ORIGINAL ARTICLE

# Treatment of Nonunion of Humeral Shaft Fracture with Dynamic Compression Plate and Cancellous Bone Graft

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**Background:** This study was conducted to evaluate the treatment of aseptic nonunion of the humeral shaft with a dynamic compression plate (DCP) and cancellous bone graft.

**Methods:** One hundred and five cases of nonunion of a humeral shaft fracture between 1982 and 2001 were analyzed retrospectively. The study population comprised 66 males and 39 females with an average age of 46.2 years (range, 17–81 years). Sixty-seven fractures were defined as atrophic nonunion, and 20 as hypertrophic nonunion, whereas 18 could not be defined clearly. All the fractures were managed by open reduction and internal fixation with DCP and cancellous bone graft. The mean follow-up period was 20 months (range, 14–28 months).

**Results:** All nonunion fractures united within an average of 16 weeks (range, 10–26 weeks). Complications included 4 patients with temporary radial-nerve palsies, and 3 patients with wound infections. At the final follow-up, shoulder and elbow functions of the operated limbs were all satisfactory.

**Conclusion:** Fixation by DCP with supplemental cancellous bone graft is a reliable and effective treatment for nonunion of a humeral shaft fracture. [*J Chin Med Assoc* 2005;68(2):73–76]

**Key Words:** bone graft, dynamic compression plate, humeral shaft fracture, nonunion

## Introduction

Acute fractures of the humeral shaft are usually managed conservatively. The rate of union is high, whereas that of nonunion ranges from 1–6%.[1] However, surgical treatment for humeral shaft fracture has become popular in recent decades. With either operative or nonoperative treatment, certain humeral shaft fractures are slow to heal or do not heal.[2] Various risk factors for nonunion have been identified, including the following: open fracture, mid-shaft fracture, transverse or short-oblique fracture, comminuted fracture, unstable fixation, fracture gap, alcoholism, poor compliance of patients, and infection.[2–4]

The treatment of nonunion of a humeral shaft fracture was considered difficult by Watson-Jones,[5] and several operative options have been reported in recent decades,[6–10] including dynamic compression plate (DCP) with cancellous bone grafting, intramedullary (IM) nailing, external fixation, vascularized bone graft, and on-lay bone-plate augmentation. Different success rates and complications have been reported for these options. There are some reports of managing nonunion of a humeral shaft fracture with DCP and bone graft with good results.[6,11] Nevertheless, these reports were for small numbers of patients. This paper also evaluates the results of treatment for nonunion of humeral shaft fracture by open reduction and internal fixation with DCP, supplemented with cancellous bone graft, but in a larger number of patients than previously.

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## Methods

From 1982 to 2001, complete records from 105 patients with aseptic nonunion of a humeral shaft fracture were reviewed and analyzed. Ten patients were excluded before analysis because they were lost to follow-up. In this study, no bilateral fractures were encountered, and nonunion was defined as failure to unite the fracture within 8 months of the initial injury.[12] Among the 105 patients, there were 66 males and 39 females with an average age of 46.2 years (range, 17– 81 years). The causes of initial injury were traffic accidents ($n$ = 75), falls ($n$ = 20), and direct contusion by miscellaneous materials ($n$ = 10). The initial state of injury showed that 55 fractures were of transverse type, 39 of oblique type, and 11 of comminuted type. Fifty-five were mid-shaft fractures, 32 distal-third fractures, and 18 proximal-third fractures. At the acute stage, 35 fractures were fixed conservatively, 25 with DCP alone, 27 with IM nailing, 12 with external fixation, and 6 with screws. Primary treatments were done at our hospital in 20 cases and at other institutions in 85 cases.

Radiographic evaluation of the nonunion found 67 fractures to be atrophic, and 20 to be hypertrophic, whereas 18 could not be defined clearly. The timing of treatment was an average of 9 months (range, 8–20 months) from the initial trauma. All patients received the same surgical protocol for treatment of the nonunion, consisting of removal of the previous implant (in patients with a previous implant *in situ*), decortication of the fracture site, refreshing the fracture site (removal of interposed soft tissue), recanalization of the intramedullary canal, reduction of the fracture, internal fixation with DCP, and application of a cancellous bone graft harvested from the ipsilateral anterior iliac crest. Bacterial and fungal cultures done in all cases were all negative. All procedures were done under general anesthesia by senior staff. An anterolateral approach was applied in 80 cases, including all cases with a middle-third fracture, and some cases with a distal-third fracture. Conversely, a posterior approach was applied in 25 cases of distal-third fracture. All fractures were reduced as anatomically as possible, and both proximal and distal to the fracture site, at least 6 cortices were fixed rigidly by cortical screws through the DCP. Thus, 35 cases were fixed with 7-holed DCP, 45 with 8-holed DCP, 19 with 9-holed DCP, and 6 with 10-holed DCP. An interfragmental screw was used in 34 cases. Arm slings were used and range-of-motion (ROM) exercises were started immediately after the operation. Any labor with the injured limb was not allowed until the appearance of bridging callus or union. No other supplemental fixation, such as cast or brace, was used after operation. The functional result was supervised by senior staff throughout the follow-up period.

After the operation, each case was followed once every 2 weeks in the first month and once every month thereafter. Additional visits were prescribed if needed. Functional evaluation was done at every visit and once every 2 months after fracture union. Each patient had a special chart with a detailed record of personal data, mechanism and associated condition of the injury, type and classification of the fracture and nonunion, management course (including timing of treatment, the implant chosen, size or number of implant, status of fixation, course of operation, blood loss, operation time, type and duration of antibiotics used, hospital stay, early complication, late complication, and management of complication), condition and course of fracture healing, and functional recovery, until the final follow-up. An X-ray check-up was done at every follow-up visit, and all evaluations were done by senior staff. Normal union was defined as the appearance of bridging callus (or bridging of the cortex) and partial obliteration of the fracture site within 5 months; delayed union as union evident in 6–8 months; and non-union as no evidence of union in 8 months. Malunion was defined as varus or valgus deformity ≥ 15°, anterior or posterior angulation ≥ 15°, rotational deformity ≥ 15°, or shortening ≥ 15 mm, compared with the contralateral side. The follow-up period was an average of 20 months (range, 14–28 months).

If the active ROM of the elbow and shoulder were reduced, patients were unable to return to their pre-injury work or activity after operation, or patients had unrecoverable neural injury, the functional results were deemed unsatisfactory; otherwise, functionality was considered satisfactory.

## Results

All fractures united solidly, and thus, no case needed revision (Figure 1). The mean operation time (from incision to complete wound closure) was 107 minutes (range, 90–160 minutes), intraoperative blood loss was 525 mL (range, 350–1,050 mL), the hospital stay was 7.5 days (range, 5–14 days), and the union time was 16 weeks (range, 10–26 weeks). Based on preoperative and intraoperative findings, the causes of nonunion in these 105 fractures were soft-tissue interposition ($n$ = 35), poor reduction ($n$ = 26), inadequate fixation ($n$ = 15), secondary traumatic insult

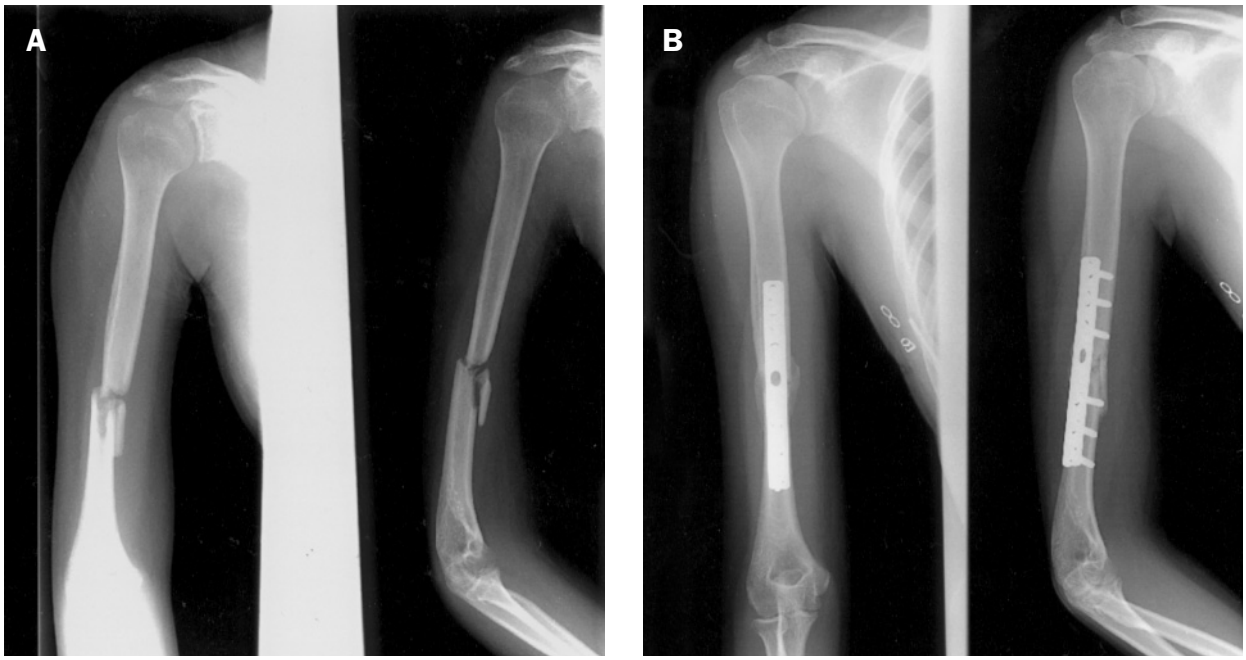


**Figure 1.** A 21-year-old female received conservative management for a right humeral shaft fracture and developed nonunion: (A) preoperative plain film showing nonunion; (B) postoperative plain film showing union, 12 weeks after application of a dynamic compression plate with a supplemental cancellous bone graft.

($n$ = 10), multiple causes ($n$ = 10), and no significant cause ($n$ = 9).

The overall complication rate was 6.7% (7/105) in this series. Three episodes of superficial infection were noted (2.9%), and all developed in the upper arm. All infections healed after debridement and antibiotic therapy. No deep infection developed in this series. Iatrogenic radial-nerve injury developed in 4 patients (3.8%), all of whom had distal-third fractures. The injuries seemed to be neuropraxia due to inappropriate stretch, and unrelated to the approach itself. All 4 patients recovered completely in 2–6 months without any treatment and without any functional impairment at the final follow-up visit. The incidence of neural injury in patients with distal-third fractures was 12.5% (4/32). No malunion was noted in this series.

All patients had satisfactory functional results, with nearly normal shoulder and elbow function, without noticeable pain, and a full return to pre-injury activities and work, without pain at the final follow-up visit.

## Discussion

Various methods have been introduced for the management of humeral shaft fracture and with good results.[6–10] Nevertheless, nonunion remained a problem, irrespective of whether fractures were managed conservatively or operatively. Some authors recently advocated the use of IM nailing to treat nonunion of humeral shaft fractures.[4] However, unlocked IM nailing was reported in selected cases of delayed union, but not in nonunion, with the disadvantage of poor rotational control of the nails.[12,13] Locked IM nailing has been suggested by some authors for managing nonunion of humeral shaft fractures because of better rotational control of the nails, although this procedure has some disadvantages that have limited its use, such as X-ray exposure, a more demanding technique, impaired shoulder ROM, and possibly, intractable shoulder pain.[4,7,14,15] The use of a DCP to fix an ununited fracture of the humeral shaft could avoid the disadvantages of IM nailing. The combined use of a DCP and a cancellous bone graft could achieve both rigid fixation (by DCP) and improve osteogenesis (by cancellous bone graft). Thus, the problems of nonunion (either poor fixation in hypertrophic nonunion, or poor osteogenesis in atrophic nonunion) could be overcome, and union could be achieved as expected, as was shown in this series. The results presented in this study also revealed a satisfactory functional outcome for the ipsilateral shoulder and elbow in all patients. To date, this is the largest series to report results in the English literature for the treatment of nonunion of humeral shaft fracture with a DCP and bone graft.

The disadvantages of using a DCP are more soft-tissue stripping and an increased incidence of iatrogenic radial-nerve palsy.[1–18] In this series, the incidence of

superficial infection was 2.9%, which is comparable with other reports. The incidence of radial-nerve palsy was 3.8%, which is also comparable with other reports. To avoid such soft-tissue injuries, it is important to manage the soft tissue meticulously during surgery, especially in cases of nonunion of fractures of the distal third of the humeral shaft. We did not explore the radial nerve routinely, since this seemed to be of no benefit.[14] The management of postoperative radial-nerve palsy arising from treatment of humeral shaft fracture remains controversial. Pollock et al suggest that management should be conservative with careful observation for improvement in nerve function, and that nerve exploration should only take place 3.5–4 months after injury if there is no improvement.[18] In our series, the 4 radial-nerve injuries were managed conservatively instead of with early exploration, and all patients recovered completely within 6 months.

In conclusion, removal of a previous fixation device, refreshing the nonunion site, and fixation with a DCP and a supplemental cancellous bone graft is effective and, therefore, recommended for patients with nonunion of a humeral shaft fracture.

## References


1. Raschke M, Khodadayan C, Maitino PD, Hoffmann R, Sudkamp NP. Nonunion of the humerus following intramedullary nailing treated by Ilizarov hybrid fixation. *J Orthop Trauma* 1998;12: 138–41.
2. Foulk DA, Szabo RM. Diaphyseal humerus fracture: natural history and occurrence of nonunion. *Orthopedics* 1995;18: 333–5.
3. Healy WL, White GM, Mick CA, Brooker AF Jr, Weiland AJ. Nonunion of the humeral shaft. *Clin Orthop* 1987;219:206–13.
4. Lin J, Hou SM, Han YS, Chao EYS. Treatment of humeral shaft fractures by retrograde nailing. *Clin Orthop* 1997;342: 147–55.
5. Watson-Jones R. *Fracture and Joint Injuries*, 6th edition. New York: Churchill Livingstone, 1982:578.
6. Muller ME, Thomas RJ. Treatment of nonunion in fracture of long bone. *Clin Orthop* 1979;138:141–53.
7. Crolla RM, de Vries LS, Clevers GJ. Locked intramedullary nailing of humeral fracture. *Injury* 1993;24:403–6.
8. Patel VR, Menon DK, Pool RD, Simonis RB. Nonunion of the humerus after failure of surgical treatment. Management using Ilizarov circular fixator. *J Bone Joint Surg Br* 2000;82:977–83.
9. Jupiter JB. Complex non-union of the humeral diaphysis. Treatment with a medial approach, an anterior plate, and a vascularized fibular graft. *J Bone Joint Surg Am* 1990;72:701–7.
10. Hornicek FJ, Zych GA, Hutson JJ, Malinin TI. Salvage of humeral nonunion with onlay bone plate allograft augmentation. *Clin Orthop* 2001;386:203–9.
11. Barquet A, Fernandez A, Luvizio J, Masliah R. A combined therapeutic protocol for aseptic nonunion of the humeral shaft: a report of 25 cases. *J Trauma* 1989;29:95–8.
12. Rosen H. The treatment of nonunions and pseudoarthroses of humeral shaft. *Orthop Clin North Am* 1990;21:725–42.
13. Foster RJ, Dixon GL Jr, Bach AW, Appleyard RW, Green TM. Internal fixation of fractures and nonunions of humeral shaft. *J Bone Joint Surg Am* 1985;67:857–64.
14. Te Velde EA, van der Werken C. Plate osteosynthesis for pseudoarthrosis of humeral shaft. *Injury* 2001;32:621–4.
15. Laing PG. The arterial supply of the humerus. *J Bone Joint Surg Am* 1956;38:1105–16.
16. Robinson CM, Bell KM, Court-Brown CM, McQueen MM. Locked nailing of humeral shaft fractures. Experience in Edinburgh over a two-year period. *J Bone Joint Surg Br* 1992; 74:558–62.
17. Heim D, Herkert F, Hess P, Regazzoni P. Surgical treatment of humeral shaft fractures: the Basel experience. *J Trauma* 1993;35:226–32.
18. Pollock FH, Drake D, Bovill EG, Day L, Trafton PG. Treatment of radial neuropathy associated with fractures of the humerus. *J Bone Joint Surg Am* 1981;63:239–43.