Role of Autologous Bone Graft in the Surgical Treatment of Atrophic Nonunion of Midshaft Clavicular Fractures

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abstract

A retrospective study was conducted to evaluate the role of autologous bone graft in treating atrophic nonunion of midshaft clavicle fracture with a limited-contact dynamic compression plate (LC-DCP). Between 1995 and 2008, sixty cases of atrophic nonunion of midshaft clavicle fractures were managed with open reduction and internal fixation with an LC-DCP. The cases were separated into 2 groups to evaluate the effect of autologous bone graft in the enhancement of bone union. In group 1 (n=24), autologous bone graft was not used; in group 2 (n=36), autologous bone graft was used. Pre- and postoperative management were the same in both groups. Radiographic results and functional outcomes according to the Quick Disability of Arm, Shoulder, and Hand score were evaluated. Average follow-up was 25.2 months (range, 24-48 months).

No statistically significant difference was found between the 2 groups regarding demography and preoperative functional scores (P>0.05). Operative time and hospital stay were statistically significant longer in group 2 (P<0.001), and donor site pain was apparent in group 2. All 60 patients had uneventful union. No statistically significant differences were found between the 2 groups regarding union time (average, 9.8 weeks in group 1 and 9.2 weeks in group 2) and postoperative functional scores (P>0.05).

Limited-contact dynamic compression plate fixation is an effective method for treating atrophic nonunion of midshaft clavicle fractures. Autologous bone graft was not needed.
Clavicle fractures are common, accounting for 2.6% to 4% of adult fractures. Fractures of the midshaft clavicle account for 69% to 82% of all clavicle fractures.\(^1\)\(^-\)\(^3\) Nonoperative treatment for midshaft clavicle fracture has been proposed to have good outcome in certain fracture patterns, but recently, more studies demonstrate that operation in certain fracture patterns, but recently, has been proposed to have good outcome treatment for midshaft clavicle fracture excluded from this study.\(^4\)\(^,\)\(^8\)

Regardless of the procedure for treating midshaft clavicle fractures, nonunion is always a problem. Symptomatic nonunion usually requires surgery. Many methods have been reported to treat nonunion, such as open reduction internal fixation with plates and screws; intramedullary screws, nails, or pins; and external fixators.\(^9\)\(^-\)\(^15\) Autologous bone graft is often recommended for enhancing union, especially in atrophic nonunion, but the effect of autologous bone grafting in atrophic nonunion of midshaft clavicle fractures has not yet been clarified. The purpose of this retrospective study was to evaluate the role of autologous bone graft in treating atrophic nonunion of midshaft clavicle fractures with a limited-contact dynamic compression plate (LC-DCP).

**MATERIALS AND METHODS**

Between 1995 and 2008, sixty consecutive atrophic nonunions of midshaft clavicle fractures in 60 patients were treated with LC-DCP at our institution. The indications for operation were symptomatic nonunion, failure after at least 3 months of nonoperative treatment, and pain or instability over the fracture site. Forty patients were not managed initially in our institution. No open fracture, fracture with neurovascular injuries, fracture of the same side upper extremity, infectious nonunion, or re-fracture of the same clavicle were included. Two patients who were lost to follow-up and 1 patient with hardware fixation failure due to a fall were excluded from this study.

No history of immunological disease or steroid use was noted in the 60 patients. All nonunions were interpreted to be atrophic by radiographic evaluation.\(^16\)\(^,\)\(^17\) The 60 patients were separated into 2 groups: in group 1, autologous bone graft was not used; in group 2, autologous bone graft from the ipsilateral anterior iliac crest was used. No specific indication for using autologous bone graft existed (surgeon’s discretion).

Group 1 comprised 24 patients (12 men and 12 women) with an average age of 43.0 years (range, 18-74 years). Eleven left clavicles and 13 right clavicles were fractured. The mechanism of injury was traffic accident in 16 patients, fall from a height in 6, and miscellaneous causes in 2. The average duration of conservative treatment was 28.1 weeks (range, 12-120 weeks). Seven patients were habitual smokers.

Group 2 comprised 36 patients (20 men and 16 women) with an average age of 43.8 years (range, 19-70 years). Eighteen left clavicles and 18 right clavicles were fractured. The mechanism of injury was traffic accident in 26 patients, fall from a height in 8, and miscellaneous causes in 2. The average duration of conservative treatment was 27.4 weeks (range, 12-100 weeks). Ten patients were habitual smokers.

All operations were performed by 3 of the authors (C.-C.C., Y.-P.S, F.-Y.C) while patients were under general anesthesia. Patients were placed in the beach-chair position with their head turned to the shoulder opposite the fracture. Prophylactic antibiotic with intravenous 500 mg cefazolin preoperatively and intravenous 500 mg cefazolin postoperatively were given to all patients. For group 2 patients, autologous cancellous bone graft was taken from the ipsilateral anterior iliac crest preoperatively.\(^18\)\(^,\)\(^19\)

In both groups, a horizontal skin incision was made along the superior side of the clavicle and centered over the nonunion site. The skin, platysma, and subcutaneous tissue were raised as 1 flap. The nonunion site was exposed, and bacterial culture was done in all cases (negative culture result in all cases). The interposed fibrous tissue between the nonunion ends was removed. Decortication of both proximal and distal fragments was performed with an osteotome, and care was taken to protect the surrounding fascial and periosteal sheath. The sclerotic ends were freshened, and the medullary canal was opened and reamed with a drill.

A 3.5-mm LC-DCP was contoured to the shaft and applied on the superior surface of the shaft. At least 3 screws with good bicortical purchase were placed in both the distal and proximal fragments.\(^20\)\(^,\)\(^21\) If the reduced junction was an oblique plane, a 3.5-mm lag screw was placed for interfragmentary fixation if possible. If a butterfly fragment presented, the fragments were reduced after freshening the fibrotic surface and fixed by the compressing plating method. If possible, an interfragmentary compression screw was used for the butterfly fragment.

The nonunion ends were shaped and reduced in contact, and the structural fragments were reduced to avoid further shortening of the clavicle. All small bone chips and reaming dusts collected during the reposition procedure were packed back to the nonunion site. In group 2, autologous cancellous bone graft from the iliac crest was packed to the nonunion site. Finally, the wound was closed in layers, with specific care taken in closure of the periosteal sleeve in all patients. Mean operation time was 90.9 minutes (range, 60-125 minutes) in group 1 and 123.9 minutes (range, 80-175 minutes) in group 2. During the hospital stay, no complications developed in either group. Mean hospital stay was 3.3 days (range, 3-4 days) in group 1 and 4.2 days (range, 3-6 days) in group 2.

Postoperatively, the arm was placed in a sling, with passive and active mobilization allowed as tolerable. Gradually, return to sports or heavy work with the injured limb was allowed after solid union. Patients were examined postoperatively at 2 and 6 weeks and every month thereafter.
Radiographic evaluation in a standard anteroposterior view was performed at each follow-up. All radiographs were evaluated by independent observers (H.-K.H, C.-C.C., C.-L.L). Union was defined as completely bridging bone with obliteration of the fracture gap (Figure).

Functional evaluation was performed beginning at the third follow-up and recorded using the Quick Disability of the Arm, Shoulder, and Hand score. The final functional evaluations were evaluated and interpreted by all the authors. Each patient had a chart with detailed records of their personal data, smoking habits, mechanism and associated condition of the injury, pattern of the initial fracture, type and classification of nonunion, course of management (including initial treatment), timing of nonunion treatment, course of operation, operation time, length of hospital stay, early complications, late complications, management of complications, condition and course of the fracture healing, and functional recovery. Average follow-up was 26.2 months (range, 24-48 months) in group 1 and 24.5 months (range, 24-40 months) in group 2.

All patients were measured for all response variables, which included demographic variables and important outcomes. Data were presented as mean and standard deviation for continuous response variables or percentages for discrete variables. Chi-square test was used to compare differences between the 2 groups for each discrete variable, and Student t test was used for each continuous variable. SPSS version 17.0 software (SPSS, Inc, Chicago, Illinois) was used to test the difference of the results. Significance was set at P=.05 for each test before analysis.

RESULTS

All 60 nonunions had uneventful union. No complications developed in any patient. No statistically significant difference was found between the 2 groups regarding demography, period of preoperative conservative treatment, pre- and postoperative functional scores, union time, and follow-up period (P>.05) (Table). All patients subjectively felt they had full return of preinjury function of the injured upper limb at final follow-up. Operative time and hospital stay were statistically significantly longer in group 2 (P<.001) (Table), and donor site pain was reported to be more severe than that of the clavicle side by all of the patients in group 2.

DISCUSSION

Fracture of the midshaft clavicle is common, and nonunion is a common complication after nonoperative treatment. More emphasis has been placed on this issue because symptomatic nonunion with pain or instability will weaken the function of shoulder and limb. The results of the current study showed that atrophic nonunion of midshaft clavicle fractures could be

![Figure: Radiograph of the right clavicle of a 56-year-old man 24 weeks after injury showing atrophic nonunion (A). Eight-month follow-up radiograph after treatment with a limited-contact dynamic compression plate with no autologous bone graft showing bone union (B).](image-url)
managed successfully by open reduction and rigid internal fixation with an LC-DCP.

In this series, the union rate was 100%, and the union time was comparable to those in other series. Studies report intramedullary fixation, external fixation, double plating, or locking plating for the treatment of clavicle non-union. Intramedullary fixation has the disadvantage of poor rotation control; external fixation has the disadvantages of a bulky frame and technical demand; double plating has the disadvantages of more soft tissue stripping and impairment of local blood supply; and locking plating has the disadvantage of higher cost. These disadvantages limit the use of the aforementioned implants, and use of an LC-DCP for nonunited clavicle fracture could avoid these disadvantages.

All patients in the current study had atrophic nonunion after nonoperative treatment. Common causes of atrophic nonunion are poor fixation and poor osteogenesis. According to Schwarz and Hocker, the use of an LC-DCP with 3 to 4 bicortical screws in both proximal and distal fragments could overcome the problem of poor fixation. To overcome the problem of poor osteogenesis, supplemental autologous bone graft has been suggested for clavicle nonunion in many studies. In group 1 in the current study, autologous bone graft was not used, but local bone grafting from local bone chips and reaming dust was performed. All atrophic nonunions in group 1 healed uneventfully, so this may be considered that local bone graft with refreshing the fracture, good bony contact, less periosteal stripping, and good preservation of the periosteal sleeve is sufficient to overcome the problem of poor osteogenesis in non-united midshaft clavicle fractures. These, together with rigid internal fixation, may overcome poor fixation and poor osteogenesis so that union can be achieved.

The aforementioned rigid fixation and improved osteogenesis were the key points to getting a high union rate. Autologous bone graft from the iliac crest or elsewhere might make the union more promising, but its associated clinical shortcomings (operation site pain and significantly longer operation time and hospital stay) were apparent in the current study. Also, its necessity was not proven in our study because radiographic and functional results were not statistically different between groups 1 and 2. Endrizzi et al reported that autologous bone graft is not routinely necessary for clavicle nonunion, but their results were not specified according to nonunion type. However, in the current study, all patients experienced nonunion after nonoperative treatment, not operative treatment, and no case of massive bone loss was noted. Thus, the role of autologous bone graft in nonunion after operative treatment of clavicle fracture and nonunion of clavicle fracture with massive bone loss could not be defined from the results of our series.

Many factors have been reported as risky to the healing of clavicle fractures. In our series, all 60 nonunions healed uneventfully, and no definite factors, including age, sex, smoking status, and mechanism of injury, were shown to affect nonunion healing. However, the risk factors of the initial nonunions in these 60 patients could not be analyzed and evaluated because 40 patients were not managed initially at our institute.

The effect of clavicle shortening after fracture union is still controversial. Some authors report that it will impair shoulder function, and some report that it has no clinical significance. Because shortening was difficult to evaluate radiographically and clinically, even by comparing with the other side of the clavicle, we did not check the radiographs of the other side of the clavicle to evaluate shortening. However, all of the patients subjectively reported a full return to preinjury function of the injured upper limb at final follow-up. Although shortening is not the main concern in our procedures, we tried to avoid further shortening of the clavicle if possible.

Functional results showed a return to preinjury levels in all patients, which supports the use of early range of motion exercises of the injured extremity after rigid fixation with an LC-DCP. Degenerative changes of the shoulder with deteriorating function would be an important factor affecting the long-term function of the shoulder and upper limb, and this should be considered in the functional evaluation of patients undergoing clavicle surgery, especially elderly patients. The disadvantage of using an LC-DCP is more soft tissue stripping. In our series, no infections or poor wound healing developed, which highlights the importance of meticulous intraoperative soft tissue management.

The main limitations of the current study include the retrospective nature of the reviews and the relatively small sample size. Although some bias in evaluation could not be avoided, our results were helpful for surgeon reference.

**CONCLUSION**

Open reduction, refreshing the nonunion site, and rigid fixation by an LC-DCP are effective and reliable methods for treating atrophic nonunion of midshaft clavicle fractures after failure of nonoperative management. Autologous bone graft is not needed.

**REFERENCES**