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Review Article

Management of Forearm Nonunion

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Abstract

Forearm nonunion is rare but a possible complication after standard treatment of the fracture of radius and ulna. The importance of precise restoration of length and anatomical relationship of both bones are among usual concerns. The situation is more complex when the infection is present in the union site. The several techniques have been applied to manage forearm nonunion consisting of osteosynthesis and using cancellous autograft, allograft, nonvascularized fibular graft, fibular flap, bone transport, induced membrane (Masquelet technique), and pedicled flap such as posterior interosseous and radial forearm bone flap (RFBF). Reviewing the recent studies focusing on treating forearm nonunion is the purpose of this review.

Keywords: Forearm; Bone Fractures; Fracture Healing; Treatment

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Background

Forearm movements are based on the function of a tri-articular complex joint including proximal radioulnar joint (PRUJ), distal radioulnar joint (DRUJ), and middle radioulnar joint (MRUJ). In contrast to PRUJ and DRUJ, the middle part of this complex does not have cartilage and instead consists of interosseous membrane (IOM), allowing supination and pronation (1). If we consider radius and ulna shaft as an intra-articular part of a joint, the treatment of forearm fractures should follow the principles of any articular fractures, namely anatomic reduction, rigid fixation, and early mobilization (2). Therefore, open reduction and internal fixation (ORIF) with plate has been the standard treatment for both bone and isolated radius fractures in adults (3, 4). The indication of cancellous iliac bone graft during ORIF of acute fracture is not clear, but it is logical in true bone loss or for those that future loss is impending due to sever soft tissue striping (5).

After ORIF of forearm fracture, nonunion is uncommon (5%) (6, 7); however, when it occurs, it is a real challenge for both the surgeon regarding the restoration of complex anatomical relationship of two bones and available options and the patient for the resulted disability. The situation is even more complicated in the presence of infection (8). Discussion about the possible recent techniques to approach (non-infected and infected) forearm nonunion can gather the armamentarium for orthopedic surgeons to face this rare complication. In this review, we addressed different techniques that have been applied in most related studies published in the current century.

Techniques (Table 1)

Iliac Bone Graft: Still, re-ORIF and bone grafting is a main technique to treat forearm nonunion. Ring et al. treated 35 forearm nonunions with autogenous cancellous bone graft and plating. Eleven patients had been operated due to deep infection before index surgery. The length of final defect ranged from one to six cm (mean: 2.2 cm). Union occurred uneventfully within six months in all patients after a single operation. After a mean follow-up of 43 months, functional outcome was unsatisfactory (due to elbow and wrist stiffness) in 31% and poor (because of malunion) in 2% of patients (9). Dos Reis et al. by using autologous and bone grafting with compression plating treated 31 forearm nonunions including eight ones with history of infection. Union and good outcome were achieved in 30 and 29 patients, respectively (10). Choi et al. treated 8 patients by application of locking plate and autologous corticocancellous iliac bone graft. All non-infected forearm nonunions united before six months and the measured pain and functional scores improved in 12 months postoperatively without any complications (11). Rollo et al. could not find any advantages to treat aseptic forearm nonunion by autograft or allograft, and those forearm nonunions treated with fresh frozen bone graft healed even earlier (12). De Vitis et al. showed in 49 forearm nonunions including two infected ones that intramedullary nailing and possible tricortical iliac bone grafting (ten cases) could result in almost 94% union rate and excellent and good results in nearly 92% of patients. Two failures of healing occurred for the only two infected forearm nonunions in this series (13). For 15 septic forearm nonunions, Prasarn et al. after aggressive debridement in 14 days, definite fixation, and leaving the wound open to let it be closed by secondary intension, continued intravenous (IV) antibiotics for six weeks (8).

Table 1. Different techniques for the management of forearm nonunion and the related data

Author	Number of forearm nonunions	Infection	Technique	Graft or flap length (cm)	Age (year)	Mean follow-up	Mean union time	Complications	Function
Ring et al. (9)	35	11: (history of infection)	Autologous cancellous BG & compression plate	Mean: 2.2 (range: 1-6)	Mean: 40 (range: 21-66)	43 months (range: 1-19)	Within 6 months (no mean)	Two Darrach's procedure, one malunion	Unsatisfactory and poor Anderson score: 34% due to limited elbow and wrist
Dos Reis et al. (10)	31	8: infected nonunion	Autologous tricortical BG & compression plate	Mean: 2.3 (range: 1-5)	Median: 31, > 18	3.6 years (range: 2-6)	3.5 months (range: 2-5)	Nonunion: 1, infection: 2	29 of 31: good Tscherne criteria
Choi et al. (11)	8	0	Autologous corticocancellous BG & locking plate	Range: 1.6-4.2	Mean: 38 (range: 18-52)	18 months (range: 12-24)	4.2 months (range: 3-6)	No	Significant improvement of grip strength, pain, and DASH score
De Vitis et al. (13)	49	2	Tricortical BG + intramedullary nailing (10 cases)		Mean: 37 (SD: 13.4)	31.8 months (SD: 23)	6.3 months (SD: 2.5)	Failed union: 3 cases (2 of infected forearm nonunion)	Excellent and satisfactory Anderson: 92%
Prasarn et al. (8)	15	15	Aggressive surgical debridement and leaving wound open, internal fixation after 7-14 days, tricortical iliac crest BG, secondary intention, 6 weeks of IV AB	Mean: 2.1 (range: 1-7)	Mean: 45 (range: 17-79)	5 years (range: 2-15)	13.2 weeks (range: 10-15)	One nonunion leading to one bone forearm	Functional ROM in 11 forearms
Perna et al. (14)	18	18	Two-staged: debridement, gentamicin-loaded cement spacer for defect > 3 cm + external fixator, targeted AB therapy till normal ESR & CRP, plating + strut & intercalary BG	Mean: 2.3 (range: 1.5-5)	Mean: 34.5 (range: 19-57)	6 years (range: 2-10)	5 months (range: 2-10)	3 cases healed by secondary intention needing skin graft, one post interosseous nerve palsy, one plate impingement, one infection relapse	Excellent and satisfactory Anderson: 83%, no or slight ADL limitation: 83%, significantly improved pain score
Dhar et al. (15)	12	12	Two staged Masquelet technique: debridement, fixation with plate + antibiotic cement, after 4-6 weeks BG was placed in the membrane	Mean: 5 cm (range: 3.5-7)	Mean: 37.91 (range: 19-56)	Range: 1-4 years	7.8 months (range: 6-12)	-	Improved wrist and forearm motion
Faldini et al. (17)	20	0	Autologous nonvascularized fibular BG + reconstruction or compression plate	Mean: 8 (range: 7-10)	Mean: 31 (range: 17-48)	14 years (range: 12-24)	-	Forearm: No, foot and ankle: slight ankle ROM limitation in 2 patients	Improved pain and Anderson score, grip, and ROM
Safoury (18)	18 (10 acute segmental defects)	4	Free vascularized fibula bone flap	Mean: 17 (range: 15-28)	Mean: 34 (range: 22-66)	3 years (range: 2-4)	4 months	Proximal nonunion: one needing BG and 2 cases of malunion	Different functional outcomes in terms of primary injury
Liu et al. (19)	21	21	Debridement and bone transport with unilateral external fixator + 6 weeks of IV & 3 m oral AB	Mean: 3.5 (range: 2.1-5.3).	Mean: 27.1 (range: 15-56)	77.5 months (range: 21-136)	Mean external fixation time: 42.5 cm/day (range: 37.9-51.6), mean gained length: 3.5 cm (range: 2.1-5.3)	Pain during distraction, pin tract infection (57.1%), pin loosening (28.6%), docking site BG (19%), recurrent infection (14.3%)	Improved grip strength and ROM
Ebied and Elseedy (20)	9	9	Debridement, AB, ring external fixator +/- corticotomy (2 cases), cancellous BG	Range: 2.5-3.5	Mean: 49 (range: 45-52)	34 months (range: 24-47)	Mean external fixation time: 22.6 weeks (SD: 3)	Not tolerating external fixator/synostosis: 1, pin tract infection: 9, adjustment of external fixator: 2	Reduced DASH from 90.5 to 40.4
Kamrani et al. (21)	9	0	PIBF + plating	Maximum: 5.5	Mean: 41.7 (range: 27-74)	21 months (range: 9-48)	3 months (range: 3-6)	Donor site tenderness for 6 months: 2	Significantly improved DASH score
Shahryar et al. (23)	7	1	RFBF + plating	Mean: 3.9 (range: 3-4.5)	Mean: 41.3 (range: 20-72)	34 months (range: 7-80)	3.8 months (range: 3-6)	Paresthesia in superficial radial nerve (SRN) territory: 2, donor site pain: 1 (for 7 months)	Significant improvement of quick DASH score & ROM
Kamrani et al. (24)	7	7	One-staged PIBF + plating	Mean: 6.7 (range: 3-11)	Mean: 41 (range: 24-75)	25.7 months (range: 9-48)	3.8 months (range: 3-6)	No	Significant improvement of quick DASH score & ROM
Barrera-Ochoa et al. (25)	4		Vascularized ulnar periosteal pedicled flap +/- new osteosynthesis/no BG	Range: 3-5	Range: 21-51	Range: 12-20 months	Range: 3-5 months	No	Improvement of quick DASH score, ROM, and grip

BG: Bone grafting; IV: Intravenous; AB: Antibiotics; ESR: Erythrocyte sedimentation rate; CRP: C-reactive protein; PIBF: Posterior interosseous bone flap; RFBF: Radial forearm bone flap; SD: Standard deviation; ROM: Range of motion; DASH: Disabilities of Arm, Shoulder, and Hand; ADL: Activities of daily living

Other than one failure leading to one bone forearm procedure, although the mean length of defect was 2.1 cm (range: 1-7), union was achieved in others at average in 13 weeks (8). Treating 18 infected forearm nonunions, Perna et al. used a two-staged approach including debridement and insertion of external fixator that continued by targeted antibiotics. After the normalization of inflammatory markers [erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP)], internal fixation and bone grafting was applied. Most patients had acceptable outcomes considering that the required intercalary graft length was at average 2.3 cm (range: 1.5-5) (14). Masquelet technique was also applied successfully for treating septic forearm nonunion of 12 patients by Dhar et al. This two-staged procedure which consists of debridement and plate fixation plus insertion of antibiotic cement between the freshened parts of nonunion and after 6 weeks, bone graft insertion into the created membrane around the cement, worked without any complication or defects of 3.5 to 7 cm (mean: 5 cm) in this study. All forearms united and the results about wrist and forearm range of motion (ROM) were acceptable at final follow-up (at least one year) (15). Ma et al. achieved 84.5% excellent and satisfactory results applying Masquelet technique in 32 infected forearm nonunions. The internal fixation in their study was done in the second stage instead of the first one (16).

Fibular Graft: Faldini et al. substituted nonvascularized fibular autograft to increase the volume of the used graft in 20 aseptic forearm nonunions. They combined a massive fibular cortical autograft strut with a plate and associated a fibular intercalary autograft in case of a segmental bone defect. Other than some minor complications in donor site, their results in long term were acceptable (17).

When the segmental defect is more than six cm or forearm nonunion is associated with infection, surgeons are not sure about the success of simple bone grafting; thus, there have been several studies to apply other techniques to decrease this concern.

Free Fibular Flap: Safoury treated 18 patients with forearm nonunion (four infected) and large segmental defect by applying free fibular flap (18). This technique requires complex microsurgical procedures. Similar to autologous bone grafting, it may cause donor site morbidity.

Bone Transport: Bone transport by external fixation is another option. Liu et al. reported satisfactory functional and cosmetic outcomes in 21 infected forearm nonunions by a mean lengthening of 3.5 cm (range: 2.1-5.3). However, pin tract infection and loosening was a common complication in their study (19). Ring external fixator here is also an applied device. Ebied and Elseedy treated 9 septic forearm nonunions by staged debridement, antibiotic therapy, and insertion of Ilizarov external fixator. Corticotomy was performed for only two forearms and correction of shortening and angulation was enough in other patients. Cancellous bone graft was added at the nonunion site for all patients. One patient could not continue this treatment and one had synostosis and lost forearm rotation. Functional scores improved partially by this technique (20).

Vascularized Bone Flap: To bypass the donor site morbidity and take benefits of vascularized bone flaps in a series of studies, Kamrani et al. applied forearm originated bone flaps for septic and aseptic forearm nonunions. In 2013, successful treatment of nine aseptic forearm nonunions using posterior interosseous bone flap (PIBF) was reported. Another advantage is that the removal of sclerosis was only done on one side of bone fragments at nonunion site with the reliance on union of the other side by the abundance of the vascularity. Defects up to 5.5 cm were treated by this method. The only complication was donor site tenderness for a maximum duration of six months. This technique had both benefits of a vascularized flap-type blood supply and the feasibility and simplicity of the technique that did not need microsurgical technique (21). The next study assessed the role of radial forearm bone flap (RFBF) in forearm nonunion. RFBF resulted in good outcomes in seven patients including one infected nonunion. The graft length was at average of 3.9 cm (range: 3-4.5) and the septic forearm nonunion was treated like non-infected ones (22, 23). Expanding the applicability of local pedicled bone, in another case series, Kamrani et al. applied PIBF to treat eight infected forearm nonunions in one stage. The results resembled non-infected forearm nonunion regarding the time of union and improvement of clinical factors. However, the average length of the bone flap was 6.7 cm (range: 3-11). This extent of the flap can open the hands of orthopedic surgeons to be less worried about large defects of forearm bones. Moreover, RFBF and PIBF were used to bridge the nonunion of both radius and ulna in two forearms (24). In a recent research, Barrera-Ochoa et al. stepped more to apply pedicled flap by using only periosteal part of posterior interosseous flap. They treated 11 nonunions of elbow, forearm, and hand including four forearm nonunions. All of forearm nonunions united between three and five months and the functional results were encouraging, although the previous osteosynthesis remained in three forearms and no bone graft was added to the nonunion site (25).

Conclusion

Management of forearm nonunions is a real challenge for orthopedic surgeons. Having a pool of options can make the surgeon stronger to select the best available options on the basis of patient's wishes, intraoperative findings, existing equipment, and surgeon's experience.

Conflict of Interest

The authors declare no conflict of interest in this study.

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