Step-Cut Osteotomy for Recalcitrant Humeral Shaft Nonunion

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The gold standard for the treatment of humeral shaft nonunion is meticulous decortication of sclerotic bone, stable plate fixation, and application of bone graft. The majority (range, 91%-100%) of nonunions will unite following application of these principles.1-6 Recalcitrant nonunions of the humeral shaft are frustrating for patients and challenging for orthopedic surgeons. The authors describe the use of a step-cut osteotomy of the humeral diaphysis coupled with neutralization plating and autologous bone grafting for the management of humeral shaft nonunions that were recalcitrant to initial surgical management. In the authors’ experience, this technique has been a valuable adjunct for obtaining adequate reduction and subsequent union in these complex cases. [Orthopedics. 2016; 39(3):e587-e591.]

Abstract: The majority of humeral shaft nonunions resolve following operative intervention; however, a small percentage will persist despite surgical efforts. These cases of persistent nonunion are frustrating for patients and challenging for orthopedic surgeons. The authors describe the use of a step-cut osteotomy of the humeral diaphysis coupled with neutralization plating and autologous bone grafting for the management of humeral shaft nonunions that were recalcitrant to initial surgical management. In the authors’ experience, this technique has been a valuable adjunct for obtaining adequate reduction and subsequent union in these complex cases. [Orthopedics. 2016; 39(3):e587-e591.]

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Materials and Methods

This study was conducted at an academic medical center following institutional review board approval. Patients who underwent operative treatment of recalcitrant humeral shaft nonunion by the senior author (M.T.A.) from 2002 to 2013 were identified from a fracture treatment database. Inclusion criteria were a humeral shaft nonunion confirmed both clinically and radiographically, failure of prior surgical intervention to repair the nonunion, and revision with a step-cut osteotomy of the humeral diaphysis, plate stabilization, and autogenous bone graft.

Thirty-four surgically managed humeral shaft nonunions were identified, 6 of which were recalcitrant and definitively treated with a step-cut osteotomy of the humeral diaphysis. The main outcome measurement was humeral shaft union, which was verified with anteroposterior and lateral radiographs of the humerus coupled with clinical examination. Five patients were included because they had documented clinical and radiographic union.

Operative Management

Staged reconstruction was used to rule out infection because all patients had a history of prior surgery. The initial procedure involved removal of previously placed implants coupled with bone and soft tissue biopsy. Gram stain and culture of specimens were obtained to rule out occult infection. In all cases, at the first-
stage hardware removal and biopsy surgery, it was thought that the bone ends were atrophic and/or necrotic, and that osteotomy would be required to obtain healthy bone ends for healing. In the absence of infection, a second-stage procedure using a step-cut osteotomy was performed for nonunion reconstruction 7 to 30 days after the first-stage procedure. The indication for step-cut osteotomy was based on the residual anatomy at the nonunion site (oblique bone ends) as well as the concept that improved rotational stability at the nonunion site would promote healing.

In all cases, during the reconstructive stage, iliac crest or proximal tibia autograft was harvested. The approach to the humerus was largely dependent on previous surgical procedures and nonunion location. An effort was made to use prior incisions when deemed appropriate and safe. An anterolateral approach was used for middle and proximal third nonunions (3 cases), whereas a posterior approach was implemented for distal third nonunions (2 cases).

For the first-stage procedure, the approach was carried down through the skin and subcutaneous tissues to expose the nonunion. Care was taken to identify and protect at-risk structures (eg, radial nerve), as the presence of abundant scar tissue from multiple procedures can distort local anatomy. The nonunion was meticulously exposed circumferentially using a periosteal elevator, with multiple bone and soft tissue specimens obtained for Gram stain and culture. As all cases were atrophic, recalcitrant nonunions, the synovial nonunion was thoroughly debrided and nonviable, sclerotic bone was excised to expose healthy tissue. Similarly, the intramedullary canal was reestablished through curettage and reaming.

Osteotomy Technique

A step-cut osteotomy of the humerus was then created using an oscillating saw with a small blade (approximately 1 cm wide × 2 cm long). The osteotomy is cut so that oblique fracture ends are incorporated into the osteotomy to minimize bone loss (Figure 1). The cuts are created at the mid-canal so that the remaining bone ends retain approximately half the diameter of the shaft. The long axis length of the osteotomy is somewhat dependent on the residual bone ends, but is generally 1.5 to 2.0 times the width of the perpendicular cut. The 2 ends of the step-cut osteotomy are then geometrically opposed and compressed with a pointed reduction clamp. The construct is then fixated with a lag screw (2.7 or 3.5 mm) placed obliquely across the osteotomy to further compress the cut bone surfaces. A neutralization plate is then applied with a minimum of 6 cortices on either side of the osteotomy, although more cortices are obtained when possible. When additional stabilization is desired, a dual orthogonal plating technique can be implemented as previously described.19,20

Finally, autogenous bone graft is packed circumferentially around the step-cut osteotomy prior to wound closure.

**RESULTS**

The series consisted of 3 women and 2 men. Ages ranged from 44 to 86 years (mean, 63 years). Mechanisms of injury consisted of 3 ground-level falls, 1 motor vehicle accident, and 1 gunshot wound. Three fractures were closed and 2 were open. One case was complicated by osteomyelitis, which grew cultures positive for *Diphtheroid bacillus*. All patients had previously undergone 1 or 2 unsuccessful attempts of operative fixation for the nonunion. One nonunion was in the proximal segment, 2 were midshaft, and 2 were in the distal third of the humeral shaft (Table 1).

An anterolateral approach was used in 3 patients and a posterior approach was used in 2. Two patients were treated with a single plate (Figure 2), whereas 3 patients underwent dual plating (Figure 3). Average operative time was 154
minutes (range, 94-208 minutes), with a mean estimated blood loss of 380 cc (range, 200-500 cc). All 5 patients progressed to clinical and radiographic union of their humeral shaft. One case was complicated by a radial nerve palsy that was persistent at final follow-up. No other complications were encountered (Table 2).

**DISCUSSION**

A small percentage of humeral shaft nonunions fail to resolve following surgical intervention.1-6 The application of sound surgical principles is imperative for achieving union; the chosen intervention should provide adequate fixation across the fracture, while simultaneously fostering an environment conducive to bone healing. Some authors have reported successful management of recalcitrant humeral shaft nonunions with meticulous decortication of sclerotic bone, followed by revision open reduction and internal fixation with compression plating supplemented by bone graft.1,4,18 The current authors think that the use of a step-cut osteotomy can be a valuable adjunct to this protocol, especially in patients with poor-quality bone or other comorbidities.

Step-cut osteotomies of diaphyseal bone have been successfully used for the treatment of pediatric supracondylar deformities, metacarpal and phalangeal rotational deformities, ulnar shortening, and nonunions of the radial and ulnar shafts.21-24 A step-cut osteotomy of the humeral diaphysis can be an effective addition to plate fixation when addressing a nonunion of the humeral shaft unresponsive to initial surgical management.24 The step-cut osteotomy creates ample surface area for bone-to-bone contact. Furthermore, it provides excellent rotational control of the humeral fragments. The intrinsic rotational stability provided by a step-cut osteotomy is reinforced with a compression lag screw. The disadvantage of the technique is requisite humeral shortening. Fortunately, shortening of the humerus up to 3 cm is well...
tolerated by patients without adversely affecting functional outcomes.25

To the authors’ knowledge, only 1 article has been published describing the use of a step-cut osteotomy of the humeral diaphysis for the treatment of humeral shaft non-union. Khan24 retrospectively reviewed patients with long bone diaphyseal nonunions that were treated with a step-cut osteotomy supplemented with a dynamic compression plate. Seven of these cases involved the humeral shaft. Average patient age was 31 years, with a mean time from injury to osteotomy of 19 months. Nonunion developed after initial management with plate fixation in 6 patients and plaster cast application in 1. All patients were subsequently treated with a step-cut osteotomy of the humeral diaphysis supplemented by compression plating without bone graft. All 7 patients progressed to union in an average of 4 months (range, 3-5 months). No complications were reported.

The current authors’ patient population differed from that reported by Khan.24 The current patients were older (mean age, 63 vs 31 years), underwent more surgeries prior to the index procedure (mean, 1.4 vs 0.9), and waited longer for definitive fixation (mean, 35 vs 19 months). The current authors’ surgical protocol included application of autologous bone graft to the nonunion site. They observed complete union in all 5 studied patients. One case was complicated by persistent iatrogenic radial nerve palsy.

CONCLUSION

A step-cut osteotomy of the humeral diaphysis is a valuable adjunct for the treatment of calcific humeral shaft nonunions that fail initial surgical management. The authors’ indications for the use of a step-cut osteotomy are a humeral shaft nonunion confirmed both clinically and radiographically, failure of prior surgical intervention to repair the nonunion, absence of infection following hardware removal, and an obliquely oriented fracture pattern. The procedure increases the area of bone-to-bone contact between opposing fragments, which may improve intrinsic stability and healing potential. Successful union of recalcitrant humeral shaft fractures can be achieved using a step-cut osteotomy coupled with plate fixation supplemented with autologous bone graft.

REFERENCES


10. McKee MD, Miranda MA,


