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Vascularized Osteocutaneous Posterior Interosseous Bone Flap for the Treatment of Nonunion of Forearm Bones

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Background: Forearm nonunion is a challenging condition for orthopaedic surgeons.

Objectives: In this study, we used a new technique for the treatment of forearm nonunion with bone loss and/or current signs of infection. Patients and Methods: Four patients were managed with thorough debridement and a vascularized regional osteocutaneous flap from the distal ulna based on the posterior interosseous artery.

Results: Union was achieved after an average of 3.75 months. Skin flap was viable in all patients. The Quick DASH score, VAS score and forearm and elbow range of motion improved compared to preoperative evaluations.

Conclusions: A posterior interosseous osteocutaneous flap from the distal ulna is a reliable vascularized bone graft for managing forearm nonunion.

Keywords: Bone Flap; Fractures; Ununited; Forearm

1. Background

Vascularized bone grafts have been used for the treatment of forearm bones nonunion with variable success (1). The main indication is large bone defect because of infection, trauma with bone loss, tumor resection and congenital anomalies (2). Conventional bone graft is not favorable in these situations because it either fails or results in slow revascularization of dead bone with creeping substitution. However, vascularized bone graft would heal with a mechanism like fracture union, due to viable osteocytes (3).

There are different techniques for vascularized bone graft in forearm region as either free graft or pedicled regional bone flap. Free vascularized fibula graft has been used with high union rates (4). Because of difficult microsurgical technique and resultant donor site morbidity accompanying free vascularized graft, introducing regional vascularized bone flap seems more operational, especially for younger hand surgeons (5).

Radial forearm bone flap and posterior interosseous bone flap have been used in the treatment of upper extremity nonunions (6). We previously reported our successful results with posterior interosseous bone flap in forearm nonunion (7). However, there are situations where reconstruction of bone defect or debridement of infected tissues results in a soft tissue defect, in which the primary closure is impossible. One of the solutions to this problem is designing osteocutaneous bone flap. In this study, we reported our results of posterior interosseous bone flap combined with its covering skin layer in the treatment of forearm bone nonunion with soft tissue defect.

Brief Report

2. Objectives

In this study, we reported our results of posterior interosseous bone flap combined with its covering skin layer in the treatment of forearm bone nonunion with soft tissue defect.

3. Patients and Methods

3.1. Patients

We analyzed the results of using posterior interosseous osteocutaneous flap (PIOF) in patients presented with forearm bone nonunion with bone defect or current signs or previous history of infection at nonunion site. This study was conducted between December 2012 and March 2014. Four patients were included in the study, three of them had proximal ulna nonunion and one of them had radial shaft nonunion. There were evidences of active infection in three patients, in form of active discharge from sinus tracts and CRP(C-reactive protein) rise.

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Three patients had one or more previous failed internal fixation surgeries and one patient referred with external fixation and bone gap due to open radius fracture. An informed consent was obtained from each patient.

3.2. Evaluations

Preoperative evaluations consisted of AP and lateral Xrays, local and systemic signs of infection, range of motion (ROM) of the elbow, forearm and wrist using a goniometer and the quick disability of the arm, shoulder and hand score (Quick DASH score) (8) and visual analogue score for pain.

Postoperative visits were planned at 1, 3 and 6 weeks after the operation and every three months thereafter until complete union achieved. All preoperatively measured variables were examined in postoperative visits.

3.3. Operative Technique

First, the volar or dorsal Henry skin incision was performed according to the affected bone. The area of skin to be removed, containing active sinus tracts or severely scarred soft tissue, was marked as a fish mouth flap. According to the resultant skin defect, a skin flap was designed over the harvesting site of posterior interosseous osteocutaneous bone flap (PIOB) over the distal ulna (Figure 1 A).

After exposure of nonunion site, in cases of infected nonunion, through debridement of necrotic soft tissue, sinus tracts and sclerotic bone ends was performed until obtaining bleeding bone ends. In cases of non-infected nonunion with bone gap, less aggressive debridement of scarred poor quality soft tissue and sclerotic bone ends was performed. A step cut in 1 cm length was performed on each bone end to facilitate bone graft matching with recipient site and make contact area larger.

Provisional fixation with a bridging 3.5 locking plate was performed in proper length and rotation of the bone. To harvest the antegrade PIOF, the plane between the extensor carpi ulnaris and extensor digiti minimi was developed proximally and the posterior interosseous artery and its branches to the ulna periosteum were identified. Care was taken to maintain overly skin attachments to the bone flap intact and not to exert any traction or excess manipulation on the vascular pedicle (Figure 1 B). Half of the diameter of ulna bone in desired length according to defect length was harvested containing skin flap attached to it and transferred gently to the donor site (Figure 1 C). The bone graft was fixed under the plate and with additional fixation with screws through the plate or from recipient bone to the graft (Figure 1 D). The skin flap was sutured to the edges of skin and completely covered the soft tissue defect.

The forearm was splinted for up to one week. Patients were asked not to perform heavy activities for six weeks, but were encouraged to use the arm and hand actively (Figure 2). Plate removal was performed after solid union was achieved or if there were device-related symptoms.

4. Results

4.1. Case 1

A 46 year-old man was admitted with proximal ulna infected nonunion due to gunshot wound. The accident was 14 months earlier and he had undergone several episodes of debridement, internal fixation and conventional bone grafting, all ended up with a 4-cm bone gap with several sinus tracts with active discharge. He had painful and limited range of motion of elbow in flexion and extension and forearm supination and pronation (Table 1).



Figure 1. Patient 1, A. Skin Flap Design, B. Vascularized Osteocutaneous Flap Harvest, C. Transfer of Bone Flap to Recipient Site, D. Definite Fixation.







Figure 2. Patient 3, A. Preoperative X-Ray. B, C. Post-Operative X-Rays

The bone defect was bridged with 6 cm bone flap and the resected area of sinus tract was covered by skin flap. After

three months follow-up, there were no signs of discharge or collection and CRP returned to normal limit. Skin flap was viable and complete bone union was achieved after four months. DASH and VAS scores both improved compared to preoperative values (Table 1). Forearm and elbow range of motions improved at the last follow-up visit.

4.2. Case 2

A 44-year-old man was admitted with a history of proximal radioulnar fracture eight months earlier, which was internally fixed with plate and screw. He was presented with ulna bone nonunion with local tenderness, swelling and active discharge. Forearm and elbow range of motion were limited and painful.

After aggressive debridement, PIOF was performed as previously mentioned. He had dramatic improvement in pain, DASH score and range of motion after the operation. Skin flap was viable and bone union was achieved after 3.5 months of surgery (Table 1).

4.3. Case 3

A 31-year-old man was admitted with a history of radius shaft open fracture six months earlier treated with external fixator and multiple debridement. He presented with a 5-cm bone defect and sinus tracts along the nonunion site.

After through debridement and external fixator removal, PIOF with 7 cm bone was transferred to the defect site. In this patient, the donor bed of skin was covered with split thickness skin graft.

Postoperative evaluations showed improvements in DASH and VAS scores and increase in forearm and elbow range of motion (Table 1). Complete bone union was achieved in 4.5 months and skin flap healed uneventfully.

Table 1. Patients' Data										
Patient Number	Gender, Age and Occupation	Side	Initial Fx Type	Site of NU/ Type	Presentation	Graft Length, mm	Forearm Rotation Loss Before/After	Elbow ROM Loss Before/ After	Dash Score Before/After	VAS Score Before/After
1	Male/46 worker	Rt	Both bone open (IIIA)	Ulna proximal atrophic	Chronic sinus tract on ulna with discharge	65	50/25	60/30	95/10.2	7/3
2	Male/44 teacher	Rt	Both bone close	Ulna proximal atrophic	Pain, chronic intermittent swelling and erythema	55	45/30	70/30	95/6.8	9/3
3	Male/31 seller	Rt	Radius open (IIIA)	Radius, middle, atrophic	Chronic Pain, erythema and swelling	65	120/45	40/10	79.5/6.8	8/2
4	Male/28 student	Rt	Ulna Close	Ulna, Proximal, Oligotrophic	Chronic Pain	45	0/0	0/0	54.2/0	5/1

4.4. Case 4

A 28-year-old man presented with proximal ulna nonunion and pain after previous failed internal fixation two years ago.

After plate removal and through debridement, the PIOF with 5 cm bone was transferred to the nonunion site and fixed with plate and screw. The skin flap sutured to the recipient area.

At follow-up visits, the skin flap was viable and bone union achieved in three months. DASH score, VAS score and range of motion showed improvement compared to preoperative results (Table 1).

5. Discussion

Forearm bones nonunion, although rare, is still one of the challenges of upper extremity reconstruction. Treatment strategies should target several goals including restoration of anatomic relationship between two bones, establishment of favorable soft tissue bed for bone healing, eradication of infection, achieving stable internal fixation and stimulation of bone regeneration by providing osteoinductive and osteoconductive materials (1).

In the presence of large bone defects, especially associated with poorly vascularized soft tissue bed and/or underlying infection, conventional bone graft usually is not a favorable technique. It either fails or ends up to dead bone segment, incorporating to recipient bone by slow creeping substitution (2, 9).

There are several reports of successful application of vascularized bone graft in forearm nonunions (4, 5). Good vascularity and presence of alive osteocytes can change the unfavorable local physiology to more favorable condition needed for bone regeneration. Moreover, the structural bone graft can restore the bony anatomy. Vascularized free fibula graft has been used in several studies with great success (4). The precise and sometimes sophisticated microsurgical technique and donor site morbidity are the main problems mentioned for this method. Local vascularized bone flaps are less technical demanding and favorable outcome was reported in several studies about hand and wrist injuries. There are few reports of using regional bone flaps in forearm bones. Mullett et al. (6) successfully applied radial forearm bone flaps in an antegrade fashion for five cases of recalcitrant infected nonunion of the distal humerus. Union was achieved in all of their cases after an average of 17.2 months and the author considered the possibility of treating forearm nonunion by this approach. Pagnotta et al. (5) applied a pedicled distal radius bone graft on the basis of the posterior interosseous artery to treat two cases of ulnar nonunion. Kamrani et al. (7) treated nine forearm bones with aseptic nonunion using a posterior interosseous bone flap (PIBF). All of the fractures were united uneventfully after an average of three months. With our new technique of osteocutaneous bone flap, we achieved a complete bony union in four patients in average of 3.75

months. There was no clinical evidence of active infection at the last follow-up and all sinus tracts were healed. The transferred skin flap was viable in all patients and healed to the surrounding tissue. Functional outcome assessed with DASH score and range of motion improved and patients were satisfied by the result of their treatment.

By combining skin flap with bone flap, we are trying to solve two main shortcomings of our previous technique of PIBF. First, we can easily and clinically assess the viability of the flap from appearance and viability of the overlying skin flap. It is a well-known technique used in other pedicled muscle and osseous flaps. Second, because of poorly vascularized and scarred surrounding soft tissue often accompanying forearm nonunions with history of several attempts of surgical treatment and several sinus tracts in infected nonunions needing aggressive debridement, we sometimes face a skin defect in the recipient site. Solutions for this soft tissue defect coverage consist of secondary healing, skin graft and skin flap. Transfer of skin flap along with the bone flap is completely operational with minimal added time of operation and has favorable cosmetic result.

One of the shortcomings of this study was low number of patients, which limited the statistical evaluations of the results and comparison to other studies on forearm nonunion. Forearm nonunion is a rare problem; however, the treatment is still challenging and long-term studies with larger number of patients are necessary.

According to the results of this study, the technique of posterior interosseous osteocutaneous flap can be a vise option for forearm bones nonunion, especially in the presence of infection and sinus tracts, bone loss and scarred surrounding soft tissue.

Authors' Contributions

Leila Oryadi Zanjani: study design, writing manuscript; Reza Shahryar Kamrani: design and conceiving study, critical review; Yousof Fallah: data analysis and interpretation; Mohammad Hossein Nabian: patients assessment, writing manuscript.

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