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. 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. Very few studies have been published about the use of locking compression plate (LCP) in the management of a nonunion of humeral fractures. 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.

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
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 intraoperatively. 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. 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](image_url)
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.\(^6\)\(^-\)\(^{11}\) 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) | Outcome | 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   | Delayed union |
| 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           | LCP 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 = Kuntscher 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. 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. 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. Nonvascularized fibular autografts 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.

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. 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. Plate osteosynthesis has been considered by several authors to be better than intramedullary nailing for primary management of humeral shaft fractures. 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. 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. 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
treated nonunion of humeral diaphysis fractures with osteoporosis. 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.

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. 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.

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.

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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