



Minimally invasive plating versus either open reduction and plate fixation or intramedullary nailing of humeral shaft fractures: a systematic review and meta-analysis of randomized controlled trials



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Hypothesis: The purpose of this study was to perform a meta-analysis comparing the clinical outcomes and complications between anterior humeral minimally invasive plate osteosynthesis (MIPO) and the 2 standard techniques, either open reduction and plating or humeral nailing.

Methods: We performed a systematic review of Medline, Embase, Scopus, and Google Scholar to identify relevant randomized controlled trials in the English- and German-language literature. Eligibility criteria included randomized controlled trials comparing at least 1 surgical intervention with MIPO and reporting the primary clinical outcome using a validated functional scoring system and description of complications. Publication bias was assessed by funnel plot, and the risk of bias was established using the Cochrane Collaboration's Risk of Bias Tool. Heterogeneity was assessed using χ^2 and I^2 statistics.

Results: Eight prospective randomized studies (N = 376) met the eligibility criteria and were included in the analysis. The pooled estimate for clinical outcome showed that MIPO resulted in a significantly better outcome (standardized mean difference, 0.366; 95% confidence interval, 0.16 to 0.571; $P = .0001$; $I^2 = 61\%$). The pooled estimate for all complications showed that the open reduction–internal fixation/nail group had a significantly higher complication rate (odds ratio, 0.507; 95% confidence interval, 0.285 to 0.905; $P = .021$; $I^2 = 97\%$).

Conclusion: Current evidence indicates the MIPO approach has better clinical outcomes with a lower rate of complications compared with alternative surgical techniques. However, the results of this meta-analysis are limited by problems inherent in the primary studies, including poor reporting of randomization protocols, as well as possible attrition bias and reporting bias, of the primary studies. Future publications may therefore change the trend of the pooled estimate in either direction.

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Level of evidence: Level II; Meta-Analysis

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Humeral shaft fractures are common, and most heal with appropriate conservative care.²⁹ Nevertheless, a limited number of cases require surgery to maintain satisfactory reduction and promote union, but there are significant risks associated with either open plating (open reduction–internal fixation [ORIF]) or intramedullary nailing (IMN).²³ Currently, there is insufficient evidence in the literature to determine which method provides the best result, as both techniques achieve comparable outcomes.^{5,15}

Open plating requires an extensile approach with significant soft-tissue stripping and local vascular disruption. As such, there is a reported risk of nonunion between 3% and 20%,¹⁵ in addition to the risk of infection or iatrogenic radial nerve injury. Open plating can be done through a posterior approach to the humerus, although this predisposes the vulnerable radial nerve to injury during the exposure, as it traverses the middle of the humerus.^{23,26} An anterolateral approach can be used instead, but the radial nerve is then not routinely visualized and may be injured indirectly.

To minimize the risk of direct radial nerve injury, a humeral fracture can instead be stabilized using intramedullary nails, allowing the fracture to heal rapidly by virtue of their insertion via a minimally invasive approach.²⁰ Unfortunately, clinical series of fractures stabilized with humeral nails often report shoulder problems related to the insertion site, possible technical difficulties, more radiation exposure intraoperatively, and a higher rate of revision surgery.^{5,7,10}

As an alternative to these 2 common methods of fracture stabilization, minimally invasive plate osteosynthesis (MIPO) was developed as a form of “biological plating.” This involves indirect reduction of the fracture without disrupting early callus, potentially resulting in reduced soft-tissue damage.^{14,21} The aim of MIPO is to achieve relative stability and secondary bone healing, using a locked plate to bridge the fracture site as an “internal fixator.”¹⁴ Using a technique originally developed for use on lower limb fractures, Livani and Dias Belangero¹⁸ published the first study using a minimally invasive anterior approach for humeral fractures. Preliminary evidence suggests use of this less invasive technique results in a high rate of rapid union with a decreased incidence of iatrogenic radial nerve injury.²⁸ The percutaneous surgical technique potentially appears to offer the “best of both worlds” by incorporating the minimally invasive stabilization of an intramedullary nail yet avoiding the associated shoulder problems, while also minimizing the risk of complications associated with open plating.

For surgeons unfamiliar with the technique, one of the primary concerns with MIPO plating of the humerus is the potential of iatrogenic nerve injury.^{3,8,16} A simple technical trick to avoid this complication is to position the arm in supination throughout the procedure so that the radial nerve moves away laterally.³ With the distal incision, the cutaneous branch of the musculoskeletal nerve can be easily identified on the anterior aspect of the brachialis muscle. Varus malunion is another theoretical concern but has not been observed by most authors.^{2,4,8,11,13,16-18,28,30} Reduction can be more difficult in mid–distal-third fractures when compared with an open approach but can be assisted by temporary external fixation.¹⁶ Possible limitations of this technique are grade III open fractures, pathologic fractures, proximal fractures with an intra-articular extension, severe soft-tissue loss, infection, and the classic Holstein-Lewis fracture where the nerve may have been caught within the bone fragments.^{17,28}

The purpose of this study was to perform a meta-analysis comparing the clinical outcomes and complications between anterior humeral MIPO and the 2 standard techniques, either open reduction and plating or humeral nailing.

Methods

The research was conducted according to the methods described in the *Cochrane Handbook*.¹² The results are reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines statement.²²

Eligibility criteria

All randomized controlled trials that compared at least 1 standard surgical intervention with MIPO in patients 18 years and older were identified. This included studies comparing 3 surgical interventions. Retrospective studies, prospective observational studies, case series, and case reports were excluded. The following inclusion criteria were applied: all studies describing humeral plating via an anterior percutaneous surgical approach; surgery after primary injuries of the midshaft and distal-third humeral diaphyseal fractures; and complete documentation in tables or main text describing demographic details, complications, time to radiographic union, and at least 1 validated functional outcome scoring system (Constant; Disabilities of the Arm, Shoulder and Hand; University of California, Los Angeles; American Shoulder and Elbow Surgeons). Studies were excluded if treated patients presented with multitrauma, head injury, nonunion, grade III open fractures, or proximal humeral fractures. It is acknowledged that the omission of these “gray” data could result in publication bias.

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