Functional outcome after surgical plating for humeral shaft nonunion

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Background

Although the great majority of fractures of the mid-third of the humeral shaft heal uneventually when treated nonoperatively, nonunion is not a rare condition. The prevalence of nonunion as a complication of both nonoperative and operative treatment has been reported to be as high as 13%. Open reduction and plate fixation combined with autologous bone grafting can result in reliable healing of these humeral nonunions with excellent functional outcome.

Patients and methods

Between 2002 and 2007, 30 consecutive nonunion cases of the midpart of the humeral shaft were treated with open reduction and internal fixation by a single surgeon. The series included 14 female patients and 16 male patients with an average age of 42 years (range 19–57 years). The patients were followed up for an average of 28 months (range 24–56 months). The time from diagnosis of nonunion to our treatment of the nonunion averaged 9 months (range 6–24 months).

Result

According to the Stewart and Hundley Criteria, the functional postoperative result was excellent or good in 24 (73%) cases and fair in six (27%) cases. One year after surgery, all patients had an essentially normal range of motion of the ipsilateral elbow and shoulder. According to the scoring system of Constant and Murley the postoperative average score was 90 (range 88–96).

Conclusion

Surgical compression plating and autologous bone grafting of humeral diaphyseal nonunions resulted in 100% union rate and mostly excellent or good functional results without significant morbidity.

Keywords:

bone graft, functional outcome, humeral fractures, nonunion, plating

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Introduction

Although the great majority of fractures of the mid-third of the humeral shaft heal uneventually when treated nonoperatively [1], nonunion is not an infrequent condition. The prevalence of nonunion as a complication of both nonoperative and operative treatment has been reported to be as high as 13% [2–4]. Although plate fixation remains one of the most valid techniques for the treatment of these nonunion cases, poor bone quality or a deficient plate technique may lead to nonunion [5–11].

Delayed union or nonunion of fracture of the humerus is a debilitating complication, but open reduction and internal fixation combined with autologous bone grafting can result in reliable healing of these nonunion cases; however, there is morbidity associated with the bone graft donor site [12,13].

There are little reports in the literature on the outcome of humeral shaft nonunion treatment using a uniform surgical technique [14,15], and most reports lack substantial numbers of patients. Compression plating of the humeral shaft nonunion, especially after previous surgery, is often associated with a high risk for radial nerve injury [16].

The aim of this article was to report on the results of compression plating of nonunion cases clinically, radiographically, and from the prospective of functional outcome.

Patients and methods

Between 2002 and 2008, 30 consecutive cases of humeral diaphyseal nonunion were treated with standard open reduction and plate screw fixation with autogenous iliac crest bone grafting by a single surgeon in a tertiary care center. The inclusion criteria for patient selection were as follows: an atrophic nonunion of the humeral diaphysis; a minimum of 6 months from initial injury to diagnosis; and a minimum of 24 months' follow-up. Patients' charts were retrospectively reviewed for demographic data, mechanism of injury, associated injuries, previous treatment modalities, current surgical data, and complications, and personal interviews were conducted to determine the functional outcome using the Stewart and Hundley Criteria [10] presented in Table 1, in addition to the scoring system of Constant and Murley [17] presented in Table 2, which consists of four variables that are used to assess the function of the shoulder. The right and left shoulders are assessed separately, with the subjective variables being pain and activity of daily living (sleep, work, and recreation/ sport), which give a total of 35 points, and the objective variables being range of motion and strength, which give a total of 65 points.

Radiographs were reviewed to assess nonunion preoperatively for displacement, shortening, angulation, and final union. The series included 30 patients (14 women and 16 men) with an average age of 42 years (range 19–57 years) who were followed up for an average of 26 months (range 12–56 months). The original injury was caused by a fall in 22 cases and by motor vehicles in eight. The right arm was involved in 18 patients and the left in 12. The time from initial injury to our surgical intervention for the nonunion averaged 9 months (range 6–24 months). The initial fracture treatment was nonoperative in eight cases, with a hanging cast, and operative in 22 cases. All nonunions demonstrated gross instability and no radiological signs of healing at presentation. All patients also had a degree of shortening measured clinically, ranging from 5 to 34 mm with an average of 8.5 mm. One patient with septic nonunion was treated with multistaged debridement followed by titanium cage application filled with cancellous allograft and an autogenous nonvascularized fibular shaft graft spanning the sites of the fracture in an intramedullary position, as well as plate fixation; the remaining patients underwent standard compression plating and autogenous iliac crest bone grafting after appropriate preparation of bone ends. All patients reported functional disability of the involved upper extremity due to pain and instability at the nonunited fracture site.

Table 1 Stewart and hundley criteria

Scores	Pain	Limitation of elbow or shoulder mobility	Angulations
Good	No	<20°	<10°
Fair	After efforts or work	20–40°	>10°
Poor	Permanent	>40°	Radiologic nonunion

Table 2 The scoring system of constant and murley

	Points
Pain	
Severe	0
Moderate	5
Mild	10
None	15
Activity of daily living	
Full work	
Severe	0
Moderate	2
No	4
Full recreation/sport	
Severe	0
Moderate	2
No	4
Affected sleep	
Yes	0
Sometimes	1
No	2
Use of arm in painless activity	
Waist	2
Xiphoid	4
Neck	6
Head	8
Above head	10
Range of motion	
Forward elevation	10
Lateral elevation	10
External rotation	10
Internal rotation	10
Strength	25

Details of surgical treatment

A single surgeon was involved in the study. Prophylactic first-generation cephalosporin antibiotic was administered preoperatively to all patients who were generally anesthetized in the supine position. The limb with nonunited fractures was prepared and draped in a standard manner. Surgical fixation was carried out through a standard Henry anterolateral approach [18] with the radial nerve identified between the brachialis and brachioradialis muscles distally and protected throughout the case. Thereafter, subsequent neurolysis was carried out, followed by debridement of fibrous tissues and sclerotic avascular bone segments at the fracture ends with preservation of soft tissues to avoid bone devascularization. Thereafter, reduction was achieved by gentle impaction of the proximal and distal ends at the fracture site or by using a reduction clamp. When reduction was achieved successfully, a 2.0 mm Kirschner wire was drilled through the nonunion site for preliminary stability. Autogenous cancellous bone graft obtained from the patient's anterior iliac crest was used in all cases. Hardware was selected on the basis of previous operative intervention, quality of bone, and presence of bone segment loss. The use of intramedullary nailing was excluded as all patients had atrophic nonunion and they needed debridement and bone grafting. The nonunion was fixed with a 4.5-mm-broad dynamic compression plate and screws, with at least eight cortices engaged on both sides of the nonunion for all cases (Fig. 1). This plate was secured in compression mode. A second, 3.5-mm reconstruction plate was added lateral to the first plate in two cases as there was questionable adequacy of the stability of the single-plate fixation.

In one case, which had multiple debridements, antibiotic-impregnated cement beads and intravenous antibiotics were used, and, because of severe bone loss, a strut fibular autograft with a titanium cage was also utilized (Fig. 2) in addition to a locked compression plate to improve fixation in the osteoporotic bone. The average operative time was 110 min (range 90–175 min) in all patients. The average blood loss was 180 ml (range 110–350 ml).

Postoperative management

After the operative intervention, the patients wore a functional brace and sling for 1 month. The patients were encouraged to perform active range of motion exercises of the shoulder and elbow while avoiding resisted activities until healing occurred. After healing of the nonunion, passive range of motion exercises were started. Outcome measurement included a clinical evaluation of morbidity, pain, and recovery of functional level of activity. Functional outcome scores of the Stewart and Hundley Criteria [10], in addition to the scoring system of Constant and Murley, were also utilized. Radiographic evaluation included assessment of alignment, loosening of the devices, and the presence of a bridging callus across the nonunion site. Healing was assessed clinically and radiographically and was defined as the absence of tenderness on the site of the un-united fracture and the presence of a bridging callus across the fracture site in at least three cortices on two orthogonal radiographic views.

Results

Table 3 lists the preoperative patient data including sex, age, limb involved, number of previous surgeries, fracture location, and interval from injury to index operation. Of the patients, 22 (73%) had undergone previous surgeries and eight (27%) patients had been treated conservatively with a hanging cast; 18 out of 22 cases had undergone surgical plating, three were internally fixed with an intramedullary nail and one with a rush rod. Table 3 summarizes the preoperative patient data. Table 4 summarizes the postoperative patient data including the type and number of plates used and time to radiographic union.

All patients were followed up for a mean period of 26 months (range 12–56 months). No patient required return to the operating room for a second operation or regrafting. All patients were satisfied with the surgery results during the interviews. The average time to radiographic union was 16 weeks (range 14–22 weeks) for all cases.

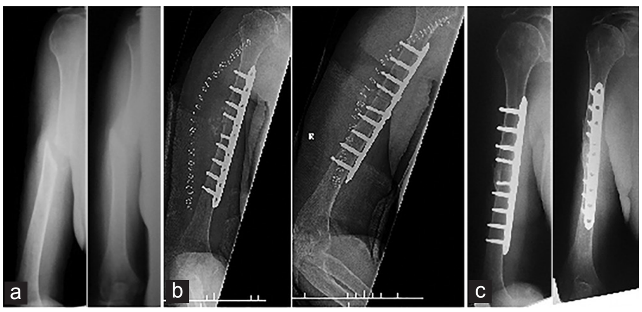
Functional results

According to the Stewart and Hundley Criteria [10], the functional preoperative results were poor in 26 (87%) cases and fair in four (13%) cases (Table 5), whereas the postoperative results were excellent or good in 24 (73%) cases and fair in six (27%) cases (Table 5). One year after surgery, all patients had an essentially normal range of motion of the ipsilateral elbow and shoulder. According to the scoring system of Constant and Murley the preoperative average score was 80 (range 74–87) and the postoperative average score was 90 (range 88–96). All patients were doing well at the final interview and had regained their functional activity before the initial trauma. No patient developed wound infection, osteomyelitis, neurovascular injury, or iliac crest graft site pain, and all achieved solid union.

Discussion

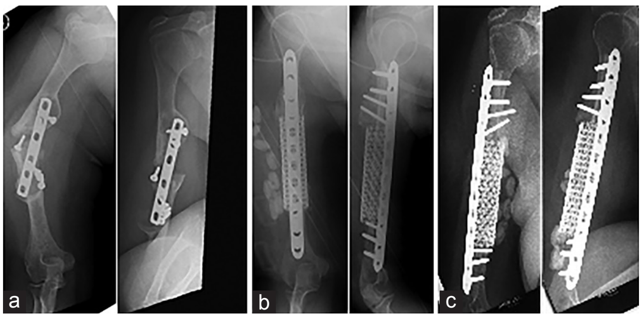
Most humeral fractures can be treated by conservative methods unless they had been caused by high-energy

Figure 1



Radiographs of a patient with atrophic nonunion of the humerus: (a) preoperatively; (b) immediately postoperatively; (c) 19 weeks postoperatively, demonstrating union.

Figure 2



Radiographs of a patient with atrophic nonunion of the humerus with bone loss after multiple failed surgical interventions: (a) preoperatively; (b) immediately postoperatively; and (c) 22 weeks postoperatively.

Table 3 Preoperative patient data

Cases	Age (years)	Sex	Involved limb[a]	Number of previous operations	Implant in place at initial visit	Location of fracture	Interval from injury to index operation. (months)
1	47	M	R	0	None	Proximal third	7
2	47	M	(R)	1	Plate	Proximal third	11
3	25	F	L	0	None	Middle third	6
4	57	M	(R)	1	Rush rod	Proximal third	10
5	23	M	L	2	Plate	Middle third	24
6	47	F	(R)	1	Plate	Proximal third	11
7	51	F	L	0	None	Middle third	7
8	44	M	L	1	Plate	Middle third	9
9	41	M	L	2	Plate	Middle third	13
10	47	F	(L)	0	none	Middle third	6
11	54	F	R	1	Plate	Middle third	8
12	19	F	R	1	Plate	Middle third	14
13	31	M	R	1	Plate	Middle third	9
14	41	F	L	2	Intramedullary rod	Proximal third	7
15	42	F	(R)	1	Plate	Proximal third	8
16	29	M	L	1	Intramedullary rod	Proximal third	7
17	35	M	(R)	0	None	Middle third	6
18	44	F	R	1	Plate	Middle third	11
19	39	F	(R)	1	Plate	Middle third	10
20	28	F	(R)	0	None	Middle third	6
21	38	M	(R)	1	Plate	Middle third	7
22	42	M	L	1	Plate	Middle third	9
23	50	M	R	0	None	Middle third	8
24	49	F	L	1	Plate	Middle third	6
25	55	F	(R)	1	Plate	Proximal third	8
26	37	F	R	1	Intramedullary rod	Proximal third	7
27	49	M	(L)	1	Plate	Middle third	6
28	37	F	(R)	1	Plate	Middle third	9
29	44	M	R	1	Plate	Proximal third	6
30	56	F	L	0	None	Middle third	10

F, female; L, left; M, male; R, right; [a]Parentheses indicate that the limb is dominant.

Table 4 Postoperative data

Cases	Type of implant used for fixation	Time to radiographic union (weeks)	Duration of follow-up (months)
1	4.5 DCP	16	54
2	4.5 DCP	19	56
3	4.5 DCP	16	18
4	4.5 DCP	21	12
5	4.5 DCP and 3.5 reconstruction plate	18	36
6	4.5 DCP	16	14
7	4.5 DCP	19	24
8	4.5 DCP	17	16
9	4.5 DCP	17	24
10	4.5 DCP	18	28
11	4.5 DCP	19	14
12	Titanium cage, antibiotic cement beads, locked compression plate	22	36
13	4.5 DCP	14	18
14	4.5 DCP and 3.5 reconstruction plate	15	13
15	4.5 DCP	18	28
16	4.5 DCP	19	23
17	4.5 DCP	14	18
18	4.5 DCP	16	22
19	4.5 DCP	14	13
20	4.5 DCP	16	16
21	4.5 DCP	14	22
22	4.5 DCP	15	34
23	4.5 DCP	19	18
24	4.5 DCP	20	36
25	4.5 DCP	18	18
26	4.5 DCP	16	42
27	4.5 DCP	15	18
28	4.5 DCP	14	48
29	4.5 DCP	16	36
30	4.5 DCP	17	24

DCP, Dynamic compression plate.

Table 5 Preoperative and postoperative functional assessment data

Cases	Functional results according to the Stewart and hundley criteria		Functional results according to the scoring system of constant and murley	
	Preoperative	Postoperative	Preoperative	Postoperative
1	Poor	Excellent	80	90
2	Poor	Excellent	77	89
3	Fair	Excellent	86	96
4	Poor	Excellent	81	88
5	Poor	Fair	80	88
6	Poor	Excellent	78	89
7	Poor	Excellent	77	89
8	Poor	Excellent	79	92
9	Poor	Excellent	80	91
10	Poor	Excellent	78	89
11	Poor	Excellent	76	89
12	Poor	Fair	75	88
13	Fair	Excellent	84	93
14	Poor	Fair	81	88
15	Poor	Excellent	74	90
16	Poor	Excellent	80	92
17	Fair	Excellent	83	94
18	Poor	Excellent	78	89
19	Poor	Excellent	79	91
20	Poor	Excellent	82	90
21	Fair	Excellent	81	94
22	Poor	Fair	87	89
23	Poor	Excellent	85	89
24	Poor	Excellent	78	90
25	Poor	Excellent	74	89
26	Poor	Excellent	84	91
27	Poor	Fair	83	89
28	Poor	Excellent	79	93
29	Poor	Excellent	81	90
30	Poor	Fair	82	89

trauma and needs surgical fixation to obtain adequate reduction and good functional outcome. However, Ostermann *et al.* [19] reported a nonunion rate of 2%, whereas other authors reported a nonunion rate up to 13%, which can be severely disabling [2–4]. Plate fixation in combination with bone grafting appears to be more reliable in the treatment of nonunions of the humeral shaft even in the presence of poor bone quality due to osteopenia or loss of cortical integrity [9,20]. Healy *et al.* [4] concluded that plate fixation is the most reliable treatment for humeral nonunion. They pointed out that the main factor for success was a stable plate achieved by securing fixation of at least six cortices proximal and distal to the nonunion site, whereas other authors recommended eight cortices proximal and distal to the fracture site [21]. Although plate fixation remains one of the most valid techniques for the treatment of these nonunions, poor bone quality or a deficient plate technique may lead to nonunion [5–11].

Foster *et al.* [5] reported a 96% rate of union in their study on fixation of both fractures and nonunions. They used both single-plate and dual-plate constructs either with or without lag screws. The treatment of nonunion differs from that of acute fractures [22–25]. A nonunion usually requires thorough debridement of the sclerotic bone, synovial tissue, and fibrous tissue to obtain a well-vascularized bone bed and optimize placement of a bone graft in the nonunion site.

We reported successful open reduction and internal fixation of atrophic nonunion augmented with autologous iliac crest grafting of the humerus. Hypertrophic nonunions were not included in this study as they present different treatment challenges. The efficacy of autologous bone grafting in the treatment of delayed union and nonunion has been confirmed [26,27]. The surgical approach and plate fixation technique are of immense importance to avoid radial nerve injuries and achieve a high degree of absolute stability. This was accomplished with interfragmentary lag screws when possible with compression and rigid plate fixation, which provided a stable construct and an ideal biomechanical environment required for successful bone healing. After the refreshment of the fracture site by radical debridement, enhancement of the local biology was accomplished using autologous bone grafting. We have found it mandatory to perform resection of the nonunion and remove all fibrous tissue to ensure a new vascularized bed at the fracture site, which in turn enhances migration of osteogenic cells and prepares the host environment for successful graft integration. In one case, the bone loss was replaced using a titanium mesh cage filled with bone graft.

We successfully used rigid internal fixation with bone grafting to achieve union with a high success rate and excellent functional outcome. In our experience, we found that humeral diaphyseal nonunion treated with surgical plating and autologous bone grafted yielded a 100% union rate with no radial nerve injury or wound infection. The functional outcome of our cases based on two functional scores showed outstanding results.

Conclusion

Humeral nonunion is a debilitating condition that can result in long-term sequelae and loss of function, which can be successfully treated by surgical plating and autologous bone grafting to have the best postoperative functional results.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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