Minimally invasive plate osteosynthesis using a locking compression plate for diaphyseal humeral fractures

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ABSTRACT

Purpose. To assess outcomes of minimally invasive plate osteosynthesis (MIPO) using a locking compression plate (LCP) for 42 humeral shaft fractures.

Methods. 28 men and 14 women aged 18 to 68 (mean, 34; median, 29) years underwent closed reduction and MIPO using a LCP for type 12-A (n=26) and type 12-B (n=16) humeral shaft fractures. Eight of the patients were aged ≥50 years. Patients were followed up monthly until radiological union in at least 3 of the 4 cortices. Functional assessment was based on the Disabilities of Arm, Shoulder and Hand (DASH) score.

Results. The mean follow-up period was 25 (range, 14–35) months. The mean DASH score was 35.1 at month 3 and improved to 8.9 at month 6 and 5.2 at year 1. The mean angulation was 4º in the coronal plane and 7º in the sagittal plane. All fractures united after a mean of 14 weeks. Two patients with transverse fractures had delayed union and received bone marrow injections at 12 or 13 weeks; they achieved union at week 20. One patient developed a radial nerve palsy immediately after surgery and underwent surgical exploration through the anterolateral approach. The plate was re-applied, and the nerve recovered in 48 hours with full power in all the muscle groups.

Conclusion. MIPO with LCP is a safe and effective technique for fixation of diaphyseal humeral fractures, and results in faster bone union, better cosmesis, and minimal complications.

INTRODUCTION

Humeral shaft fractures are common owing to an increase in high-speed transportation and geriatric population. Such fractures account for 4 to 5% of all traumatic fractures. Treatment methods range from casting or functional cast bracing to external fixation, and from intramedullary nailing to open reduction and internal fixation with plates. Conservative treatments prolong immobilisation and result in a high incidence of fracture disease in the
future. Open reduction and internal fixation enables better reduction, but is associated with extensive soft-tissue stripping and disruption of the periosteal circulation of the fracture fragments, loss of fracture haematoma, and higher risks of infection and non-union. Moreover, poor purchase of conventional screws in osteoporotic bones may lead to implant failures. With the advent of locking compression plates (LCP), minimally invasive plate osteosynthesis (MIPO) has gained popularity. We assessed outcomes of MIPO using a LCP in 42 patients with humeral shaft fractures.

**MATERIALS AND METHODS**

Between June 2007 and May 2009, patients aged >18 years underwent MIPO using a LCP for types 12-A, 12-B, and 12-C closed diaphyseal humeral fractures. The patients were prospectively evaluated. Patients with multiple or open fractures, associated perarticular or intra-articular fractures of the shoulder or elbow, radial nerve palsy, or entailed polytrauma were excluded. Four patients in whom satisfactory closed reduction was not feasible by indirect methods were also excluded.

28 men and 14 women aged 18 to 68 (mean, 34; median, 29) years underwent MIPO using a LCP for type 12-A (n=26) and type 12-B (n=16) humeral shaft fractures. Eight of the patients were aged ≥50 years. The bone quality was assessed using radiographs; DEXA scan to assess osteoporosis was not used.

Patients were positioned supine and operated on by a single senior surgeon under general anaesthesia and image intensifier guidance. Two incisions were made over the anterior aspect of the arm, with the forearm supinated (Fig. 1). In the supinated position, the radial nerve moves away from the anteriorly placed LCP thus reducing the risk of radial nerve injury. The first incision was made at the deltopectoral groove. The cephalic vein lies in this interval. The vein was identified and protected while dissecting through the interval. Dissection was carried down to the humerus, where the anterior border of the humerus distal to the crest of greater tubercle was identified. The anatomic importance of the anterior humeral border is that it extends in almost a straight line up to the coronoid fossa, so that a straight plate can be placed on it without precontouring. In patients with big muscle bulk, the anterior part of the deltoid insertion was released. A blunt Cobb periosteal elevator was passed to make an extraperiosteal sub-muscular tunnel under the brachialis.

A narrow (n=26) or broad (n=16) 4.5-mm LCP was used depending on the width of the bone. The length of plate was sufficient to accommodate at least 2 screws in each fragment. In 4 patients aged 27 to 39 (mean, 33) years, only 2 screws in either of the fragments were inserted. In the remaining patients, ≥3 screws in either of the fragments were inserted. The plate was passed from the proximal incision to the distal fragment through the sub-muscular tunnel. The plate bypassed the fracture and was observed over the distal fragment under image intensifier. Fracture reduction was performed under image intensifier guidance by the indirect method, using gentle traction (Fig. 2). When needed, Steinman pins were placed in each of the fragments as joysticks to aid reduction. An assistant held the elbow semi-flexed with the forearm supinated. A second incision was made over the distal part of the plate, over the lateral border of biceps muscle, which was retracted medially to expose the brachialis muscle. Fibres of brachialis were...
split longitudinally, providing extraperiosteal access to the anterolateral distal humeral shaft. The radial nerve lies laterally, protected by the lateral portion of brachialis. A 4.2-mm drill bit was used to make a screw hole in the proximal fragment but the drill bit was not removed. Fine tuning of the fracture reduction was carried out under image intensifier guidance and another 4.2-mm drill bit was used to make a screw hole in the distal fragment. The drill bit was left in situ and reduction checked again under image intensifier. With the fracture satisfactorily reduced both the drill bits were replaced by appropriately sized locking head screws. After provisional fixation, at least 2 screws were placed in each fragment.

Postoperatively, an arm pouch sling was used for support. Assisted elbow and shoulder mobilisation was allowed on day 1. Sutures were removed on week 2. Patients were followed up monthly until radiological union in at least 3 of the 4 cortices (Fig. 3). Functional assessment was based on the Disabilities of Arm, Shoulder and Hand (DASH) score.10

RESULTS

The mean follow-up period was 25 (range, 14–35) months. The mean operating time was 52 (range, 40–82) minutes. The mean blood loss was 84 ml. The mean hospital stay was 2.8 days. The mean DASH score was 35.1 at month 3 and improved to 8.9 at month 6 and 5.2 at year 1 (Table). The mean angulation was 4° in the coronal plane and 7° in the sagittal plane. No patient had angulation of >10° in either plane. All fractures had united within a mean of 14 weeks. Two patients with transverse fractures had delayed union and inadequate callus formation, with pain at the fracture site and difficulty in activities of daily living. Both patients received bone marrow injections 12 or 13 weeks later and achieved union at week 20. No bone grafting or refixation was undertaken. One patient in whom a 14-hole broad LCP was used developed a radial nerve palsy immediately after operation. He underwent surgical exploration through the anterolateral approach and plate re-application, and the nerve recovered within 48 hours with full power restored in all the muscle groups. The LCP provided a potential space between the plate and the bone. The comminuted fracture may have resulted in a soft bed against which the nerve was pressed resulting in a neuropraxic injury to the nerve. Two patients had hypertrophic scars but none were functionally dissatisfied. No patient had a wound infection or implant failure warranting refixation.

Figure 3  Radiographs and photographs showing good bone union, range of motion, and cosmesis.
TABLE

| Sex/age (years) | Fracture type (AO classification) | Locking compression plate size | No. of screws used (proximal/distal) | Disabilities of Arm, Shoulder and Hand score | Range of motion of elbow at year 1 | Range of motion of shoulder at year 1* |
|----------------|-----------------------------------|-------------------------------|-------------------------------------|---------------------------------------------|----------------------------------|-------------------------------------|
| M/30           | 12-B1                             | 14-broad                      | 3/3                                 | M1                                         | 0º–130º                          | M1                                  |
| M/27           | 12-B1                             | 14-narrow                     | 2/2                                 | M1                                         | 0º–120º                          | M1                                  |
| M/68           | 12-A2                             | 14-narrow                     | 3/4                                 | M1                                         | 5º–130º                          | M1                                  |
| M/34           | 12-B1                             | 14-narrow                     | 3/3                                 | M1                                         | 0º–130º                          | M1                                  |
| F/25           | 12-A3                             | 14-narrow                     | 3/3                                 | M1                                         | 0º–135º                          | M2                                  |
| M/20           | 12-A2                             | 14-narrow                     | 3/3                                 | M1                                         | 5º–130º                          | M1                                  |
| M/23           | 12-A3                             | 14-broad                      | 4/4                                 | M1                                         | 0º–130º                          | M1                                  |
| M/26           | 12-A3                             | 14-narrow                     | 3/3                                 | M1                                         | 0º–130º                          | M1                                  |
| M/34           | 12-A3                             | 14-broad                      | 4/4                                 | M1                                         | 10º–110º                         | M2                                  |
| M/24           | 12-A2                             | 12-narrow                     | 3/3                                 | M1                                         | 0º–120º                          | M1                                  |
| M/62           | 12-B1                             | 14-broad                      | 3/3                                 | M1                                         | 0º–130º                          | M1                                  |
| M/26           | 12-B1                             | 12-narrow                     | 3/3                                 | M1                                         | 0º–120º                          | M1                                  |
| M/24           | 12-A2                             | 14-narrow                     | 3/3                                 | M1                                         | 0º–130º                          | M1                                  |
| M/32           | 12-B1                             | 12-narrow                     | 2/2                                 | M1                                         | 0º–130º                          | M1                                  |
| F/39           | 12-A3                             | 12-narrow                     | 3/3                                 | M2                                         | 0º–130º                          | M1                                  |
| M/20           | 12-A2                             | 14-narrow                     | 3/3                                 | M1                                         | 0º–135º                          | M2                                  |
| F/28           | 12-A2                             | 12-narrow                     | 3/3                                 | M1                                         | 0º–135º                          | M1                                  |
| M/26           | 12-A3                             | 12-narrow                     | 3/3                                 | M1                                         | 0º–130º                          | M1                                  |
| M/68           | 12-A2                             | 14-narrow                     | 3/4                                 | M1                                         | 0º–130º                          | M1                                  |
| M/24           | 12-A2                             | 12-narrow                     | 2/2                                 | M1                                         | 5º–130º                          | M1                                  |
| M/34           | 12-B1                             | 12-narrow                     | 3/3                                 | M1                                         | 0º–120º                          | M1                                  |
| M/24           | 12-A2                             | 12-broad                      | 3/3                                 | M1                                         | 0º–120º                          | M1                                  |
| M/24           | 12-A2                             | 12-narrow                     | 3/3                                 | M1                                         | 0º–120º                          | M1                                  |
| M/32           | 12-A2                             | 12-narrow                     | 2/2                                 | M1                                         | 4º–120º                          | M1                                  |
| F/39           | 12-A3                             | 12-narrow                     | 3/3                                 | M2                                         | 0º–130º                          | M1                                  |
| F/57           | 12-A1                             | 12-narrow                     | 3/3                                 | M1                                         | 0º–130º                          | M1                                  |
| F/21           | 12-B3                             | 12-broad                      | 3/3                                 | M1                                         | 0º–130º                          | M1                                  |
| M/20           | 12-B1                             | 12-broad                      | 3/3                                 | M1                                         | 0º–130º                          | M1                                  |
| F/60           | 12-A2                             | 12-narrow                     | 3/3                                 | M1                                         | 0º–130º                          | M1                                  |
| M/34           | 12-A3                             | 14-broad                      | 4/4                                 | M1                                         | 0º–130º                          | M1                                  |
| M/24           | 12-A2                             | 12-broad                      | 3/3                                 | M1                                         | 5º–130º                          | M1                                  |
| M/18           | 12-A3                             | 12-broad                      | 4/4                                 | M1                                         | 0º–120º                          | M1                                  |
| M/42           | 12-A1                             | 12-broad                      | 3/3                                 | M1                                         | 0º–120º                          | M1                                  |
| F/25           | 12-A3                             | 12-narrow                     | 3/3                                 | M2                                         | 4º–120º                          | M1                                  |
| M/30           | 12-B1                             | 12-broad                      | 3/3                                 | M2                                         | 0º–120º                          | M1                                  |
| M/30           | 12-B1                             | 14-broad                      | 3/3                                 | M1                                         | 0º–120º                          | M1                                  |
| M/26           | 12-B2                             | 14-broad                      | 3/3                                 | M1                                         | 0º–120º                          | M1                                  |
| F/60           | 12-A2                             | 12-broad                      | 3/3                                 | M1                                         | 0º–120º                          | M1                                  |

* Classification of the range of motion of the shoulder:

| Range of motion of the shoulder | M1 | M2 | M3 | M4 |
|----------------------------------|----|----|----|----|
| Flexion 0º–170º/180º             |    |    |    |    |
| Extension 0º–40º/45              |    |    |    |    |
| Abduction 0º–170º/180º           |    |    |    |    |
| Internal rotation 0º–80º/90º     |    |    |    |    |
| External Rotation 0º–80º/90º     |    |    |    |    |

DISCUSSION

MIPO has been successful in managing various fractures of the distal tibia, supracondylar femur, proximal tibia, and humeral shaft. The rate of non-union after plate fixation can be as high as 5.8%, and the time to union ranged from 12 to 32 weeks with the mean being 16.2 weeks. In our series, fractures healed faster (mean, 12.1 weeks). This was attributed to more biological fixation of the fracture, preservation of fracture haematoma, and better quality of fixation by the angular stable LCP.
Iatrogenic radial nerve palsy is a common complication of the open plating technique. Despite meticulous radial nerve protection, the incidence of iatrogenic radial nerve palsies has been reported to be 5.1% to 17.6%. In our series, no pressure was exerted on the drill while drilling the far cortex of the humerus. Care was taken not to overshoot the bone while measuring the depth of the drill hole and tapping the bone. To avoid radial nerve entrapment below the plate, the arm should be kept fully supinated and the plate passed anteriorly, thus avoiding the lateral pillar. This enables the radial nerve to be clear of the plate by 2 to 5 mm. MIPO also minimises intra-operative blood loss. The limitations of our study were a small cohort, relatively less complex fracture patterns, and the absence of a control group who underwent open plating. Nonetheless, MIPO with a LCP is a safe and effective technique for fixation of diaphyseal humeral fractures, and results in faster bone union, better cosmesis, and minimal complications. MIPO is not suitable for fractures in the distal third humerus owing to the risks of radial nerve entrapment under the plate. Radiation exposure through the image intensifier is a concern.

REFERENCES

1. Paris H, Tropiano P, Clouet D’orval B, Chaudet H, Poitout DG. Fractures of the shaft of the humerus: systematic plate fixation. Anatomic and functional results in 156 cases and a review of the literature [in French]. Rev Chir Orthop Reparatrice Appar Mot 2000;86:346–59.
2. Camden P, Nade S. Fracture bracing of the humerus. Injury 1992;23:245–8.
3. Bell MJ, Beauchamp CG, Kellam JK, McMurtry RY. The results of plating humeral shaft fractures in patients with multiple injuries. The Sunnybrook experience. J Bone Joint Surg Br 1985;67:293–6.
4. Marsh JL, Mahoney CR, Steinbronn D. External fixation of open humerus fractures. Iowa Orthop J 1999:19:35–42.
5. Flinkkila T, Hyvonen P, Lakovaara M, Linden T, Ristiniemi J, Hamalainen M. Intramedullary nailing of humeral shaft fractures. A retrospective study of 126 cases. Acta Orthop Scand 1999;70:133–6.
6. Zhiquan A, Bingfang Z, Yeming W, Chi Z, Peiyan H. Minimally invasive plating osteosynthesis (MIPO) of middle and distal third humeral shaft fractures. J Orthop Trauma 2007;21:628–33.
7. Pospula W, Abu Noor T. Percutaneous fixation of comminuted fractures of the humerus: initial experience at Al Razi hospital, Kuwait. Med Princ Pract 2006;15:423–6.
8. Jiang R, Luo CF, Zeng BF, Mei GH. Minimally invasive plating of complex humeral shaft fractures. Arch Orthop Trauma Surg 2007;127:531–5.
9. Apivatthakakul T, Arpornchayanon O, Bavornratanevech S. Minimally invasive plate osteosynthesis (MIPO) of the humeral shaft fracture. Is it possible? A cadaveric study and preliminary report. Injury 2005;36:530–8.
10. Altman GT, Gallo RA, Molinero KG, Muffly MT, Mascarenhas L. Minimally invasive plate osteosynthesis for proximal humerus fractures: functional results of treatment. Am J Orthop (Belle Mead NJ) 2011;40:E40–7.
11. Cole PA, Miclau T 3rd, Ly TV, Switzer JA, Li M, Morgan RA, et al. What’s new in orthopaedic trauma. J Bone Joint Surg Am 2008;90:2804–22.
12. Bottlang M, Doornink J, Lujan TJ, Fitzpatrick DC, Marsh JL, Augat P, et al. Effects of construct stiffness on healing of fractures stabilized with locking plates. J Bone Joint Surg Am 2010;92(Suppl 2):12–22.
13. Lim KE, Yap CK, Ong SC, Aminuddin. Plate osteosynthesis of the humerus shaft fracture and its association with radial nerve injury—a retrospective study in Melaka General Hospital. Med J Malaysia 2001;56(Suppl C):8–12.
14. Livani B, Belangero WD, Castro de Medeiros R. Fractures of the distal third of the humerus with palsy of the radial nerve: management using minimally-invasive percutaneous plate osteosynthesis. J Bone Joint Surg Br 2006;88:1625–8.