

# Outcome of locking compression plates in humeral shaft nonunions

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## ABSTRACT

**Background:** Nonunion of diaphyseal fractures of the humerus are frequently seen in clinical practice (incidence of up to 15% in certain studies) and osteosynthesis using dynamic compression plates, intra medullary nails and Ilizarov fixators have been reported previously. Locking compression plates (LCP) are useful in the presence of disuse osteoporosis, segmental bone loss and cortical defects that preclude strong fixation. We report a prospective followup study of the outcome of the use of LCP for humeral nonunion following failed internal fixation in which implants other than LCP had been used.

**Materials and Methods:** Twenty four patients with nonunion of humeral shaft fractures following failed internal fixation were included in the study. The mean followup period was 3.4 years (range: 2.4 to 5.7 years) and the minimum followup period was 2 years. Mean age of the patients was 41.04 years (range: 24 to 57 years). All 24 patients underwent osteosynthesis using LCP and autologous bone grafting (cortico-cancellous iliac crest graft combined with or without fibular strut graft). Main outcome measurements included radiographic assessment of fracture union and pre and postoperative functional evaluation using the modified Constant and Murley scoring system.

**Results:** 23 out of 24 fractures united following osteosynthesis. Average time to union was 16 weeks (range: 10 to 28 weeks). Complications included delayed union ( $n = 2$ ), transient radial nerve palsy ( $n = 2$ ) and persistent nonunion ( $n = 1$ ). Functional evaluation using the Constant and Murley score showed excellent results in 11, good in 10, fair in two and poor outcome in one patient.

**Conclusions:** Locking compression plating and cancellous bone grafting is a reliable option for achieving union in humeral diaphyseal nonunion with failed previous internal fixation and results in good functional outcome in patients with higher physiological demands.

**Key words:** Nonunion humerus, internal fixation of humerus, locking compression plates, osteosynthesis

## INTRODUCTION

The incidence of nonunion of humerus has been as high as 15% of all humeral fractures.<sup>1</sup> Various devices such as dynamic compression plates (DCP), angled blade plates, wave plates, autograft or allograft struts, locked intramedullary nails and Ilizarov external fixators have been used in the management of nonunion of fractures of

humeral diaphysis.<sup>2</sup> Very few studies have been published about the use of locking compression plate (LCP) in the management of a nonunion of humeral fractures.<sup>3,4</sup> LCP is a useful implant in the presence of poor bone quality due to disuse osteoporosis, stress shielding from the previous plate, enlarged screw holes of previous loose screws, cortical thinning due to a loose intramedullary nail and segmental bone defect due to nonunion. The present study is a prospective followup study of evaluating outcome of the use of LCP in osteosynthesis of humeral diaphyseal nonunion following previous failed internal fixation using other types of implants.<sup>2-4</sup>

## MATERIALS AND METHODS

Twenty-four patients with nonunion of humeral shaft fracture following failed previous internal fixation, treated between April 2007 and March 2010 were included in the study. Permission of the hospital ethics committee was obtained prior to inclusion of patients in the study. Informed written consent of all the patients was obtained prior to clinical and radiographic assessment. There were 19 male

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Access this article online	
Quick Response Code:	Website: www.ijoonline.com
	DOI: 10.4103/0019-5413.108899

and five female patients. The mean age was 41.04 years (range 24-57 years). Thirteen patients had left side and 11 patients had right side involvement. Twenty-one patients had atrophic type and three patients had hypertrophic type of nonunion. Five patients had nonunion at the proximal third and middle third junction, sixteen patients had nonunion at the middle third of the humerus and three patients had involvement of the middle third and distal third junction. Two patients had pseudarthrosis and three patients had gap nonunion.

The mean duration of nonunion was 26.3 months (range 7-276 months). 12 patients underwent reoperation between 5 and 10 months from the time of index operation; 7 patients were re-operated between 11 and 20 months and 3 patients were re-operated between 21 and 30 months. One patient had osteosynthesis after 72 months and one patient had re-operation after 276 months following the index operation. Implants that had been used previously at the time of index operation included DCP ( $n = 19$ ), IM-IL nail ( $n = 3$ ) and intramedullary Küntscher nail ( $n = 2$ ).

Implant failure was obvious on the preoperative radiographs in 17 patients. Out of which two patients had breakage of the DCP and two patients had breakage of IM nails. Five patients had broken screws alone. In four patients, there was loosening of the plates with dislodgement of screws and in the remaining four patients there was bending of the plate without breakage. In five patients with nonunion, implant failure was not evident on preoperative radiographs but there was evidence of loosening of the implant intra operatively. Only in two patients with nonunion of relatively short duration, the previously used DCP was intact despite the nonunion.

All patients underwent osteosynthesis of the humerus with LCP and cortico-cancellous bone grafting. In the preoperative period, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP) and complete blood counts were obtained in all patients to investigate the possibility of latent infection. Anterolateral approach was used in 17 patients and posterior approach was used in seven patients. Posterior approach was used when there was radial nerve palsy and in distal third nonunions. The previous implant was removed and the edges of the nonunion were freshened followed by recanalization of the medullary canal in both proximal and distal fragments. Intraoperative cultures were obtained in all the patients. The fragments were reduced and stabilized using LCP. A minimum of 8 cortices were purchased on either sides of the fracture and when the previous implant was a DCP, longer LCP was used to provide additional purchase over a minimum of 2 cortices in each fragment.

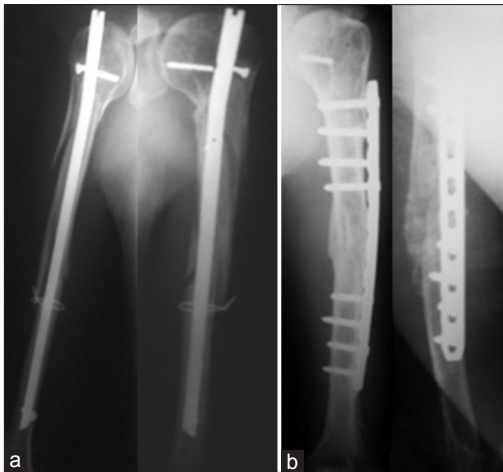
Cortico-cancellous bone graft harvested from the iliac crest was used in all patients. Fibular strut in-lay auto grafts of 6 to 7 cm in length was used in three patients who had gap nonunion or very osteoporotic cortices adjacent to the site of nonunion. The limb was immobilized in an above-elbow plaster slab for 3 weeks following the operation. Active, assisted shoulder and elbow exercises were commenced after 3 weeks. Patients were followed up at monthly intervals till radiographic union was seen and then at 4 monthly intervals for a minimum period of 2 years. The mean followup period was 3.4 years (range 2-5 years). Functional assessment was done using the modified Constant and Murley functional evaluation score.<sup>5</sup> Scoring was obtained preoperatively (before the osteosynthesis) and postoperatively at the time of final followup.

## RESULTS

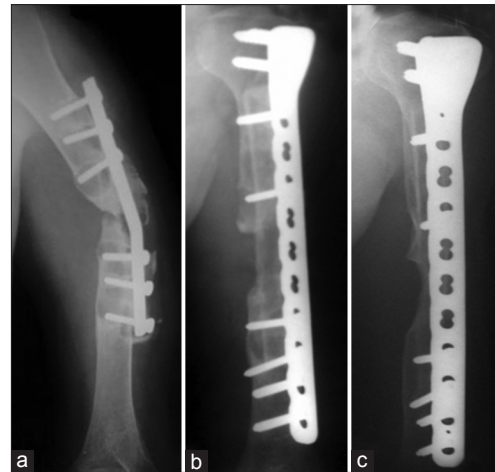
All fractures except one united following osteosynthesis and two patients required additional bone grafting to promote union [Figures 1-5]. Average time to union was 16 weeks (range 10-28 weeks). In five patients, union occurred between 10 and 12 weeks following osteosynthesis, in eight patients union occurred between 13 and 16 weeks and in eight patients union occurred between 17 and 20 weeks. In three patients who had delay in union beyond 20 weeks, second bone grafting procedure was carried out and union was achieved within 28 weeks in two of these patients. Possible contributors to nonunion following the index operation included soft-tissue interposition in three patients, improper fracture reduction in three patients, inadequate fixation in seven patients, systemic causes such as diabetes and smoking in four patients. No obvious cause could be seen in seven patients [Table 1].



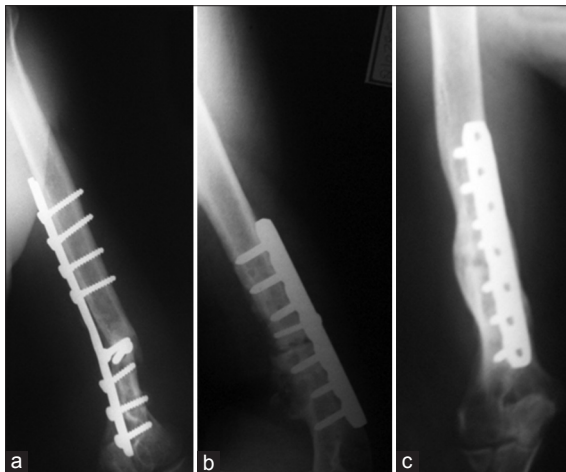
**Figure 1:** X-ray anteroposterior and lateral views of humerus showing (a) nonunion following fixation with dynamic compression plates (b) Sound union achieved 8 months following osteosynthesis with locking compression plate and bone grafting



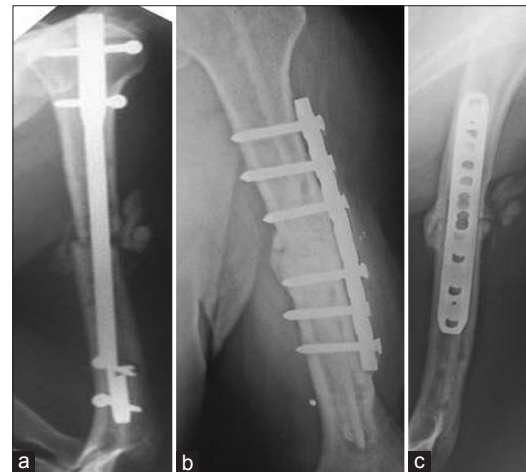
**Figure 2:** X-ray anteroposterior and lateral views of humerus showing (a) nonunion following interlocking intramedullary nailing of the humerus (b) union achieved following nail removal and osteosynthesis with locking compression plate and bone grafting



**Figure 4:** X-ray anteroposterior view (a) of humerus showing nonunion at the junction of proximal third and mid shaft with implant failure (b) osteosynthesis using proximal humeral locking compression plate, fibular strut graft and iliac crest graft (c) union of the fracture at final followup



**Figure 3:** X-ray distal 3/4 of humerus anteroposterior view (a) showing nonunion following dynamic compression plates fixation of fracture distal third of the humerus (b) osteosynthesis done using locking compression plate and bone grafting (c) sound union noted at final followup



**Figure 5:** X-ray anteroposterior view (a) Interlocking nail was used for osteosynthesis of nonunion following previous fixation with DCP (note the screw holes left by the earlier DCP); IM nail also failed to achieve union and nail breakage occurred (b) IM nail was removed and repeat osteosynthesis was done using fibular graft and LCP (c) Lateral view showing sound union in progress

Complications included delayed union in two patients necessitating further bone grafting when there was no radiographic evidence of callus after 6 months following osteosynthesis. Two patients had radial palsy that recovered after a period of 5 to 7 months. In one patient union did not occur even after the second bone grafting procedure. There were no superficial or deep infections following osteosynthesis. Using the modified Constant and Murley scoring, 11 patients had excellent results, 10 had good results and 2 had fair results and one patient had poor result. The mean Constant and Murley score was 11.95 in the preoperative period (range 0-29) and 73.70 (range 33-95) at the time of final followup and the improvement was statistically significant ( $P < 0.005$ , paired student's *t*-test).

## DISCUSSION

Dynamic compression plates have been utilized by several authors in the management of nonunion of humeral fractures and high rates of union have been claimed.<sup>6-11</sup> DCP can be applied quite satisfactorily in ununited fractures of humerus that have been treated conservatively with reasonable bone quality and without any implants *in situ* at the time of osteosynthesis. In patients who have had internal fixation using plate osteosynthesis as the index procedure, osteosynthesis is challenging due to the presence of stress shielding under plates, thinning of cortex and widening of screw holes due to screw loosening. Osteopenia interferes with the strength of purchase of screws during osteosynthesis

Table 1: Clinical details of patients

Age (years)	Sex	Duration of nonunion (months)	Site of nonunion	Previous implant	Type of treatment	Time to union (weeks)	C-M score (preop)	C-M score (postop)	Out come	Complication
36	M	8	Mid1/3	ILIM nail	LCP7H+BG+FSG	18	22	85	Excel	
25	M	9	Mid1/3	DCP 7H	LCP10H+BG+FSG	20	29	83	Excel	
47	F	9	Mid1/3	DCP 8H	LCP8H+BG	15	9	89	Excel	
46	M	10	Dist1/3	DCP10H	LCP7H+BG	24	17	83	Excel	Delayed union
40	M	7	Pro1/3	DCP 9H	LCP10H+BG	20	0	77	Good	
48	F	13	Mid1/3	DCP 7H	LCP8H+BG	26	12	81	Excel	Delayed union
24	M	2	Mid1/3	DCP 7H	LCP10H+BG	20	7	82	Excel	
54	M	276	Pro1/3	K nail	LCP7H+BG	19	14	50	Fair	
31	F	13	Mid1/3	IMIL nail	LCP8H+BG	16	18	72	Good	
30	M	12	Mid1/3	DCP 8H	LCP9H+BG	15	10	64	Good	
41	M	14	Mid1/3	IMIL nail	LCP11H+BG	8	25	95	Excel	
32	M	24	Pro1/3	DCP 8H	LCP8H+BG+FSG	12	13	68	Good	
35	F	22	Mid1/3	DCP 6H	LCP8H+BG	10	14	60	Good	
54	M	9	Dist1/3	DCP 6H	LCP7H+BG	11	20	88	Excel	
42	M	24	Mid1/3	DCP 9H	LCP9H+BG	16	28	92	Excel	
30	M	12	Mid1/3	DCP 7H	LCP8H+BG	20	6	87	Excel	Radial palsy
40	F	7	Mid1/3	DCP 7H	LCP8H+BG	18	13	71	Good	Radial palsy
35	M	10	Pro1/3	DCP 7H	LCP8H+BG	20	7	81	Excel	
57	M	14	Mid1/3	DCP 8H	LCP9H+BG	12	0	69	Good	
49	M	12	Mid1/3	DCP 9H	LCP8H+BG	12	0	75	Good	
45	M	9	Mid1/3	DCP 8H	LCP8H+BG	10	4	46	Fair	
48	M	10	Pro1/3	DCP 7H	LCP10H+BG	14	2	70	Good	
48	M	72	Mid1/3	K nail	LCP7H+BG	NA	17	33	Poor	Nonunion
26	M	10	Dist1/3	DCP 6H	LCP9H+BG	12	0	68	Good	

Mid 1/3 = Middle third, Pro 1/3 = Proximal third, Dist 1/3 = Distal third, IL IM nail = Interlocking intramedullary nail, K-nail = Küntscher nail, DCP = Dynamic compression Plate, 7 H = 7 holed, LCP = Locking compression plate, BG = Bone grafting (cancellous), FSG = Fibular strut graft, Excel = Excellent

using plates.<sup>12</sup> Screw holes made previously may also interfere with the purchase of screws inserted subsequently. PMMA bone cement has been used to improve the purchase of screws but carries the disadvantage of additional foreign body introduction and loosening.<sup>3</sup> Double plating using two DC plates at right angles to each other, use of on-lay allograft strut or in-lay fibular autograft strut along with DCP has been described.<sup>6,10,11</sup> On-lay grafts and double plating entail more extensive soft tissue stripping and devascularization of the humerus. Nonvascularized fibular auto grafts longer than 6 cm have been shown to have decreased capacity for incorporation and healing. Vascularized fibular grafts increase the complexity and cost of the osteosynthesis procedure.<sup>13</sup>

Locked intramedullary nails have been used for primary osteosynthesis of humeral shaft fractures. However, in the presence of nonunion, exchange nailing of humerus has not been as successful as that of tibia or femur. High failure rate of exchange nailing of humerus has been attributed to absence of cyclical loading due to weight bearing and higher amount of distractive and torsional loads on the humerus.<sup>14</sup> In addition, intramedullary nailing has been reported to carry higher complication rates including persistent pain in the shoulder, subacromial impingement, rotator cuff injury, iatrogenic fracture comminution or propagation, higher rates

of delayed union and nonunion. Radial nerve palsy has also been reported following closed intramedullary nailing of humerus.<sup>15,16</sup> Plate osteosynthesis has been considered by several authors to be better than intramedullary nailing for primary management of humeral shaft fractures.<sup>17-22</sup> Cortical thinning might be present in patients with nonunion following intramedullary nailing, due to the toggling of the loosened nail in the medullary canal. This was observed in four out of five patients with previous IM nails in our series. In two patients, the distal portion of the nail had broken through the cortex, causing complete loss of cortex on one side (requiring strut graft). Locking bolts also leave holes in the cortex that can interfere with sound purchase of screws inserted subsequently.

Ilizarov external fixation has been used by several authors in the management of humeral nonunion.<sup>23-28</sup> In the presence of infection, Ilizarov fixation has distinct advantages over internal fixation modalities. Disadvantages of Ilizarov fixation include the presence of a bulky implant on the arm, pin track infection; painful impingement of the frame on the chest wall and the possibility of neurovascular injury due to the wires.<sup>28</sup> Treatment of aseptic nonunion using internal fixation is likely to be associated with higher degree of patient comfort and compliance.

Ring *et al.* used LCP (locking compression plate) for

treating nonunion of humeral diaphysis fractures with osteoporosis.<sup>3</sup> They reported successful union in all the 24 patients they had treated using LCP. The average duration of nonunion of 26.3 months in our series (range: 7-276 months) was comparable to that of Ring *et al.* who had reported an average interval of 28 months (5 -192 months). The mean age of our patients was 46 years in comparison with the mean age of 72 years in the study by Ring *et al.* Another difference from the series by Ring *et al.* is that 9 out of 24 patients in their series had delayed union and 15 had nonunion, whereas in our series, all patients had established nonunion. Thirdly, all patients in our series had failed previous internal fixation. Our results suggest that LCP is associated with good outcome even in younger patients with higher activity levels and heavier demands on upper extremity function. While we concur with Ring *et al.* regarding the role of LCP in the presence of osteoporosis, the main focus of our study is to highlight the utility of LCP when either DCP or IM nail have failed to achieve union previously. Laboratory studies have also shown that locking plate constructs were superior to unlocked plate and screw constructs in osteoporotic diaphyseal humeral fracture models tested *in vitro* using cyclical torsional loading.<sup>29</sup> Contrary to the convention of leaving few empty screw holes in the LCP, we inserted screws in all the holes in the plate. It may be argued that insertion of screws in all the holes would make the construct very stiff. However, the presence of segmental bone loss and cortical defects necessitated the insertion of maximum possible screws so as to minimize the risk of plate failure. In our study, good outcome was noted in proximal third fractures as well as mid-shaft and distal third nonunions. Thus, LCP is useful at all levels of the humeral shaft. Nadkarni *et al.* have used LCP in two patients with nonunion with previously inserted intramedullary nail.<sup>4</sup> The nails were left *in situ* and LCP was applied along with bone grafting. Union occurred in about 6 months. Unlike Nadkarni *et al.*, we removed the previous intramedullary nail prior to LCP application. This facilitates better application of the plate and allows intramedullary placement of bone grafts.<sup>4</sup>

The strength of our study is that it was a prospective study that allowed comparison between the functional status in the preoperative and postoperative periods. The drawbacks of the present study are the absence of a control group for comparison with the treatment group. However, considerable data are available in the literature regarding the merits and demerits of other modalities of management of humeral diaphyseal nonunion. Comparison of outcomes in published literature with our results indicate that LCP and bone grafting is a reliable option to achieve union of humeral nonunion even in younger patients with higher physiological demands.

LCP seems to fare well even in the presence of significant bone loss requiring strut grafts. Along with LCP, cortico-cancellous iliac crest grafts are adequate in the absence of segmental bone defects. Autologous fibular strut grafts are often required along with iliac crest grafts for nonunions following previous IM nailing. Nonvascularized fibular auto grafts longer than 6 cm have been shown to have decreased capacity for incorporation and healing and we recommend combination of fibular strut grafts with iliac crest grafts in all cases.<sup>13</sup>

To conclude LCP is reliable in achieving union even in patients belonging to the younger age group with higher activity levels. A second episode of bone grafting may be necessary to accelerate union in some patients. The DCP is perhaps useful in the management of nonunion of humerus following conservative management (without previous implant). However, in the management of nonunion of humerus following a previously failed DCP or IM nail without infection, the LCP should probably be the implant of choice and it has been associated with excellent outcomes in the few studies on the topic performed so far.

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**How to cite this article:** Kumar MN, Ravindranath VP, Ravishankar MR. Outcome of locking compression plates in humeral shaft nonunions. *Indian J Orthop* 2013;47:150-5.

**Source of Support:** Nil, **Conflict of Interest:** Authors declare that there is no conflict of interest involved in this study. Authors have not received any financial support to conduct this study. Ethics committee approval – The study has been duly scrutinized and approved by the hospital ethics committee.

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