Healing and Graft-Site Morbidity Rates for Midshaft Clavicle Nonunions Treated With Open Reduction and Internal Fixation Augmented With Iliac Crest Aspiration

Robert Z. Tashjian, MD, and Daniel S. Horwitz, MD

Abstract

We conducted a study of the healing and graft-site morbidity rates for midshaft clavicle nonunions treated with open reduction and internal fixation (ORIF) augmented with iliac crest aspiration.

Thirteen patients who had undergone ORIF augmented with iliac crest aspiration and tricalcium phosphate for symptomatic midshaft clavicle nonunions (5 hypertrophic, 8 atrophic) were retrospectively evaluated for nonunion healing, complications, and graft-site morbidity. No patient required intercalary allograft for severe bone loss.

Ten nonunions had complete follow-up; 3 did not. Nine (90%) of the 10 with complete follow-up healed; the patient whose nonunion did not heal developed a postoperative infection. Five patients required hardware removal. No graft-site morbidity was documented.

Clavicle nonunions treated with iliac crest aspirate augmentation have healing rates comparable to those of nonunions treated with autograft, as reported in the literature, and there is no graft-harvest-site morbidity.

Clavicle fractures are extremely common, accounting for 2.6% of all fractures.[1] Midshaft fractures account for approximately 70% of all clavicle fractures and traditionally have been treated nonoperatively, even in the setting of significant displacement.[1,2] Nonoperative treatment has been the treatment of choice given its relatively low reported nonunion rates.[2] Other authors have reported nonunion rate increases of up to 30% to 40% in the setting of fracture comminution and female sex.[3] Further, an increased rate of nonunion in high-energy fracture patterns has led some authors to recommend acute operative fixation of these injuries.[4] Nevertheless, nonoperative treatment is still the standard of care for most midshaft fractures; some of these will eventually result in nonunion.

Open reduction and internal fixation (ORIF) augmented with autogenous bone graft is the treatment of choice for nonunited midshaft clavicle fractures.[5-7] Rates of healing after internal fixation with autograft range from 94% to 100%.[5-7] Approximately 23% of patients who undergo anterior crest autograft harvest develop complications, which include hematoma, temporary or permanent sensory disturbances, and temporary or permanent pain.[8] Permanent complications secondary to graft harvest have also been reported in series evaluating the treatment of clavicle nonunions with anterior iliac crest autograft.[6] Despite its complication rates, this bone graft material is still considered optimal.[9]

Other forms of bone graft have been used to augment nonunion fixation. Iliac crest aspiration of osteoprogenitor stem cells has been described as an alternative to autograft for the cellular component of bone graft material.[10] Aspirated osteoprogenitor cells have been combined with allograft as bone graft material in various areas of orthopedics, including spinal surgery.[11] Iliac crest aspirates have been used to treat nonunited tibia shaft fractures with percutaneous injection alone (no internal fixation), and results have been excellent.[12] Using iliac crest aspiration to augment repairs of nonunions, including midshaft clavicle nonunions, may be a reasonable alternative treatment for these injuries and does not have the inherent morbidity associated with autogenous iliac crest graft harvesting.

We conducted a study of the union and complication rates associated with internally fixed midshaft clavicle nonunions augmented with iliac crest aspiration. We compared our union rates with previously reported rates for autograft augmentation of internally fixed midshaft nonunions to try to establish whether adding iliac aspirate without autograft would result in similar union rates.

Patients and Methods

We surgically treated 13 patients with midshaft clavicle nonunions between January 2001 and November 2007. All patients had persistent pain and dysfunction localized to the shoulder and a history of a midshaft clavicle fracture treated nonoperatively for at least 6 months without radio-

Dr. Tashjian is Assistant Professor, and Dr. Horwitz is Associate Professor, Department of Orthopaedics, University of Utah School of Medicine, University of Utah Orthopaedic Center, Salt Lake City, Utah.

Address correspondence to: Robert Z. Tashjian, MD, Department of Orthopaedics, University of Utah Orthopaedic Center, 590 Wakara Way, Salt Lake City, UT 84108 (tel, 801-587-5457; fax, 801-587-5411; e-mail, robert.tashjian@hsc.utah.edu).

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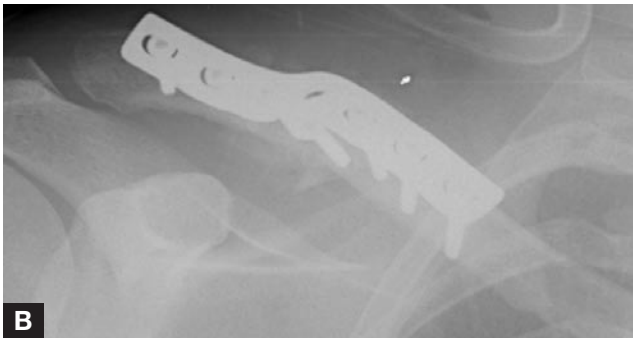

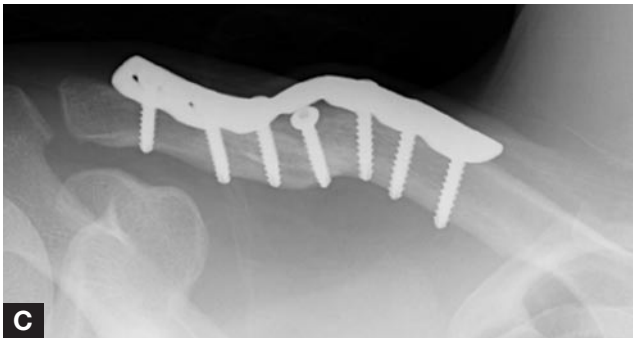

Figure. (A) Radiograph of painful midshaft clavicle nonunion 6.5 months after injury. (B) Postoperative radiograph of midshaft clavicle nonunion treated with open reduction and plate fixation augmented with iliac crest aspiration. (C) Healed nonunion with bridging callus 1 year after surgery.

graphic or clinical signs of healing. In addition, in all cases, preoperative clavicle radiographs showed a persistent gap at the nonunited fracture site. *Atrophic nonunions* were defined as fractures with no or very slight callus formation at the fracture gap and no extra bone formation attached at the fracture edges of the medial or lateral clavicle fragments. *Hypertrophic nonunions* were defined as fractures with increased bone formation at the fracture gap attached to the medial and lateral clavicle fragments, though some gap between the fragments and the callus was still present. No fractures were considered atrophic with a segmental bony deficit at the fracture site. Nonunions were either hypertrophic (5 patients) or atrophic (8 patients) without a segmental bone loss. Eight patients underwent ORIF with a plate-and-screw construct (Synthes, Waldenburg, Switzerland), and the other 5 patients underwent ORIF with an intramedullary Rockwood clavicle pin (DePuy, Warsaw, IN). In all cases, surgical treatment was augmented with tricalcium phosphate. No patient had a defect large enough to require intercalary bone grafting, and no patient had a prior history of surgery on the clavicle.

The 8 patients who underwent ORIF with a plate-and-screw construct received either an anteriorly applied, 3.5-mm pelvic reconstruction plate (6 patients) or a superiorly applied, 3.5-mm limited-contact dynamic compression plate (2 patients). At least 3 screws were placed on either side of the fracture site. The 5 patients treated with a clavicle pin underwent a limited open reduction at the nonunion site.

In all cases, nonunion callus was removed, and intramedullary drilling was followed by direct reduction, which provided cortical contact for medial and lateral clavicle fragments. For 4 weeks after surgery, patients wore a sling while performing protected motion exercises. Active motion was allowed after sling removal.

Hospital investigational review board approval was obtained to retrospectively evaluate the charts of these patients for the presence of fracture union and complications. Postoperative radiographs were reviewed, and union was determined by presence of bridging bone at the nonunion site and absence of pain.

Results

Three of the 13 patients had incomplete radiographic follow-up (Table). Six weeks after surgery, 2 of these 3 patients had full active shoulder motion with no pain, and radiographs confirmed alignment of the repaired nonunion; these patients were lost to follow-up. The third patient died 3 weeks after surgery of causes unrelated to the operation.

The other 10 patients had complete radiographic follow-up (Table), and there were no complaints of symptoms localized to the iliac crest aspiration site, even at the first postoperative visit. In 9 (90%) of these patients, radiographic healing was confirmed by the presence of bridging callus at the site of the nonunion (Figure), which was present in all 9 patients by 3 months postoperative. No hardware loosening was found. All 9 patients had complete return of full active shoulder motion symmetric in elevation and external rotation with the motion of the opposite shoulder.

The 3 patients with a clavicle pin and a healed nonunion developed pain over the posterior aspect of the shoulder at the site of pin insertion; in each case, the pin was removed within 3 to 4 months (mean, 3.5 months), and the pain resolved. Two patients with a healed nonunion after plate fixation (reconstruction plate in one case, limited-contact dynamic compression plate in the other) developed pain that resolved with plate removal (8 and 13 months after surgery, respectively).

The 1 failure occurred in a patient who, 3 weeks after open reduction and clavicle pin fixation, developed a postoperative wound infection. The pin was removed, and repeat débridements were performed. Cultures were positive for methicillin-resistant *Staphylococcus aureus*.

Table. Profiles of Patients With Midshaft Clavicle Nonunions Treated With Open Reduction and Internal Fixation Augmented With Iliac Crest Aspirate and Tricalcium Phosphate

Patient	Fixation Construct (Location of Plate Application)	Nonunion Type	Complete Follow-Up	Radiographic Healing	Months (n) Between Surgery and Hardware Removal	Complications
1	3.5-mm pelvic reconstruction plate (anterior)	Hypertrophic	Y	Y	—	—
2	3.5-mm pelvic reconstruction plate (anterior)	Atrophic	Y	Y	—	—
3	3.5-mm pelvic reconstruction plate (anterior)	Atrophic	Y	Y	—	—
4	3.5-mm pelvic reconstruction plate (anterior)	Atrophic	Y	Y	—	—
5	3.5-mm pelvic reconstruction plate (anterior)	Atrophic	Y	Y	8	Painful hardware
6	3.5-mm limited-contact dynamic compression plate (superior)	Atrophic	Y	Y	13	Painful hardware
7	Clavicle pin	Hypertrophic	Y	Y	3	Painful hardware
8	Clavicle pin	Atrophic	Y	Y	3.5	Painful hardware
9	Clavicle pin	Hypertrophic	Y	Y	4	Painful hardware
10	Clavicle pin	Atrophic	Y	N	0.75	MRSA infection
11	3.5-mm pelvic reconstruction plate (anterior)	Atrophic	N (6 weeks)	NA	—	—
12	3.5-mm limited-contact dynamic compression plate (superior)	Hypertrophic	N (6 weeks)	NA	—	—
13	Clavicle pin	Hypertrophic	N (3 weeks, died of unrelated causes)	NA	—	—

Abbreviations: Y, yes; N, no; NA, not applicable, MRSA, methicillin-resistant *Staphylococcus aureus*.

The patient was treated with intravenous vancomycin for 6 weeks, and the infection resolved. At follow-up, radiographs showed a persistent nonunion, and the patient complained of persistent pain. No further treatment of the nonunion was pursued.

Discussion

Our results show that, for midshaft clavicle nonunions, ORIF augmented with tricalcium phosphate combined with iliac crest aspirate provides healing rates comparable to those of fixation with autograft. This is the first report on a series of patients with nonunited fracture treated with a combination of internal fixation and bone marrow aspiration. Autogenous graft has osteoconductive and osteogenic properties and is considered the gold standard in the treatment of nonunited fractures. Bone marrow aspirates provide osteoblastic stem cells, cytokines, and growth factors similar to those provided by autograft but lack osteoconductive properties. Tricalcium phosphate can be added for its osteoconductive properties. Our technique therefore provides the individual components of autograft without any graft-site complications.

Numerous authors have reported results of treating midshaft clavicle nonunions.[5-7] Ballmer and colleagues[5] reviewed the cases of 37 patients after ORIF of midshaft clavicle nonunions treated with autologous grafting and reported a 95% healing rate. One patient had a superficial wound infection, and 2 others had painful hypertrophic scars. There was no mention of graft-site morbidity. Laursen and Døssing[6] reviewed the cases of 16 patients with midshaft clavicle nonunions treated with ORIF augmented with iliac crest allograft and reported a 100% healing rate, though 1 patient complained of persistent graft-site pain. The incidence of graft-site morbidity in these series is much less than in other studies specifically addressing the issue of crest graft-site morbidity.[8] One possible explanation for this discrepancy is underreporting in the series evaluating clavicle nonunions. If we assume that the graft-site morbidity rate is equal to the published rate in studies specifically addressing this complication (23%) and compare this with our morbidity rate, we see that aspiration significantly reduces the incidence of graft-site complications. Similarly, our healing rates are comparable to rates reported for autograft augmentation, so we conclude that our technique reduces the incidence of graft-site morbidity without compromising healing rates.[5-7]

Iliac crest marrow aspiration has been used in the treatment of atrophic tibia nonunions. Hernigou and colleagues[12] treated 60 noninfected atrophic tibia nonunions with iliac crest aspiration and percutaneous injection under fluoroscopy only. Three to 5 aspirations of 4 mL each were performed on both iliac crests, centrifuged, and percutaneously injected under fluoroscopy. Fifty-three (88%) of the 60 nonunions healed without further surgical intervention. Wientroub and colleagues[13] reported on 23 pediatric patients who required bone graft for various reasons and were treated with a combination of allograft and bone marrow aspirations; 22 of these patients had excellent results without recurrence. No other authors have reported results of a series of fracture nonunions treated with fixation augmented with allograft and bone marrow aspiration.

Our study limitations include small sample size and retrospective review. Although retrospective chart review is not as effective as a prospective study in evaluating

functional outcomes after treatment, the primary goal of this study was not to evaluate outcomes. Similarly, patients were followed up only until fracture healing was radiographically evident (3 months). Although this period may be considered short for an outcome study, the principle outcomes of this study were radiographic nonunion healing and presence or absence of graft-site morbidity. Consequently, both study objectives were met with this short-term retrospective review. We recognize that the study sample was small and that our healing rates can be difficult to compare with published rates. If we considered all 3 patients lost to follow-up as patients who did not heal, our healing rate would be 69%. Nevertheless, the small sample size can be compared with several published series ranging in size from 10 to 20 patients.[6,7] Finally, in our study we included several different fixation techniques with a unified method of grafting. Fixation type, which may be an important factor in healing rates, was not examined in this study. Similarly, internal fixation without grafting may be an option for these injuries, but we did not examine this technique. It may be a potential subject of future research.

Conclusions

Nonunited midshaft clavicle fractures can be treated with internal fixation augmented with iliac crest bone marrow aspirate and tricalcium phosphate. This treatment is safe and effective, and the healing rates are similar to those reported for similar nonunions treated with fixation and autograft augmentation, but there is no graft-site morbidity. Further research is required to directly compare healing and complication rates in repaired nonunions using a single method of fixation augmented with nothing, autograft, and bone marrow aspirate in a prospective randomized trial.

Authors' Disclosure Statement

Dr. Tashjian reports no actual or potential conflict of interest in relation to this article. Dr. Horwitz reports that he is a consultant to DePuy, which manufactures the clavicle pin used in this study.

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