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RECONSTRUCTION OF COMBAT RELATED SEGMENTAL BONE DEFECTS OF THE FOREARM AND HAND WITH VASCULARISED BONE GRAFTS

Plastic Surgery

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ABSTRACT

Background: Upper limb trauma is one of the commonly noted limb injury in association with polytrauma. Skeletal defects are common in a combat setting due to high velocity projectiles and cavitation phenomenon caused. Reconstruction of these composite defects is difficult, and patients benefit from a single stage reconstructive modality

Aim: To assess the time taken for union, resuming activity and donor site morbidity in patients with segmental post-traumatic bony defects of the upper limb.

Methods: The study was a prospective observational study, conducted in an Armed Forces Referral Hospital from 2013 to 2015. 09 patients with segmental skeletal defects of forearm and hand were included in the study and were operated at this center. The average patient age was 31.6 years with the youngest being 18 years of age. All patients were referred to our center after an initial procedure at the nearest primary health care facility.

Results: All patients were operated by a single surgical team. 05 patients underwent free fibula flap, 01 patient underwent a split radius flap, 02 patients underwent 2,3 ICSRA based flap and 01 patient had a 'spare parts' surgery. Semi-rigid fixation with intramedullary nail or K wires were used and all grafts healed over an average of 10.5 months. There was significant improvement (p=0.029) in pre- and post op DASH scores in these patients.

Conclusion: Vascularised bone graft offers a single stage option for one stage reconstruction of these difficult defects. We recommend that this option should be used even in those patients who do not fit in the conventional criteria for use of vascularised bone grafts.

KEYWORDS

segmental bone defect, forearm and hand, vascularised bone grafts, bone union

Introduction:

Trauma to forearm and hand constitute 27% of all skeletal trauma cases in our center. They may be open or closed and when there is a segmental bone defect, these are difficult to reconstruct. The standard modalities of skeletal restoration that are otherwise used in the lower limbs like non-vascularised bone grafts and Illizarov distraction osteogenesis become technically difficult. The aim of restoration of bone defects in the upper limb is to provide a stable platform for adequate function of the hand. Post-traumatic segmental bone defects in forearm and hand are usually due to high energy transfer and invariably are associated with composite soft tissue loss including skin, fascia, tendons and/ or nerves. A reconstructive modality would be considered as ideal if all these missing elements could be replaced in one setting. Reconstruction of these complex defects with a single stage modality is beneficial in speeding up the time for rehabilitation. We attempted to prove the efficacy of vascularised bone grafts in restoration of function in complex defects of the upper extremity.

Aims & Objectives:

The aim of this study was to assess the time taken for union, resuming activity and donor site morbidity in patients with segmental post-traumatic bony defects of the upper limb. The secondary objective was to prove that vascularised bone grafts are a modality of choice, despite its complexities.

Materials & Methods:

The study was a prospective observational study, conducted in an Armed Forces Referral Hospital from 2013 to 2015. 09 patients with segmental skeletal defects of forearm and hand were included in the study and were operated at this center. The average patient age was 31.6 years with the youngest being 18 years of age. All patients were referred to our center after an initial procedure at the nearest primary health care facility. Initial procedures included wound debridement, skeletal stabilisation with external fixation or intramedullary nailing and thorough wound toilet. The patients were taken up for bone reconstruction on an elective setting. For patients requiring a free fibula flap, the right leg was the preferred donor site. A pre-operative assessment was done with a foot Allen's test to ensure patency of anterior and posterior tibial vessels. Hand held Doppler was used to mark the skin perforators in the territory of the peroneal artery. Flap harvest was done in the standard fashion under a pneumatic tourniquet. The entire fibula except the proximal 6 cms and the distal 5 cms was harvested along with the skin paddle where required and the maximal length of the peroneal pedicle. The bone defect in the recipient site was freshened till bleeding bone ends were noted. Appropriate recipient vessels were dissected and kept ready for anastomosis to the flap vessels. The required length of bone was trimmed on the bench and placed to achieve maximal contact with the ends of the native bone. Fixation was done using an intra-medullary titanium nail or K-wire passed from the native bone through the medullary cavity of the fibula. The peroneal pedicle was then anastomosed to the recipient vessels and skin paddle inset over drains. The limb was then immobilised in a static splint. Gradual mobilisation was started once the bone ends showed signs of union on X-ray and the range of movements progressively increased, under supervision. Pre- and post-op DASH scores were taken and documented.

Results:

We conducted a single center prospective observational study to assess the efficacy of vascularised bone grafts in segmental skeletal defects of forearm and hand, over a period of 02 years. There were 09 patients and all were males. The average age was 31.6 years with a range of 18 to 41 years. The most common mode of injury was gunshot wound to the forearm and/ or hand. Other mechanisms of injury encountered were motor vehicle accidents, machine injuries and fall from height with resultant comminuted fracture and loss of bone segment. Most of the patients in the series had co-existing full thickness skin defects along with the skeletal defect.

All of the patients in our series had undergone some preliminary procedures at another center before being referred to our center. The average numbers of preliminary procedures were 2 per patient. When a distant pedicled flap was used, debridement, flap cover and subsequent flap division and inset were taken as one procedure. Five of our patients underwent free fibula flap, 01 patient had a vascularised split radius (radial artery based), 02 patients had vascularised radial cortical grafts based on inter compartmental vessels and 01 patient had a spare parts

surgery where vascularised proximal phalanx was used from a non-functional finger to reconstruct a metacarpal of a useful finger.

All patients were operated by the same surgical team and were followed up for a mean of 16 months. External fixation and K-wires were used for fixation for all patients with no rigid fixation devices used for any of the cases. All patients were placed on a static splintage till the flap stabilised. Serial radiographs were taken and patient started on a gradual progressive range of motion physiotherapy under supervision, once bone union was noted on radiographs.

The average time for bone union was 10.5 months with a range of 17 to 4 months. The patient who had severe crush injury with vascular compromise of the entire forearm and hand took the longest time for bone union.

DASH (Disability of Arm, Shoulder, Hand) scores were used pre-and post recovery for all these patients to assess the functional impact of skeletal stability. All patients, except one, reported some improvement in their DASH scores after the procedure. The improvement in DASH scores were less in those patients who had sustained severe trauma distal to wrist, whereas those patients who had sustained proximal trauma had better improvement in their DASH scores, post-operatively. Similarly, those patients who had sustained proximal injuries (forearm level) had resumed pre-injury activity faster than those who had distal injuries. (Table 1) The p value on comparison of DASH scores of forearm, hand and scaphoid were 0.072, 0.78 and 0.27 respectively, which were not statistically significant. However, when the DASH scores were compared together pre- and post operatively, the p value was .029, which was statistically significant.

All patients, except one, had uneventful healing of their flap donor sites. One patient who had undergone a radial artery based split radius flap had delayed healing of the donor site and residual pain at the forearm for about 6 months post operatively, but that eventually resolved with supportive splintage and strength building exercises. All flaps survived and healed fully. One patient required re-exploration on post op day 2 for venous compromise and the flap could be salvaged totally after a re-do venous anastomosis. There was no flap loss in our series. All patients who had undergone free fibula flap resumed their full weight bearing ambulation within 3 weeks of the procedure.

Discussion:

Upper extremities, due to the functional requirements, are vulnerable to trauma and are involved in upto 20% of patients with poly trauma.[1] Open fractures with resultant bone defects require multistaged reconstruction and often conventional methods do not lead to acceptable results.

In addressing the problem in the hand and upper limb, the surgeon has to consider 4 important parameters, namely, (i) length of bone defect, (ii) condition of the soft tissue bed in terms of infection and vascularity, (iii) adequacy of soft tissue cover, and (iv) function in the affected limb.[2] Options for reconstruction of open segmental bone defects include debridement and open cancellous bone grafting followed by soft tissue cover (Papineau technique), debridement followed by pedicled flap for soft tissue reconstruction then by a bone grafting procedure and the third option is to debride the wound and reconstruct the soft tissue cover and bone segment using a free microvascular composite tissue transfer.[3] Composite free tissue (bone & soft tissue) transfer is the only option that offers the possibility of single stage reconstruction and shortest possible time to return to pre-morbid activity for the patient.[4] The drawbacks are, of course, complete flap loss and even possibility of limb loss if the reconstructive procedure fails.

Healing of non-vascularised bone grafts depends on vascular ingrowth (revascularisation) from the surrounding well, vascularised soft tissue envelope, 'creeping substitution' of osteocytes in the graft from the recipient bed followed by consolidation of the graft and hypertrophy as per the load requirements of the limb. The entire process is dependent on the recipient bed and protection of the graft from undue load stress during the process of consolidation. In contrast, the vascularised bone graft behaves remarkably different in its healing and incorporation with the host bone. These grafts unite at the recipient –graft junction relatively early, while maintaining its structure and cellularity due to its independent blood supply. This bypasses the stage of creeping substitution as it undergoes early consolidation and hypertrophy. The extent of hypertrophy is much greater as compared to that in non-vascularised bone grafts.[5]

In a setting of post traumatic skeletal defects, vascularised bone grafts are indicated in the following conditions:

a. When the recipient bed is not conducive for a non vascularised bone graft due to poor vascularity, scarring or infection
b. When the bone defect is large (> 6 cms)
c. When prior attempts at skeletal or soft tissue reconstruction by conventional means have failed
d. When there has been non-union at the site of injury due to severe comminution or infection.[6]

In our series, the average size of bone defects in forearm bones was 5.8 cms. This was different from indications expressed by many authors. But we used vascularised bone grafts in these skeletal defects as the surrounding soft tissue was scarred or deficient and multiple previous attempts at reconstruction had failed. The most common cause of the skeletal defect in our series was high velocity gunshot wound. This causes much more widespread soft tissue damage than other modes of injury and hence the vascularity from the local tissues cannot be relied upon to support a non-vascularised bone graft of such dimensions. Hence, the use of vascularised autologous tissue becomes imperative in such cases.

Our study differed in the method of fixation adopted to secure the bone grafts. Most authors recommend use of rigid fixation with load bearing plates and screws fixed to both the graft and native bone to secure the bone graft in place.[7] We used intra-medullary titanium nail (TENS) system or simple K wires to hold the graft in place during the period of consolidation. While rigid fixation ensures that the graft remains in place till adequate healing occurs, it also entails periosteal stripping and resultant de-vascularisation may not be very conducive for healing. We postulated that non-rigid fixation, with minimal disturbance to periosteal circulation and external splintage would result in adequate healing and union. In comparison to methods using rigid fixation, we found that the period of immobilisation is nearly double in our study. The rates of union and time required for resuming activity for patients in our study is comparable to those studies that use rigid internal fixation. A postulated advantage of non-rigid fixation is avoidance of radio-ulnar synostosis in cases of defects in radius or ulna reconstructed by free fibula flap. Many authors recommend that the graft should be protected from full load bearing for at least a year after union and we follow the same protocol.[2,8]

In our study, we found that those patients who had forearm defects had a much better improvement of DASH scores after reconstruction than those who had only hand injuries. While there are no available studies comparing outcome of patients with bone loss in forearm versus hand, it may be inferred that the loss of functional integrity of hand is less compensated than that in forearm. Even though many authors advocate the creation of 'single bone' forearm in those with large defects of either radius or ulna, restoration of normal anatomy and ergonomics is possible only with reconstruction of segmental defect of either bone.[7,9]

There were no flap losses in our patients, but we had 03 patients who had delayed healing of donor sites. The patient who underwent a split radius flap had persistent pain and poor grip for 6-8 months but he recovered with continued supportive care. Two patients who had undergone free fibula osteo-cutaneous flap had delayed healing of their donor sites but had no persistent deficit.

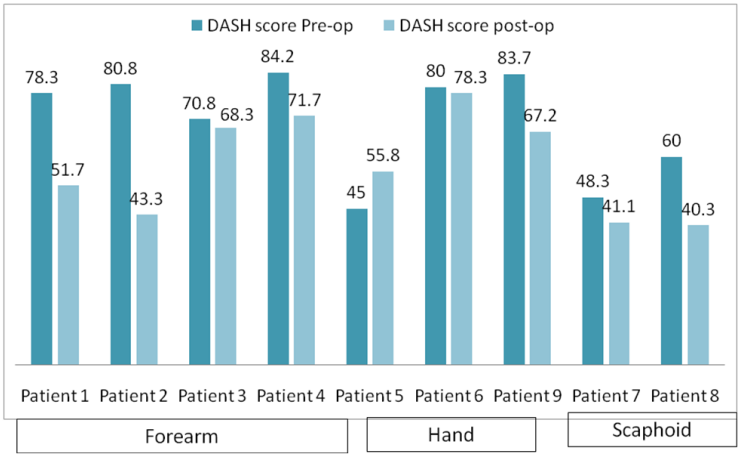
Conclusion:

Reconstruction of composite defects of forearm and hand requires careful planning and execution. Vascularised bone graft offers a single stage option for one stage reconstruction of these difficult defects. We recommend that in patients with severe trauma and an unfavourable local environment, it is better to consider the option of vascularised bone grafts initially rather than follow the conventional strategy. Due to superior bone healing and availability of plenty of vascularised tissue, this option should be used even in those patients who do not fit in the conventional indications.

Master chart:

Case no	Age/ Sex	Mechanism of injury	Defect	Initial treatment	Definitive therapy	Immobilisation	Time to union
4	28/ M	Crush injury/ MVA	5 cm radius defect with overlying skin loss	Revascularisation using RSVG and SSG cover	Free fibula osteocutaneous flap with skin paddle to cover bone segment	8 months	14 months
2	34/ M	Gun shot wound	6 cm radius defect	Ext fixation + Pedicled flap cover	Free fibula osseous flap	8 months	12 months
1	18/M	Fall from height	6 cm Ulna defect	Initial plate fixation followed by plate removal and ext fixation	Free fibula ostecutaneous flap	10 months	14 months
5	36/M	Gun shot wound Rt hand	Total 4th metacarpal defect	Release of scar and PIA flap cover	Distally based split radius for metacarpal reconstruction	6 months	6 months
6	28/ M	Gun shot wound Rt hand	Subtotal defect of 3rd metacarpal and complete loss of 4th metacarpal left hand	Debridement	Free fibula osteocutaneous flap for metacarpal reconstruction	4 months	
3	41/M	Gunshot wound left forearm	Comminuted fracture with segmental loss of left radius shaft 6 cms	Deb + ext fixator application + SSG cover	Free fibula osteocutaneous flap	4 months	
7	31/M	Fall on outstretched hand	Non union fracture scaphoid	Splintage	2,3 ICSRA based vascularised split radius graft	2 months	6 months
8	37/M	Fall while playing football	Non union fracture scaphoid	Splintage	2,3 ICSRA based vascularised split radius graft	2 months	6 months
9	24/M	Machine injury	Mangled hand and forearm	Debridement and pedicled abdominal flap cover	Vascularised proximal phalanx transfer ('Spare parts surgery')	04 months	9 months

Table 1:



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