of the RFF flaps' extensions used for contouring.

1- *The recipient site (the facial defect and the donor vessels):*

For the donor artery, preoperative Doppler neck examination was carried to evaluate the flow in the neck arteries; especially in cases of previous neck dissections or irradiation. The choice of the donor neck vessels depends on the location of the defect. In the beginning of this study, the superficial

temporal artery was used as a donor vessel for upper third facial defects. Later on, due to the difficulties encountered in the anastomosis of the superficial temporal vein, we resorted to the branches of the external carotid vessels in the neck (superior thyroid, lingual, and facial arteries) for all patients. Intra-operatively, the flow in the selected neck donor artery is tested. A satisfactory flow is mandatory to proceed for free flap transfer.

For preparation of neck recipient veins, two veins or more are usually exposed and prepared. The first one is the external jugular vein (EJV) which has a good size match with the cephalic vein harvested with the RFF flaps. The most cephalic end of the EJV was transposed to the anastomosis field (Fig. 1). Also, the common facial vein (CFV) or any other neck veins available in the surgical field could be used. Venous anastomosis with the internal jugular vein was used in two cases; as previous surgical exposures depleted other superficial sizable neck veins. After considering the estimated distance between the defect and the donor vessels, the flap final design was confirmed.

Fig. (1): The External Jugular vein (EJV) is dissected on the right side of the neck.

2- *The donor site:*

The selected arm was positioned on separate side table. The flaps were elevated under the pneumatic tourniquet inflated 100mmHg above the systolic blood pressure, for a maximum of 90 minutes. Flap harvesting started from distal to proximal with preservation of paratenon and superficial radial nerve in most of patients. If a long vascular pedicle is required for reconstruction of upper facial subunits, a Racquet shaped proximal extension of the flap was designed. This skin bridge provided coverage of the pedicle between the upper 1/3 facial defects and the neck vessels (Fig. 2). If the flap will be used for contour reconstruction, an extra cuff of forearm skin was de-epithelialized and raised with the flap.

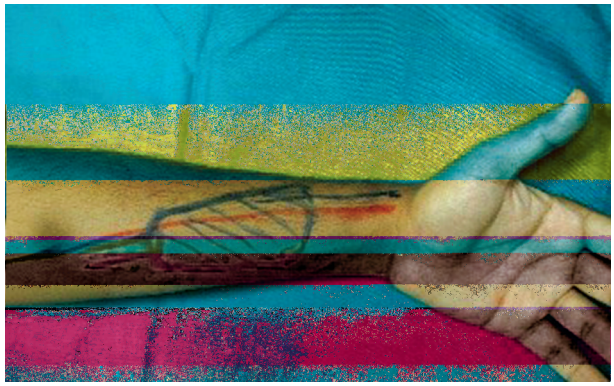

Fig. (2): The Racquet shaped modification of the RFF flap provides skin bridge to cover the pedicle between the upper 1/3 facial defects and the neck vessels.

Proximal identification of the vascular pedicle was done to provide long pedicles needed for facial reconstruction. The radial artery exploration was done till the terminal bifurcation of the brachial artery. The cephalic vein and the venae comitantes of the radial artery were included in the flap; representing the superficial and deep venous drainage of the forearm flap consequently.

After complete flap dissection, the distal part of the radial artery was clamped. The tourniquet was released, both the hand and the flap vascularity were checked. Then the radial artery and the draining veins were only divided if both the hand and the flap showed intact vascularity. Adequate distal and proximal stumps of the radial artery were left to facilitate inter-positional vein graft insertion; if the hand showed any signs of ischemia following division of the radial artery. The forearm donor area is covered with thick split thickness skin graft, with application of dorsal slab.

3- *Flap positioning:*

Preliminary flap suturing to the defect was done to achieve flap orientation and adequate fixation needed for micro vascular anastomosis. Arterial anastomosis was done between the radial artery and the selected neck artery with minimization of warm ischemia time as much as possible. After adequate vascularization of the flap is obtained, venous anastomosis was done. In all patients 2 venous anastomoses were done. The first one between the cephalic vein and the EJV which was dissected and transposed into the field. The second venous anastomosis was done between the larger of the two venae comitantes of the radial artery and one of the neck veins. The flap was then sutured to the defect with few sutures without any tension with insertion of two soft rubber drains. One drain

was inserted under the flap and the other one was inserted at the anastomosis site.

4- *Post-operative care:*

The patients were kept in semi-sitting position with the neck in neutral position. The flap was monitored clinically every hour along the first 24 hours. All patients were given antibiotics, analgesics and anti-stress medications. The patients were kept well hydrated and all measures were taken to avoid hypothermia. Anti-platelets and vasodilators were given routinely. The anti-coagulants were only given for patients with high risk to develop DVT, or if vein graft was used during surgery.

For patients with reconstructed intra oral defects, nasal Ryle tube was inserted to insure adequate enteral feeding and clear fluid oral intake was allowed 48 hours postoperative. Ryle tubes were removed and oral soft diet intake was allowed ten days postoperative, then the patients were discharged. Follow-up period range from 5 months to 2.5 years (mean ≈ 18 months).

RESULTS

No acute ischemia of the hand was seen in our patients following elevation of the RFF flap. In only one patient, ligation of a very short radial artery proximal stump caused spasm of the ulnar artery with subsequent hand ischemia. Immediate intra-operative ligature re-adjustment was efficient to regain hand vascularity.

Sixteen out of 18 flaps survived completely with success rate 88.88% (Figs. 3,4,5). Two flaps were lost; one flap was lost due delayed arterial ischemia that occurred 5 days post-operative, while the other flap was lost due to venous congestion. Venous congestion occurred in three patients for whom immediate re-exploration was done. The venous anastomosis was divided to relieve congestion, thorough irrigation of the vein with heparinized saline was done; this was followed by re-anastomosis of the vein. This could salvage two of the three congested flaps, but the third one was completely lost.

No effect on hand vascularity nor decrease in wrist range of motion were recorded in any of our patients. However, sensory loss over the anatomical snuff box was recorded in 6 patients, when a large flap was needed and its dimension exceeded the radial boarder of the forearm volar surface. Two patients suffered painful neuromas that were managed after 6 months. In one patient with orbital defect the RFF flap failed to give sufficient contour, for this patient the anterolateral thigh free flap was used to augment the contour of the periorbital region. Apart from this patient, no secondary reconstractive procedures were required for any other patients.

The aesthetic appearance of the donor sites were accepted, however young female patients showed their concerns about the aesthetic outcome. In this study none of our patients sought any cosmetic revision procedures. On the other hand, patients with tumor ablation surgery did not remark donor site morbidity.

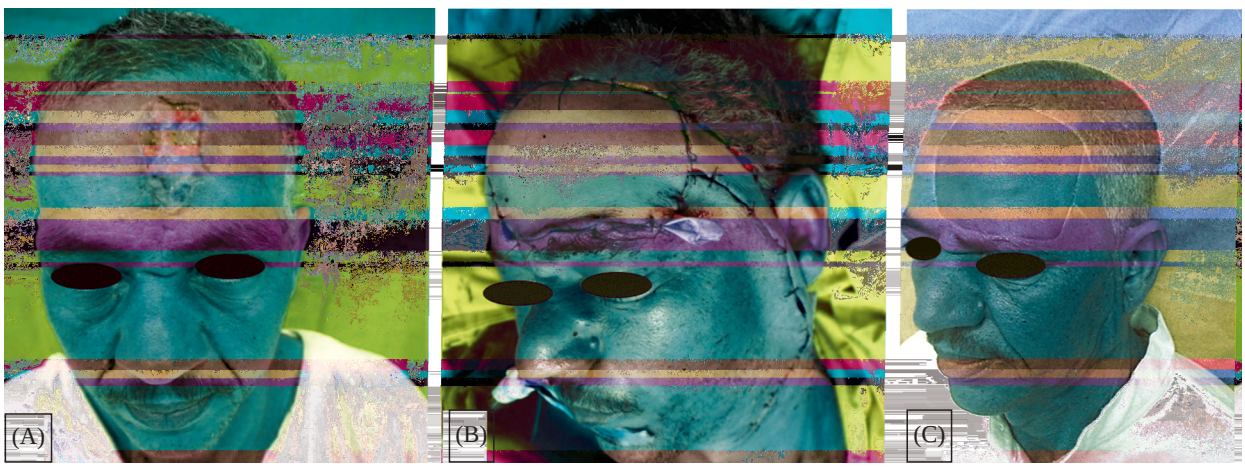

Fig. (3): (A): 48 years old male patient with recurrent BCC of the forehead. (B): Adequate excision and reconstruction with RFF flap was done, the Racquet shaped skin extension of the flap was inserted in a pre-auricular incision. (C): Fifteen months post-operative result.

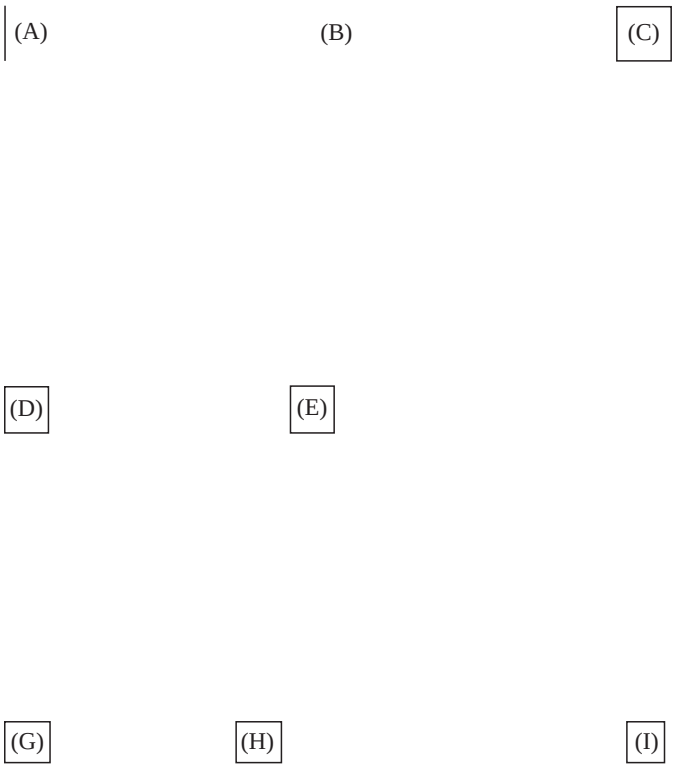

Fig. (4): 33 years old female patient with minor salivary gland tumor of the left check. (A,B and C): Left check lesion and the preoperative planning. (D,E and F): Intra-operative left check through and through defect reconstructed with RFF flap. (G,H and I): Two years post-operative follow-up result.

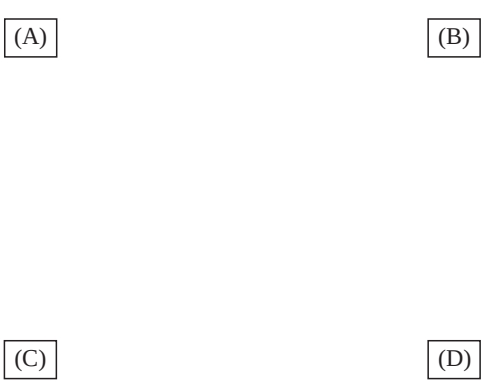

Fig. (5): Forty-four years old male patient with gunshot injury to the lower 1/3 of the face. (A): Post gunshot soft tissue defect of the lower 1/3 of face including the left check, lower lip, and intra-oral mucosal lining associated with the floor of the mouth. (B): CT 3D views showing the magnitude of mandibular comminution and loss. (C): The soft tissue defect after debridement and skeletal stabilization using reconstruction plate. (D): Immediate post-operative photo after reconstruction of the lower 1/3 face defect using RFF flap.

DISCUSSION

Reconstruction of facial defect is a challenging procedure facing plastic surgeons; as the face is aesthetically demanding and full of important anatomical structures. The reconstruction should respect the three dimensional anatomy of the face, and aim for maximum restoration of function and form **[2]**.

There are many modalities that can be used for facial reconstruction. Local flaps are widely used for small to moderate facial defects; they give excellent matching skin for reconstruction. However, using local flaps for reconstruction of sizable facial defects is not recommended; as they add more scars to the face and offers limited skin surface area; especially in young patients.

Deltopectoral fasciocutaneous flaps can be used for facial reconstruction. It offers an non bulky flap that can be used for coverage of surface defects. Nevertheless, the disadvantages of this flap are limitations of arc of rotation and the necessity to extend the reach with delay procedures. Other distant thin fasciocutaneous flaps as medial arm or groin flaps need more than one stage, and the arm is kept in a cumbersome position. This position is not accepted by most of patients **[4]**.

Various pedicled regional flaps, as the latissimus and pectoralis major musculocutaneous flaps are used for facial reconstruction. However, these flaps have many limitations as their arc of rotation, flap reach, flap size and bulkiness, unacceptable aesthetic outcome, and unreliability if used for three-dimensional reconstruction **[3]**.

Many free flaps are available for facial reconstruction. The anterolateral thigh free (ALT) flap is a valuable option in facial reconstruction. However, when it is compared with the RFF flap, the ALT has a variable vascular anatomy and it is relatively bulky if it is used for superficial defects **[2]**. Lateral arm and parascapular flaps are other options of free fasciocutaneous flaps that are commonly used for facial reconstruction. The lateral arm flap has shorter pedicle if compared with the RFF flap; and the parascapular flap needs changing the patient position during surgery that is not suitable for the two team strategy **[5]**.

Transverse Rectus Abdominis Myocutaneous (TRAM) flap is widely used musclocutaneous flap for facial reconstruction. TRAM flap gives very bulky amount of soft tissues that is suitable for obliterating large volume facial defects or for facial contouring, but it is not suitable for coverage and resurfacing indications **[6]**. The Deep inferior epigastric perforator (DIEP) flap is another version of the TRAM flap that has a longer vascular pedicle, Less bulk of tissue with less donor site morbidity. In 2009, Tan O. considered DIEP flap as the workhorse flap in head and neck reconstruction **[7]**.

The RFF flap is ideal for facial reconstruction. It has many advantages when compared with other free flaps used for head and neck reconstruction. These advantages include the following; versatility in design, adequate surface area, good color and texture match, availability of diverse tissue composition on the same pedicle, potential for re-innervation, large and long pedicle that has consistent anatomy, easy and safe flap dissection, and feasibility of a two-team approach **[2,8]**.

The most important advantage of RFF flap is its long vascular pedicle that allows the flap to reach any facial defect. For upper 1/3 facial defects, although the superficial temporal vessels can be used as recipient vessels, the superficial temporal vein may be unreliable in some cases. In such cases a long vascular pedicle is required to reach the neck vessels. In our study, the Racquet shaped modification was uses to provide skin coverage for this long vascular pedicle **[9]**.

In this study, there was high flap survival rate. No flaps suffered acute ischemia in the early post operation follow-up. This is attributed to the reliable vascularity of the RFF flap. However, one flap showed delayed ischemia 5 days postoperative. The ischemia was slowly progressive and ended up with total flap loss on 9th day postoperative. Till now, the explanation of this delayed flap failure is not clear. This delayed flap ischemia was attributed to showering of micro-emboli from the site of the anastomosis to the microcirculation or due to wound infection. Also, scarring and/or irradiation of the reconstructed defect was accused for delayed free flap ischemia. However, This phenomena may need more experimental studies using vascular evaluation tools, as vital stains, MRA, and sequential tissue biopsies **[10,11]**.

The third important advantage is that the RFF flap has deep and superficial venous systems. This allows two veins anastomoses which is associated with higher flap survival rates **[12]**. The deep system (the venae comitantes) is the primary drainage of the flap, but in large RFF flap the cephalic vein drains the forearm skin equivocally as deep system does. This can be anatomically explained as the cephalic vein communicates with deep venous system at the elbow level **[13,14]**. In our study, two

venous anastomoses were done, preferably both the superficial and deep systems were used. This allows venous drainage into two different pathways, which decrease the risk of thrombosis propagation from one vein to the other. This thrombosis propagation can frequently happen if the two venae comitantes were used routinely **[12]**.

The fourth important advantage of the RFF flap is the different tissue compositions which can be harvested with the flap. This allows us to manage complex defects and to restore function as well as form. Moreover, the segmental perforator based blood supply of the RFF flap allows true segmentation and free fashioning of the flap. So, the RFF flap can be successfully used to reconstruct surface defects and through and through defects. Also, the facial contour defects can be reconstructed simultaneously if needed **[15]**.

However, the RFF flaps have the disadvantage of sacrificing major forearm vessel that may potentially compromise the vascular supply of the hand. Although acute ischemia after classic flap harvest was reported, it is a rare event **[16,17]**. Meland reported on 13 consecutive patients without vein grafting of the radial artery that showed a delay in rewarming of the hand after 1min, but no further difference after 5min. **[18]**.

In this study, acute hand ischemia didn't occur. The hand hypo perfusion that was noticed in one of our patients after flap harvesting was due to tight ligature of the proximal radial artery stump causing tension over the ulnar artery. Normal hand perfusion was reestablished just by re-adjustment of the tight ligature. Acute hand ischemia can be avoided by performing preoperative Allen's test to ensure good collateral circulation to the hand. This was also more confirmed by intraoperative clamping of the radial artery distal to the flap before severing of the radial artery. Routinely, we keep adequate stumps of the radial artery proximally and distally to facilitate insertion of inter-positional vein graft; if this rare mishap does occur **[17]**.

Another disadvantage of the RFF is donor site morbidity. Many efforts were tried to improve the aesthetic outcome of the donor area. Some authors went to limit the donor area just to the volar forearm, others suggested to close the donor defect directly either through local flaps primarily or through secondary tissue expansion procedures **[19-22]**. Trials were also done to increase the graft take chances through supra fascial dissection or providing muscular coverage for the Flexor carpi radialis tendon **[23,24,25]**. Also, application of a full thickness skin grafts and artificial dermis were tried in an effort to enhance the aesthetic outcome of the donor site **[26,27]**. However, the appearance of the donor site remains to be a sever clinical drawback of the radial forearm flap.

Moreover, the bulk offered by the RFF flap in slim patients is not sufficient to reconstruct contour defects. Addition of forearm fascial extension was done in some of our patients to increase the flap bulkness. This can be also done to increase the bulk of tissue during tongue reconstruction **[28]**. Fat grafting can be also done to add more tissue under the transferred flap. However, resorting to other flaps as TRAM, ALT, and parascapular flaps can provide larger soft tissue volume for reconstruction than the RFF flaps can do **[2,6,28]**.

Other functional drawbacks of the RFF flap as wrist joint range of motion and sensory disturbances are objectively recorded. But, all patients subjectively showed satisfactory tolerated functional outcome **[29]**.

Conclusion:

The RFF flap is a reliable versatile fasciocutaneous flap for facial reconstruction. The RFF flaps provide large territory of good quality skin (good color match, less hair, and pliable). Constant vascular anatomy with relatively long sizable pedicle, which allows segmentation and free fashioning to suit the versatility of facial defects.

Disclosure:

There is no conflict of interest.

REFERENCES

1- Yang G.F., Chen B. and Gao Y.: Forearm free skin flap transplantation. Natl. Med. J. China., 61: 139-142, 1981.

2- Barbara S. Lutz and Fu-Chan Wei: Microsurgical Workhorse Flaps in Head and Neck Reconstruction. Clin. Plastic Surg., 32: 421-430, 2005.

3- Satoshi Yokoo, Takahide Komori, Syungo Furudoi, et al.: Three-dimensional reconstruction after oral oncologic surgery using single free radial forearm flaps or free rectus abdominis musculocutaneous flaps. J. Oral Sci., 46: 65-70, 2000.

4- R.C.L. Chan and J.Y.W. Chan: "Deltopectoral Flap in the Era of Microsurgery," Surgery Research and Practice, 34 (1): 220-205, 2014.

5- Klinkenberg M., Fischer S., Kremer T., et al.: Comparison of anterolateral thigh, lateral arm, and parascapular free flaps with regard to donor-site morbidity and aesthetic and functional outcomes. Plast. Reconstr. Surg., 131 (2): 293-302, 2013.

6- Goossen S. and Coessens B.: Facial contour restoration in Barraquer-Simons syndrome using two free TRAM

flaps: Presentation of two cases reports and long term follow-up. Microsugery, 22 (5): 211- 218, 2002.

7- Tan O.: Versatility of vertical designed deep inferior epigastric perforator flap. Microsurgery, 29 (4): 282-286, 2009.

8- Demirkan F., Chen H.C., Wei F.C., et al.: The versatile anterolateral thigh flap: a musculocutaneous flap in disguise in head and neck reconstruction. Br. J. Plast. Surg., 53: 30-36, 2000.

9- Salah Nasser, Yasser Abd Allah and Ayman Shaker: Racquet-Shaped Modification of the Island Pedicle Flaps: A Simple Design to increase its versatility and decrease the complication rate. Egypt. J. Plast. Reconstr. Surg., 35, 1 January: 31-40, 2011.

10- Salgado C.J., Smith A., Kim S., et al.: Effects of late loss of arterial inflow on free flap survival. J. Reconstr. Microsurg. Oct., 18 (7): 579-584, 2002.

11- Anavekar N.S., Lim E., Hunter-Smith D.J., et al.: Minimally invasive late free flap salvage: indications, efficacy and implications for reconstructive microsurgeons. J. Plast. Reconstr. Aesthet. Surg. Nov., 64 (11): 1517-1520, 2011.

12- Matthew M. Hanasono, Ergun Kocak, Olubunmi Ogunleye, et al.: One versus Two Venous Anastomoses in Microvascular Free Flap Surgery. Plast. Reconstr. Surg., 126 (5): 1548-1557, 2010.

13- Selber J.C., Sanders E., Lin H., et al.: Venous drainage of the radial forearm flap: Comparison of the deep and superficial systems. Ann. Plast. Surg., 66: 347-350, 2001.

14- Gottlieb L.J., Tachmes and Pielet R.W.: Improved venous drainage of the radial forearm free flap: Use of the profundus cubitalis vein. J Reconstr Microsurg., 9: 281-284, 1993.

15- Raphael Ciuman and Philipp Dost: The Forearm Flap - Indications, Appropriate Selection, Complications and Functional Outcome, Maxillofacial Surgery, Prof. Leon Assael (Ed.), ISBN: 978-953-510627-2, 2012. InTech, Available from: http://www.intechopen.com/books/maxillofacial surgery/reconstructive surgery in head and neck the forearm flap indication appropriate selection complications and functional outcome.

16- Jones B.M. and O'Brien C.J.: Acute ischemia of the hand resulting from elevation of a radial forearm flap. Br. J. Plast Surg., 38: 396-397, 1985.

17- T.W. Bruner, M.M. Hanasono and R.J. Skoracki: Radial forearm free flap morbidity: A rare case of a normal preoperative arteriogram and acute intraoperative hand ischemia. Can. J. Plast. Surg., 19 (3): 102-104, 2011.

18- Meland N.B., Core G.B. and Hoverman V.R.: The radial forearm flap donor site: Should we vein graft the artery? A comparative study. Plast. Reconstr. Surg., 91: 865-870, 1993.

19- Muhlbauer W., Herndl E. and Stock W.: The forearm flap. Plast. Reconstr. Surg., 70: 336-344, 1982.

20- Soutar D.S. and McGregor I.A.: The radial forearm flap in intraoral reconstruction: The experience of 60 consecutive cases. Plast. Reconstr. Surg., 78: 1-8, 1986.

21- Bardsley A.F., Soutar D.S., Elliot D., et al.: Reducing morbidity in the radial forearm flap donor site. Plast. Reconstr. Surg., 86: 287-292, 1990.

22- Hallock G.G.: Refinement of the radial forearm flap donor site using skin expansion. Plast. Reconstr. Surg., 81: 21-25, 1988.

23- Webster H.R. and Robinson D.W.: The radial forearm flap without fascia and other refinements. Eur. J. Plast. Surg., 18: 11-13, 1995.

24- Chang S.C., Miller, Wei F.C., et al.: Limiting donor site morbidity by suprafascial dissection of the radial forearm flap. Microsurgery, 17 (3): 136-140, 1996.

25- Fenton O.M. and Roberts J.O.: Improving the donor site of the radial forearm flap. Br. J. Plast. Surg., 38: 504-505, 1985.

26- Gaukroger M.C., Langdon J.D., Zaki G.A., et al.: Repair of the radial forearm flap donor site with a full-thickness graft. Int. J. Oral Maxillofac. Surg., 23: 205-208, 1994.

27- Lee J.W., Jang Y.C. and Oh S.J.: Use of the artificial dermis for free radial forearm flap donor site. Ann. Plast. Surg., 55: 500-502, 2005.

28- Seikaly H., Rieger J., O'Connell D., et al.: Beavertail modification of the radial forearm free flap in base of tongue reconstruction: Technique and functional outcomes. Head Neck, 31: 213-219, 2009.

29- Orlik R., Horwich P., Bartlett C., et al.: Long Term functional donor site morbidity of the free Radial forearm flap in head and neck cancer survivors. Open access, Journal of Otolaryngology - Head and Neck Surgery, 43: 1, 2014.