Minimally Invasive Plating Osteosynthesis for Mid-distal Third Humeral Shaft Fractures

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Abstract

Mid-distal third humeral shaft fractures can be effectively treated with minimally invasive plating osteosynthesis and intramedullary nailing (IMN). However, these 2 treatments have not been adequately compared. Forty-seven patients (47 fractures) with mid-distal third humeral shaft fractures were randomly allocated to undergo either minimally invasive plating osteosynthesis (n=24) or IMN (n=23). The 2 groups were similar in terms of fracture patterns, fracture location, age, and associated injuries. Intraoperative measurements included blood loss and operative time. Clinical outcome measurements included fracture healing, radial nerve recovery, and elbow and shoulder discomfort. Radiographic measurements included fracture alignment, time to healing, delayed union, and nonunion. Functional outcome was satisfactory in both groups. Mean American Shoulder and Elbow Surgeons score and Mayo score were both better for the minimally invasive plating osteosynthesis group than for the IMN group (98.2 vs 97.6, respectively, and 93.5 vs 94.1, respectively; \( P < .001 \)). Operative time was shorter and less intraoperative blood loss occurred in the minimally invasive plating osteosynthesis group than in the IMN group. Average time to union was similar in both groups. Primary union was achieved in 23 of 24 patients in the minimally invasive plating osteosynthesis group and in 22 of 23 in the IMN group. Minimally invasive plating osteosynthesis may have outcomes comparable with IMN for the management of mid-distal third humeral shaft fractures. Minimally invasive plating osteosynthesis is more suitable for complex fractures, especially for radial protection and motion recovery of adjacent joints, compared with IMN for simple fractures.
Surgical treatment of humeral shaft fractures, when indicated, is controversial. Intramedullary nailing (IMN)\(^1\,^2\) and minimally invasive plating osteosynthesis,\(^3\) which are both types of biological fixation, are safe and effective options for treating mid-distal third humeral shaft fractures. A divergence of opinion exists in the literature between the values of IMN and minimally invasive plating osteosynthesis for the treatment of mid-distal third humeral shaft fractures. Modern surgery favors treatment modalities that are minimally invasive, have low morbidity, and provide rapid recovery and prompt return to work and activities of daily living.\(^4\) Evidence shows the superiority of biological fixation over a stable mechanical fixation.\(^5\) This leads to the development and improvement of biological fixation techniques for fractures and the development of stabilization systems that help achieve biological fixation.\(^6\) Both procedures can provide excellent bone healing due to their biomechanical advantages.\(^7\)

To the current authors’ knowledge, these 2 minimally invasive treatments have not been adequately compared. Although these 2 procedures are generally considered minimally invasive, differences exist when they are compared. Both methods have inherent advantages and disadvantages that should be considered by the surgeon and patient when selecting treatment. From the standpoint of biomechanics, the disadvantages between these treatments vary. Encouraging results from recent advances in internal fixation techniques and minimally invasive skills have led to the expansion of surgical indications for such fractures and a dilemma concerning the procedure of choice.

This prospective randomized study compared the effectiveness and potential risks of these 2 approaches, which were applied to mid-distal third humeral fractures. The authors analyzed the features of each approach and which approach was appropriate in different situations.

**Materials and Methods**

This study was performed with the approval of the authors’ medical ethics committee. Between October 2007 and August 2010, forty-seven consecutive patients with a mid-distal third humeral shaft fracture underwent either minimally invasive plating osteosynthesis or IMN. Intramedullary nailing procedures consist of antegrade and retrograde nailing. All patients were skeletally mature. Orthopedists selected the patients based on randomized numbers generated by using the sealed-envelope method. Patients were prospectively randomized into 1 of 2 treatment groups using a sealed-envelope method. The IMN group (n = 23) underwent antegrade and retrograde locked IMN fixation, among which 14 patients underwent retrograde IMN. The second group underwent minimally invasive plating osteosynthesis (n = 24). All fractures were closed injuries in both groups.

Inclusion criteria were patients with closed displaced unstable middle or distal third humeral shaft fractures or both. Exclusion criteria were undisplaced middle or distal third humeral shaft fracture with associated radial nerve injury, proximal shaft fracture, skeletal immaturity, open fracture, intra-articular fracture, and pathological fracture. All patients were appropriately clinically and radiologically evaluated before surgical intervention was offered. All fractures were classified in order of increasing fracture complexity severity: type A was simple, type B was wedge, and type C was comminuted.

**Retrograde IMN Approach**

The patient is placed in the lateral or supine position, with the injured arm leaning against the chest. A midline longitudinal incision is made over the posterior aspect of the distal humerus directly down to the olecranon fossa by splitting the triceps muscle. The posterior fat pad in the fossa is preserved as much as possible. The entry portal is at the superior edge of the olecranon fossa. Multiple drill holes are first created in the medullary canal and then connected with a burr to form a longitudinal slot approximately 1.5 to 2 cm long. Passing the guide pin, fracture reduction, medullary canal reaming, and nailing are almost the same as described for antegrade IMN. The locking screws are directed from a posterior-to-anterior or posterolateral-to-anteromedial direction. The number of locking screws used and the intraoperative checkup with the image intensifier are also the same as for antegrade IMN.

**Surgical Technique**

**Antegrade IMN Approach**

A longitudinal skin incision is made over the greater tuberosity. The deltoid muscle is split, and the subdeltoid bursa is incised and retracted. A small longitudinal incision is made on the supraspinatus tendon right medial to the greater tuberosity. While protecting the rotator cuff, a drill bit is used to create a tunnel into the humeral canal. The guide pin is passed across the fracture site while the fracture is reduced in a closed manner. The entry portal and the medullary canal are limited reamed. For stronger or more curved bone, overreaming of 1 or 2 mm may be necessary. For osteoporotic bone with a wider canal, reaming may be unnecessary. The extent of over-reaming depends on trial nail insertion. The nail is inserted manually along the guide pin until it countersinks in the humeral neck. The nail should pass the fracture site by at least 5 cm. Transfixing screws are inserted from a lateral-to-medial direction. The axillary and radial nerves are protected by blunt dissection of the soft tissue. Two locking screws at either nail end are used for fractures with a wider canal, and 1 screw is used for fractures with a smaller canal. An image intensifier is used intraoperatively. If a residual fracture gap exists, compression is exerted by either manual compression of the fracture fragments or a backstrike technique before static locking. Finally, the rotator cuff, bursa, and deltoid muscle are repaired.
Minimally Invasive Plating Osteosynthesis

The operation is performed with the patient in a supine position with abduction of the injured arm under image intensifier control. The cephalic vein is preserved if possible, and the proximal humeral shaft is exposed through the deltopectoral interval. A distal incision of 4 to 5 cm is made on the anterior side proximal to the elbow crease. The sensory branch of the musculocutaneous nerve is usually identified and protected after retracting the biceps muscle. The brachialis muscle is split by blunt dissection. A submuscular tunnel is then developed using the plate and locking sleeve as a handle. Under image intensifier control, reduction is achieved by manual traction, and an additional external fixator is used to maintain the reduction depending on how difficult it is to accomplish the reduction by performing manual traction. A 9- to 12-hole plate is used for fracture stabilization and is fixed on the anterior surface of the humeral shaft. In general, 3 bicortical screws (either locking or cortical screws) are inserted on each side of the fracture. However, 2 distal shaft fractures were fixed with 2 screws. No radial nerve exploration is performed.

Postoperative Course

Postoperatively, all patients’ arms were supported in neck slings for 1 week. Shoulder and elbow range of motion (ROM) were initiated at least 2 weeks preoperatively. Patients were instructed to move their shoulders and elbows and to use their operated limbs to perform activities of daily living (ie, eating and hygiene). Follow-up clinical examinations and anteroposterior and lateral radiographs were obtained every 5 to 7 weeks until bony union was achieved. Patients with no other problems were discharged 1 week postoperatively; further radiographs were obtained at 6- and 12-month follow-up.

Data Collection

Operative time was defined as the time from skin incision to closure. Union was defined as the absence of pain and presence of bridging callus on radiographs of the humerus. Nonunion was defined as the absence of fracture union 6 months postoperatively and no sign of further fracture healing. Malunion was defined as an angle of 2 parts of the line of the previous fracture segment greater than 15° (range, 15°-90°). Follow-up time was defined as the duration between the operation and the last regular follow-up before this article was written. Shoulder and elbow ROM were measured using a goniometer at the time of union. Postoperatively, operative time, intraoperative blood loss, and time to union were compared. Clinical assessment consisted of using the American Shoulder and Elbow Surgeons scoring system for shoulder joints and Mayo performance score for elbow joints. Higher scores in both systems correspond with better joint function. Range of motion and muscle power were rated by comparing the injured and uninjured arms. Functional recovery at final follow-up was compared between 23 patients who underwent IMN and 24 who underwent minimally invasive plating osteosynthesis. Complications, such as nonunion, malunion, infection, nerve injury, and implant failure, were also observed during follow-up (Table 1). Due to intraoperative radiation exposure, the time of exposure should be collected. Union rates were also compared.

Statistical Analysis

Statistical analysis was performed using SPSS version 13 software (SPSS, Inc, Chicago, Illinois). The demographic and fracture characteristics of the 2 groups
were compared using chi-square test or Fisher’s exact test for nonparametric categorical variables or by using Student’s t test for parametric variables. Operative time, intraoperative blood loss, union rate, and time to union were compared using Student’s t test and complications were compared using Fisher’s exact test.

RESULTS

Fifty-six patients (56 humeral shaft fractures) were entered in this study and randomized by a sealed-envelope method after considering the inclusion and exclusion criteria. Locked IMNs were used in 4 patients assigned to the IMN group due to 1 surgeon’s (K.L.) preference. Five patients did not undergo the operation because they could not afford it. These 9 patients were excluded from the study. The remaining 47 patients were included in the study.

No statistically significant differences existed in patient demographics or fracture characteristics, including sex, age, and AO-OTA classification, between the 2 groups (Table 2). Causes of injury were motorcycle accident (n=7), fall (n=18), motor vehicle accident (n=16), rolled in a factory machine while working (n=3), and crushed by a huge stone (n=3).

Similar distributions of injury mechanisms existed between the 2 groups. Mean follow-up for all patients was 14.5 months (range, 7-20 months), 15 months (range, 10-16 months) for the IMN group, and 14 months (range, 7-20) for the minimally invasive plating osteosynthesis group. Mean operative time for the minimally invasive plating osteosynthesis group (95 minutes; 95% confidence interval [CI], 90.30-99.70 minutes) was shorter than for the IMN group (126 minutes; 95% CI, 121.04-130.96 minutes; P<.001). Primary union was achieved in 23 (95.8%) of 24 patients in the minimally invasive plating osteosynthesis group (Figure 1) and 22 (95.7%) of 23 in the IMN group (Figure 2). Mean healing time was 17.1 weeks (95% CI, 16.30-17.90 weeks) for the minimally invasive plating osteosynthesis group and 16.8 weeks (95% CI, 16.25-17.35 weeks) for the IMN group. Mean American Shoulder and Elbow Surgeons and Mayo scores were 98.2 and 97.6, respectively, for the minimally invasive plating osteosynthesis group and 93.5 and 94.1, respectively, for the IMN group. Intraoperative radiation exposure time was 197 seconds (95% CI, 172.18-221.82 seconds) in the IMN group and 216 seconds (95% CI, 197.01-235.00 seconds) in the minimally invasive plating osteosynthesis group. No significant difference existed between the radiation exposure time of the 2 groups (P=.120). Average time to union was similar in both groups (P=.526). Operative time and intraoperative blood loss were significantly lower in patients who underwent minimally invasive plating osteosynthesis compared with those who underwent IMN (P<.001 for both). Patient results are shown in Table 1.

All patients in both groups were able to return to their previous jobs within 6 months postoperatively. Due to nail impingement in the IMN group, the fractures healed with simultaneous shoulder abduction and elbow flexion restrictions (n=1), shoulder abduction restrictions (n=3), and elbow flexion restrictions (n=2). These patients had decreased shoulder or elbow joint ROM (abduction, forward flexion, or stretch) greater than approximately 25° to 45° compared with the uninjured side. They underwent nail extraction once fracture union occurred. One nonunion and 1 malunion occurred in the minimally invasive plating osteosynthesis group, and 2 nonunions and 1 malunion occurred in the IMN group. To treat nonunion, the authors extracted the nail or the plating and performed open reduction and internal fixation combined with a graft technique. All nonunions were commuted fractures of distal shaft after minimally invasive plating osteosynthesis and IMN, probably due to inappropriate fixation and poor stability. Postoperatively, 3 radial nerve injuries occurred in IMN group and 1 occurred in the minimally invasive plating osteosynthesis group. All 4 nerve deficits resolved completely within 3 months. No patients sustained deep infection, intraoperative

### Table 2

<table>
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<tr>
<th>Demographic</th>
<th>MIPO Group (n=24)</th>
<th>IMN Group (n=23)</th>
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</tr>
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<td>Rolled in machine</td>
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<td>2</td>
<td></td>
</tr>
<tr>
<td>Crushed by huge stone</td>
<td>2</td>
<td>1</td>
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</table>

**Abbreviations:** IMN, intramedullary nailing; MIPO, minimally invasive plating osteosynthesis.

*Age of the 2 groups was compared using the independent sample Student’s t test for parametric variables. Other demographic and fracture characteristics of the 2 groups were compared using the chi-square test or Fisher’s exact test for nonparametric categorical variables. Patient demographics and clinical characteristics were similar in the 2 groups (P>.05).
or postoperative fracture, heterotopic ossification, or neurological complication. Their nails or plates were removed exclusively at their request.

**DISCUSSION**

The optimal treatment of mid-distal humeral shaft fractures has not been clearly defined. Intramedullary nailing and minimally invasive plating osteosynthesis have been the treatments of choice for mid-distal shaft fractures when operative treatment is needed. The current authors found that both IMN and minimally invasive plating osteosynthesis can achieve similar good outcomes for mid-distal humeral shaft fractures with some slight variances between them. Patients who underwent IMN required a longer time for shoulder and elbow functional recovery than those who underwent minimally invasive plating osteosynthesis. The minimally invasive plating osteosynthesis approach required shorter a operative time but was more technically demanding.

According to the recent modern biological-fixation theory, minimally invasive plating osteosynthesis and IMN have emerged as typical surgical biologic fixation procedures.

Neither the fracture sites nor the radial nerves need to be dissected when performing minimally invasive plating osteosynthesis using an anteriorly placed plate to treat humeral shaft fractures. However, during IMN, the nail needs to be inserted into the bone marrow cavity, including the fracture segment. For intraoperative clinical application, the danger zone for the radial nerve is approximately three- (37.5%) to five-eighths (62.5%) of the humeral length measured from the tip of the acromion process to the lateral epicondyle when the humeral length is divided into 8 parts. The zone that had radial nerve injuries averaged from 10.8 to 17.59 cm (36.35% to 59.20%) of the humeral length, and the most dangerous screws that penetrated or were closest to the radial nerve were the sixth and seventh holes, which lie in 12.67 to 15.8 cm (47.22% to 53.21%) of the humeral length from the lateral epicondyle.

The plate should be long enough to bridge the fracture over the danger zone of the radial nerve. Anterior intervention to the humerus, which is suitable for mid-distal third humeral shaft fractures in many minimally invasive plating osteosynthesis applications, is preferred because the radial nerve does not need to be exposed. This is partly because the coronoid fossa is in the distal part of the humerus; in fractures with small distal fragments, theoretical fixation on the anterior face of the humerus is impossible. The radial nerve is not at risk as long as the forearm is kept in supination intraoperatively when the anterior approach is used. No screws are inserted into the part of
the humeral shaft where the radial nerve runs along the spiral groove, which is a merit in preserving the radial nerve when the anterior approach is used. Surgeons have cautioned regarding the risk of radial nerve injury when either IMN or minimally invasive plating osteosynthesis are performed to treat mid-distal humeral shaft fractures. It is not uncommon to see radial nerve damage in IMN even if the nail does not touch the nerve, with the exception of preoperative radial nerve injury. Anterior dissection and posterior retraction of the radial nerve during the lateral approach may preserve its blood supply and reduce the risk of iatrogenic injury. Transient or permanent radial injury or both following distal humerus fractures may occur iatrogenically intraoperatively, and the reported incidence of radial nerve injury following surgical intervention ranges from 2% to 5%. The rate in the current study was within the range of 2% to 5%. As a general rule, no risk of axillary nerve injury exists when minimally invasive plating osteosynthesis is performed. Furthermore, the radial nerve is not at risk if the forearm is kept in supination intraoperatively and no screws are inserted into the humeral shaft where the radial nerve runs along the spiral groove. Consequently, physicians must take the dangerous zone of radial injury into consideration and must be acquainted with the anatomical position when performing minimally invasive plating osteosynthesis.

As for the humerus, it is important to distinguish rotational stress from axial stress, bending stresses, and shearing stress. With the formation of callus, plates have played an increasingly significant role in sharing the load. Double-plate fixation can sometimes improve the stability of the fixation. Moreover, if the plate is locked, the stability will move a single step forward, especially for patients with osteoporosis. Nevertheless, with the improved design and surgical technique, interlocking intramedullary nails stabilize the fracture fragment and hold the intramedullary nails back from slipping off. Compared with plates, intramedullary nails belong to axis fixation bearing smaller bending stress, which can deliver load and restore alignment and have a low stress-shielding rate. Interlocked IMNs have a stronger capacity to assist rotation than noninterlocked IMNs. Locked nailing provides a rationally stable fixation and avoids the tendency of various unlocked nails to back out. From a biomechanical standpoint, the intramedullary positioning of these devices places them in line with the mechanical axis of the humeral diaphysis, thereby subjecting the implant to lower bending loads. By being centrally positioned, the nail functions in a load-sharing capacity and mitigates the potential effects that stress shielding may play compared with compression plating.

Minimally invasive plating osteosynthesis, which is characterized by minimally invasive stabilized fixation and protecting the fracture fragment as much as possible, is an emerging procedure for the

Figure 2: Lateral (A) and anteroposterior (B) radiographs of a 48-year-old man who sustained a right humeral shaft fracture (AO-OTA 12 C1) after a motor vehicle accident. He underwent minimally invasive plating osteosynthesis with a locking plate under C-arm guidance. Postoperative lateral (C) and anteroposterior (D) radiographs showing acceptable alignment and a spiral wedge fragment of the humeral shaft that was not reduced. One-year postoperative lateral (E) and anteroposterior (F) radiographs showing osseous union between all major fragments. The patient had complete functional recovery.
treatment of humeral shaft fractures and has a wide application.\textsuperscript{10,24} Apivathakakul et al\textsuperscript{3} anatomically evaluated the feasibility of minimally invasive anterior plating and confirmed that it is clinically safe as long as plating occurred with the arm maximally supinated to avert injury to the radial nerve. Minimally invasive plating osteosynthesis prevents the need for bone grafts because of the high union rate.\textsuperscript{25}

As with the IMN procedure, fluoroscopic control must be used for a long time for minimally invasive plating osteosynthesis to have a satisfactory alignment. In the current study, no significant difference existed in intraoperative radiation exposure time. To the authors’ knowledge, few reports have investigated the effects of radiation exposure on bone healing.

Problems can occur with shoulder function when nails are inserted in an antegrade fashion, although IMN is generally considered a minimally invasive procedure.\textsuperscript{26} It has proven to be technically demanding and can be associated with iatrogenic fractures, although retrograde nail insertion was introduced to avoid shoulder dysfunction.\textsuperscript{27} However, recent reports of minimally invasive plating osteosynthesis for humeral shaft fractures have shown good ROM of adjacent joints.\textsuperscript{10,12,28} The IMN often contacts the adjacent joints, which may render the ROM of some joints abnormal. Nevertheless, Kobayashi et al\textsuperscript{29} reported that minimally invasive plating osteosynthesis is a promising option for humeral shaft fractures because of early ROM recovery in the adjacent joints. To avoid plate impingement, the distance between the distal fracture line and the upper edge of the coronoid fossa should be more than 6 cm to accept 3 screws in the distal fragment. It is preferable to insert 3 bicortical screws in the distal fragment to permit early use of the operated limb for activities of daily living.\textsuperscript{29} In regard to mid-distal humeral shaft fractures, sufficient space exists to contain 3 screws fixed in the distance between the proximal fracture fragment and the rotator cuff, which has a significant function in shoulder ROM. Anterior fixation of minimally invasive plating osteosynthesis avoids impingement of the elbow and shoulder joints to the plating, which makes early full shoulder and elbow ROM obtain quick functional recovery. However, stimulation of the interlocking nail to the shoulder or elbow often poses oppression on the round soft tissue, which causes shoulder or elbow pain.

The current study has limitations. First, a prospective study with a larger number of patients would help confirm the advantages of minimally invasive plating osteosynthesis for the treatment of mid-distal humeral shaft fractures. The trivial sample may have a certain role in the clinical applications for orthopedic surgeons to make decisions. Second, whether the exposure radiation factors that must be involved lead to some microcosmic bone transformation is a problematic facet and will be a tough question to answer. Third, other diseases associated with humeral fractures may pose general reactions that affect the time to union. Both methods have inherent advantages and disadvantages that should be considered by the surgeon and patient when selecting treatment. Patients can express their preferences after being informed of the advantage, disadvantages, and risks of both approaches.

**Conclusion**

Mid-distal third humeral shaft fractures can be effectively treated with minimally invasive plating osteosynthesis and IMN; minimally invasive plating osteosynthesis is a good option for complex fractures and IMN is a good option for relatively simple fractures. However, minimally invasive plating osteosynthesis may have the advantages of shorter time to fracture union, lower incidence of iatrogenic radial nerve palsy, and better functional outcomes compared with IMN.

**References**


