Minimally Invasive Plate Osteosynthesis Using a Helical Plate for Metadiaphyseal Complex Fractures of the Proximal Humerus

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abstract

Minimally invasive plate osteosynthesis (MIPO) has been used for humeral shaft fractures, but concerns exist about soft tissue injuries. The purpose of this study was to report the surgical technique and clinical outcomes of MIPO using a helical plate for metadiaphyseal complex humeral shaft fractures. Twelve patients with acute displacement involving proximal and middle third humeral shaft fractures (AO type C) were treated using the MIPO technique with a helical plate. Fracture union, complications, and functional outcomes were evaluated using the Constant-Murley score and Mayo Elbow Performance Score (MEPS) at final follow-up. All fractures united at an average of 17.9 weeks. No major complications, such as neurovascular injury, infection, and nonunion, were observed. Mean Constant-Murley and MEPS scores at final follow-up were 88.6 and 97.9, respectively. A MIPO technique using a helical plate can be a useful surgical option for metadiaphyseal complex fractures of the humeral shaft.
Minimally invasive plate osteosynthesis (MIPO) has been accepted as a biological approach for fracture management. The technique has evolved, and it has recently been used for humeral shaft fractures and evaluated in a cadaveric study. Several clinical studies using different approaches, including implants and surfaces fixed with a plate, have been reported. However, there are still concerns about injury to the muscles, tendons, and neurovascular structures with these new techniques. These complications may occur due to the anatomical characteristics of the humerus and surrounding soft tissues, and the risk may be increased when a longer straight plate is used.

The current authors have performed the MIPO technique using a helical plate to avoid soft tissue injuries. A helical plate was recently introduced for the fixation of long bones and for clinical applications. A helical plate on the humeral shaft facilitates insertion of a long plate and is applied along the different aspects of the humeral shaft to preserve the muscles and avoid neurovascular structures. Considering these advantages of the helical plate and the MIPO technique, the authors developed a new surgical technique for fractures of the proximal and middle humeral shaft. The purpose of this study was to report the surgical technique and clinical outcomes of MIPO with a helical plate for metadiaphyseal complex humeral shaft fractures.

**Materials and Methods**

Approval was obtained from the institutional review board of ethics, and informed consent was obtained from patients. From March 2007 to February 2012, twelve consecutive patients with an acute displaced metadiaphyseal fracture of the proximal and middle humeral shaft were treated using the MIPO procedure with a helical plate. Indications for this technique included acute displacement, either comminuted or segmental, involving fracture of the proximal and/or middle third humeral shaft (AO/OTA classification 12: C1, C2, and C3). Transverse or short oblique proximal or middle third fractures (A and B), which could be fixed by nail or conventional plate fixation after open reduction, were not indicated. Other exclusion criteria were open fractures, pathologic fractures, nonunion, and fracture associated with radial nerve injury. A single surgeon (J.-G.M.) in 1 center performed all surgeries.

The patients were 5 men and 7 women with an average age of 58.8 years (range, 37-74 years). The dominant extremity was involved in 7 patients, and all fractures were unilateral. The mechanism of injury was a traffic accident in 7 patients, fall from a standing height in 4 patients, and fall from steps in 1 patient. One patient had an associated proximal tibia fracture. According to the AO/OTA classification, 5 patients had a C1 fracture, 1 had C2, and 7 had C3. All fractures were fixed using a narrow 4.5/5.0-mm locking compression plate with 10 holes or a long Proximal Humeral Internal Locking System (PHILOS; Synthes, Paoli, Pennsylvania) plate with 12 holes; these plates were twisted in a helical shape. All patients were followed until the fracture was healed. Regular follow-up was performed at 1, 2, 3, 4, and 6 months and 1 year. Follow-up was continued after this period if necessary. At each follow-up, radiographs were obtained to assess the status of the fracture union, and shoulder and elbow function was evaluated. Union was defined as cortical continuity or bridging callus in 3 of the 4 cortices on anteroposterior and lateral humeral radiographs and the absence of pain. Functional outcomes were assessed using the Constant-Murley score for the shoulder and the Mayo Elbow Performance Score (MEPS) for the elbow at final follow-up (Table).

**Surgical Technique**

All patients were placed in the supine position under general anesthesia. The upper limb was positioned on a radiolucent table. The limb was abducted to help in reduction and to obtain anteroposterior and lateral views using an image intensifier. A long locking compression plate (a narrow 4.5/5.0-mm locking compression plate with 12 holes or a long PHILOS plate with 10 holes) was contoured preoperatively using a cadaveric dry humerus as a template. The proximal part of the plate required no contouring. The middle part of the plate was twisted to correspond to the mid-shaft of the humerus. Gradual twisting was performed so that the distal part would lie on the anteromedial surface of the humerus.

Two minimal skin incisions were made. The proximal part of the humerus was exposed using a deltopectoral approach, with a 4-cm skin incision from the anterolateral acromion. Cephalic vein dissection was restricted to the lateral side to avoid damaging the vessels supplying the humeral head. The lateral aspect of the humeral head and neck were exposed for application of the plate. Distally, a 4-cm skin incision was made on the anterior aspect of the distal humerus. After medial retraction of the biceps muscle, the lateral antebrachial cutaneous nerve was identified and protected. The brachial muscle was split into the medial and lateral portions, and the anterior aspect of the humerus was exposed. Once the proximal and distal parts of the humerus were exposed, the precontoured plate was introduced under the brachialis, but extraperiosteally. Care was taken not to damage the brachialis while introducing the plate. With a plate or long periosteal elevator, a submuscular tunnel was prepared from the lateral aspect of the proximal humerus to the anteromedial aspect of the distal humerus, passing over the fracture site. The plate could be inserted in an antegrade manner using the proximal incision or in a re-
rograde manner from the distal incision. The plate was inserted with rotation of the helically contoured plate, so that the distal part was against the medial surface of the distal humerus (Figure 1). The fracture was reduced by manipulation and traction to obtain a reasonable alignment. Reduction was checked in both the anteroposterior and lateral views using the image intensifier. The position of the plate was checked to ensure that it would not cause impingement in the shoulder. After insertion of a threaded drill sleeve and predrilling, locking screws were inserted into the proximal and distal fragments using a standard technique. If necessary, a conventional cortical screw was used to improve the alignment and reduction. Four to 6 screws were inserted at the proximal and distal fragments of the humeral shaft. Standard skin closure was performed. The patients were allowed active range of motion exercises starting the day after surgery (Figure 2).

RESULTS
All patients were periodically followed for more than 12 months (range, 12-50 months). All fractures united at an average of 17.9 weeks (range, 12-32 weeks). One patient was diagnosed with delayed union; the fracture united at 32 weeks. All patients had good alignment except 1, who had a varus alignment of 11°. Average Constant-Murley score was 88.6 (range, 71-100). Average active shoulder flexion was 164.5° (range, 135°-180°), and average shoulder abduction 153.7° (range, 105°-180°). Average MEPS was 97.9, and all patients were rated as excellent. The implant was removed in 1 patient who reported subacromial impingement. No major complications, such as neurovascular injury, infection, and nonunion, were noted (Figure 3).

DISCUSSION
This article describes a novel MIPO technique with a helical plate for complex humeral shaft fractures. These fractures can be managed by various methods, including conservative treatment, external fixation, intramedullary nailing, conventional plating, and MIPO. Conservative treatment using a splint or brace could be indicated in minimally displaced fractures or those maintained with adequate closed reduction. However, complex humeral shaft fractures involving the proximal one-third are difficult to reduce and maintain the abducted proximal fragment. Indications for surgical treatment of humeral shaft fractures have been well documented by McKee14 and widely accepted. These include failure to obtain and maintain adequate closed reduction, segmental fracture, intra-articular extension, polytrauma, or multiple injuries. The current

### Table

| Patient No./ Sex/Age, y | Injury Mechanism | AO/OTA Class | Plate Used | F/U, mo | Union Time, wk | Complications | C-M Scored | MEPS*
|------------------------|------------------|--------------|-----------|--------|----------------|--------------|------------|--------
| 1/M/37                 | Traffic accident | C3           | LCP 12H   | 50     | 16             | Subacromial impingement | 71         | 95     |
| 2/M/74                 | Fall from height | C1           | LCP 12H   | 16     | 32             | Delayed union | 78         | 90     |
| 3/F/66                 | Fall from step   | C1           | LCP 12H   | 12     | 12             | No            | 95         | 100    |
| 4/F/59                 | Traffic accident | C3           | LCP 12H   | 14     | 15             | No            | 82         | 100    |
| 5/M/42                 | Traffic accident | C3           | LCP 12H   | 15     | 24             | No            | 85         | 100    |
| 6/F/65                 | Traffic accident | C1           | PHILOS 9H | 12     | 16             | No            | 100        | 95     |
| 7/F/60                 | Traffic accident | C1           | PHILOS 10H | 20    | 18             | No            | 91         | 100    |
| 8/F/61                 | Fall from height | C2           | PHILOS 10H | 24    | 20             | No            | 85         | 100    |
| 9/M/78                 | Fall from height | C3           | PHILOS 10H | 12    | 21             | No            | 98         | 95     |
| 10/F/60                | Traffic accident | C3           | PHILOS 10H | 14    | 14             | No            | 89         | 100    |
| 11/M/41                | Traffic accident | C3           | PHILOS 10H | 13    | 12             | No            | 90         | 100    |
| 12/F/63                | Fall from height | C1           | PHILOS 10H | 12    | 15             | No            | 100        | 100    |

Abbreviations: Class, classification; C-M, Constant-Murley; F/U, follow-up; LCP, locking compression plate; MEPS, Mayo Elbow Performance Score.

*Mean age=58.8 years.
*Mean F/U=17.8 months.
*Mean union time=17.9 weeks.
*Mean C-M score=88.6.
*Mean MEPS=97.9.
authors’ technique can be indicated for comminuted or segmental fractures involving fracture of both the proximal and middle third of the humeral shaft; treatment of these fractures is challenging with conventional plating. To the authors’ knowledge, this is the first report describing the MIPO technique with a helical plate using a combined deltopectoral and brachialis-splitting approach.

Minimally invasive plate osteosynthesis has been accepted as a biological approach for fracture management. Recently, this technique has been used to treat humeral shaft fractures and has shown satisfactory outcomes. However, the technique may involve surgical risks and challenges because of injuries to the muscles, tendons, and neurovascular structures. These possible complications may occur due to the anatomical characteristics of the humerus and surrounding soft tissues. This risk can increase if a longer straight plate is applied to the entire humeral shaft.

One potential proximal humerus complication with the MIPO technique is injury to the axillary nerve. This iatrogenic injury is a major concern when using a deltoid-splitting approach and percutaneous screw insertion. In proximal humerus fractures, the deltopectoral approach is commonly used, but this approach requires extensive dissection. The current authors used a minimal anterolateral approach that does not require extensive soft tissue dissection but provides sufficient space to visualize the proximal screw holes in the plate. During MIPO for humeral shaft fracture, another structure at risk of injury is the long head of the biceps tendon, which courses down the anterior aspect of the proximal humerus. Anterior plating and percutaneous screw insertion from the anterior to the posterior can injure the biceps tendon. In addition, the musculocutaneous nerve, crossing from the medial to lateral side, needs to be considered during percutaneous screw insertion in the anteriorly placed plate. Finally, the distal extent of the deltoid muscle limits longer plate insertion. A laterally placed straight plate may detach the deltoid muscle, which is undesirable. The anteriorly twisted plate in the current technique can preserve deltoid muscle insertion.

During the MIPO technique for humeral shaft fracture, the radial nerve is a major concern in the middle and distal humerus. The occurrence of iatrogenic radial nerve injury may be affected by the surgical approach, forearm position, location of the plate, and shape or length of the plate. A cadaveric study demonstrated that in anterior plating, the radial nerve was safe in full supination of the forearm, with an average distance of 3.2 mm between the lateral border of the plate and the radial nerve. However, another cadaveric study found that the risk zone was variable, and the authors suggested that percutaneous insertion of screws should be avoided in the distal aspect of the humerus. In the current technique, this concern is specifically addressed by modifying the approach to the distal humerus anteromedially with a helical plate.

Helical implants have been developed to enable implantation at different aspects and zones of the bone. Since the concept of helical implants was introduced, several clinical applications of these implants have been attempted in long bones, including the femur, tibia, and humerus. The feasibility of a helical plate for the humerus has been described in several cadaveric studies. Gardner et al reported that the musculocutaneous nerve was the main structure at risk during application of a helical plate. Clinical applications of the helical plate in humeral fractures have been recently described. Yang reported 10 cases of humeral shaft fracture, including AO type B and C, which were treated by open or closed reduction with helical plate fixation. He used a shorter plate fitting the proximal and middle third of the humerus. The current authors used a longer plate, which covered the entire length of the humeral shaft. Gill and Torchia reported nonunion of the humeral shaft.
shaft using a helical plate. They stated that the main advantage of the helical plate was preservation of the deltoid insertion. From a biomechanical perspective, a helical plate has advantages for some fractures. Krishna et al. demonstrated that compared with a straight plate, a helical plate had superior holding strength and reduced stress shielding. They also found that a helical plate enhanced the stiffness and stability of the fractured bone by wrapping around the fractured bones on its different interfaces. In the current study’s patients, a 90° twisted helical plate could cover the entire humeral shaft, from the anterolateral aspect of the humerus proximally to the anteromedial aspect of the humerus distally.

Preparation of a helical plate involves some technical difficulties. Currently, helical plates for the humerus are not commercially available. Therefore, the authors had to contour a straight plate into a helical plate. Proper contouring for a helical shape is difficult using a straight plate. However, a locking compression plate, which is an internal fixator, does not have to be contoured accurately to fit the surface of the humerus. The gap between the bone and plate preserves periosteal blood supply, which is beneficial to bony union. Another possible concern is the damage to the locking thread due to the twisting of the plate, although the authors have not encountered this complication in their patients. They believe that this would not be a serious concern because the twist of the plate usually lies over the fracture site rather than proximal and distal part of plate. Furthermore, the damage to the locking threads, if present, can be checked preoperatively, and a conventional screw in a combination hole can be used, if necessary. Nevertheless, manufacturing of commercially available helical plates of the appropriate shape is required.

Despite technical difficulties and the small number of patients in the current study, the authors’ technique has several advantages, especially for metadiaphyseal complex humeral shaft fractures. Considering all findings and the fact that...
this technique has the advantage of being minimally invasive, it can be used to avoid soft tissue injuries of the axillary nerve, radial nerve, and biceps tendon and preserve deltoid muscle insertion. In addition, it facilitates plate insertion along the different aspects of the humeral shaft without extensive dissection. Thus, the authors’ new MIPO technique using a helical plate can be a useful surgical option for metadiaphyseal complex fractures of the humeral shaft.

REFERENCES

15. Brunner A, Thormann S, Babst R. Mini-
