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ORIGINAL ARTICLE

Forearm as a valuable source of vascularized bone graft for the distal humerus

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Background: The nonunion of a distal humeral fracture is a challenging complication. Our aim was to assess the results of the application of pedicled bone flap to treat this problem.
Methods: There were 6 men and 3 women with delayed union or nonunion of the distal humerus treated by 10 procedures of rigid fixation plus radial bone forearm or posterior interosseous bone flaps. A locking plate was applied for fixation in 4 patients and a pin and plate for 5 patients. The olecranon osteotomy was performed in 6 elbows.
Results: Patients were a mean age of 49.2 years (range, 31-70 years). The average interval between the trauma and the index operation was 19.2 months (range, 3-49 months). Eight elbows showed union within an average of 3.75 months (range, 3-6 months) in the column where the bony flap was placed. The radial forearm bone flap failed to unite the nonunion of the lateral column of 1 elbow, and additional tension banding was required. Two elbows did not heal at the medial column when the radial forearm bone flap was located on the lateral column. For 1 elbow, another posterior interosseous bone flap was applied on the medial side in another session. By a mean follow-up of 37.3 months (range, 24-79 months), the mean of the visual analog scale demonstrated significant improvement from 6.44 postoperatively to 2.22 ($P < .001$). The Mayo Elbow Performance Score and 11-Item version of the Disabilities of the Arm, Shoulder and Hand score also showed clinically and statistically significant improvements.
Conclusion: Vascularized bone flaps could be considered as an option to facilitate healing of distal humerus delayed union or nonunion.

Keywords: Nonunion; distal humerus; complication; vascularized bone flap; bone graft; internal fixation
Level of evidence: Level IV; Case Series; Treatment Study

Nonunion of the distal humerus after surgical treatment is an extremely challenging complication by a mean occurrence rate of 6%. Causes of this challenge include complex anatomy, the type of forces tolerated by the nonunion site, the small contact area of the bone, and proximity of the elbow joint, which could transfer mechanical forces to the surgical site if it has lost motion. The diminished bone stock of the distal segment, previous implant and scar tissue, and infection, if present, are the negative factors associated with nonunion.[4] The therapeutic options for this problem include open reduction and internal fixation plus autograft or total elbow implant arthroplasty when there is a severe bone defect or osteoporosis. However, any infection is a

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contraindication for elbow arthroplasty.[1,2,22] Although a nonvascularized bone graft is an easy and familiar option to correct bone defects, the possibility of survival for most osteogenic elements is low in the fibrotic and scarred environments surrounding the nonunion site of the distal humerus.

A vascularized bone graft retains its osteogenic potentials and carries blood, and if administered, antibiotics to cope with healing problems and infection.[9,14,16] The prototype of the vascularized bone graft is a free bone transfer. This type of operation is lengthy, demands complex microsurgical techniques, and facilities may not available in all hospitals. Regional pedicled bone flaps theoretically provide all of the benefits of free bone flaps without a microsurgical anastomosis. Mullett et al[16] first successfully applied a radial forearm bone flap (RFBF) in a patient with distal humerus nonunion. The useful application of the RFBF and also posterior interosseous bone flap (PIBF), as another source for pedicled bone flap for the infected and uninfected nonunion of the forearm has also been reported by Kamrani et al.[12,14,21] In this study, we assessed the results of our patients who underwent an application of the PIBF and RFBF for the nonunion of the distal humerus.

Materials and methods

Patients

Between November 2009 and October 2013, we treated 9 patients (6 women and 3 men) with distal humerus nonunions by open reduction and internal fixation, and a regional, pedicled, RFBF, or PIBF. Patients with a history of distal humeral fracture (with or without fixation) and nonunion after 6 months of injury or no progression of union in serial clinical and radiologic examinations were selected. The exclusion criteria were the patient unwillingness to participate, a severe medical condition preventing anesthesia, and any findings of vascular compromises in the limb. All patients signed an informed consent.

Nine patients were included (Table I). Two patients had a history of pain and limitation of range of motion (ROM) at the same elbow before the trauma because of severe rheumatoid arthritis. The mechanism of primary injury was a simple fall in 4 patients, motor vehicle accident in 2, a fall from height in 2, and blast injury in 1. The presenting symptoms were instability in 7 patients and pain in 4 (2 patients presented with a painfully unstable elbow). Patients had undergone an average of 1.5 operations (range, 0-5) for the injured elbow before the index operation. The interval between the initial injury and the index operation was 19.2 months (range, 3-49 months).

Assessment

At the preoperative and last follow-up visit, the patient was assessed for the range of flexion/extension of the elbow goniometer, the level of pain using visual analog scale, the Mayo Elbow Performance Score, and the 11-item version of the Disability of Arm, Shoulder and Hand score (Quick DASH score). Simple radiography of anteroposterior and lateral views was done preoperatively and just after the operation and at 3 and 6 weeks, then every 6 weeks thereafter until union was confirmed in 3 cortices, and finally at the last follow-up visit. Computed tomography (CT) scans in sagittal, coronal, and axial sections were done preoperatively. The Allen test was done to ensure the patency of the ulnar artery.

Operative technique

All procedures were performed with the patient under general anesthesia with the application of a tourniquet and by the first author (R.S.K.). The semilateral position was used. The operation comprised 4 steps: the approach to the distal humerus, débridement, fixation, and the vascularized bone flap harvest and its fixation.

Approach to the distal humerus

By using an extensile posterior approach, the skin incision was made at the midline and curved medially at tip of the olecranon. First, the ulnar nerve was explored. Second, the dorsal capsule was released. If access to all of the articular surface seemed necessary, the olecranon was osteotomized by an oscillating saw through a chevron cut. The triceps muscle was released and retraced from the distal humerus. All previous unstable devices were removed.

Débridement

The nonunion site was exposed, and all sclerotic tissue was removed from the end of the bone segments. A 2.5-mm drill bit was used to drill several points to reach the medullary bone. A sample was sent for culture and antibiogram.

Fixation

Two methods of fixation were applied depending on the size of the distal fragments and the quality of the bone. If the bone quality was appropriate and the bone fragment was large enough, after the anatomic reduction and fixation of the articular surface by screw (if needed), the nonunion site was fixed by two 3.5-mm locking reconstruction plates or 2 medial and lateral anatomic locking compression plates. If the distal bone segment was too small (low distal humeral primary fracture line) or too osteoporotic, a pin and plate fixation was used.[13] After fixation, a sterile ruler was used to measure the size of the needed bone graft.

Vascularized bone flap harvest

The PIBF or RFBF was selected by evaluating an Allen test preoperatively (when performing the RFBF required competent ulnar artery), the condition of the soft tissue, and the bone of the donor site. Finally, the surgeon's opinion was considered.

RFBF harvest. The operating table was tilted, the patient was changed to a more supine position, and the forearm was placed on a hand table. By using a Henry approach to the radius bone, the radial artery and its branches to the radius bone were identified in the plane between the flexor carpi radialis and the brachioradialis. The surgeon used a sterile ruler to measure the desired length of bone at a thickness of 10 mm and one-half of the radius width, which was cut meticulously at least 1 cm proximal to the radiocarpal joint and on the radial part of the volar side of the distal radius metaphysis. The desired length of the flap was about 3 to 5 cm. This flap was