

Original Research Article

Functional outcome of minimally invasive plate osteosynthesis technique in shaft of humerus fractures: a prospective cohort study

Chahan M. Pandya, Vishal M. Dindod*, Pratik S. Bhabhor, Nilay P. Kumar,
Devesh S. Kumar, Saurav K. Padval

Department of Orthopaedics, Zydus Medical College and Hospital, Dahod, Gujarat, India

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*Correspondence:

Dr. Vishal M. Dindod,

E-mail: vishaldindod87@gmail.com

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ABSTRACT

Background: Humeral shaft fractures require restoration of alignment while preserving soft tissue. Minimally invasive plate osteosynthesis (MIPO) with anterior bridge plating aims to achieve stable fixation with minimal soft-tissue disruption. This study evaluated the functional, clinical, and radiological outcomes of anterior bridge plating using MIPO for humeral shaft fractures.

Methods: Prospective observational cohort study at the Department of Orthopaedics, Zydus Medical College and Hospital, Dahod, Gujarat, from October 2023 to December 2025. Twenty-four patients (18-50 years) with closed or Gustilo grade I open humeral shaft fractures underwent MIPO using locking compression plates (LCP) via an anterior brachialis-splitting approach. Outcomes assessed were Constant-Murley score (CMS) and Mayo elbow performance score (MEPS) at 3 weeks, 6 weeks, 3 months, 6 months, and 12 months, along with radiological union time, operative time, blood loss, and complications.

Results: Mean age was 35.2 ± 9.4 years; 91.7% were male. AO type 12A fractures comprised 87.5% of cases. Mean operative time was 72.5 ± 7.7 minutes and mean blood loss 119 ± 14 mL. Mean radiological union time was 14.2 ± 2.7 weeks. At final follow-up mean CMS was 90.0 ± 4.0 and mean MEPS 94.1 ± 3.8 ; 91.7% of patients achieved excellent or good functional outcomes. Three complications occurred: one delayed union, one nonunion, and one deep infection. No iatrogenic radial nerve palsy was observed.

Conclusions: Anterior bridge-plate MIPO for humeral shaft fractures is safe and reproducible, yielding high rates of union and excellent functional outcomes with a low complication profile. Its minimal soft-tissue disruption makes it well suited to resource-limited settings.

Keywords: Humeral shaft fracture, Minimally invasive plate osteosynthesis, MIPO, Anterior bridge plating, Functional outcome, Radiological union

INTRODUCTION

Humeral shaft fractures account for approximately 1-3% of all fractures, with an incidence of 13-14.5 per 100,000 population annually, demonstrating a bimodal distribution affecting young males following high-energy trauma and elderly females with osteoporotic low-energy falls.¹ The management of humeral shaft fractures continues to

evolve, balancing anatomical restoration with preservation of the surrounding soft-tissue envelope.

Conventional open reduction and internal fixation (ORIF) has long been regarded as a gold standard for operative management, offering direct visualisation and precise reduction. However, extensive periosteal stripping and soft-tissue dissection increase the risk of infection, radial

nerve injury, and impaired vascular supply with resultant delayed union or non-union.²

MIPO has emerged as an alternative approach designed to limit surgical trauma while maintaining stable fixation. By placing plates submuscularly through limited incisions using the anterior brachialis-splitting interval, MIPO preserves periosteal circulation, protects the fracture hematoma, and avoids deliberate radial nerve exposure.^{3,4} LCP used in this construct provide angular stability and load-sharing without compressing the periosteum, enabling early mobilisation even in osteoporotic bone.

Despite growing evidence supporting MIPO, prospective data from the Indian subcontinent remain limited. The present study was designed to prospectively evaluate functional, clinical, and radiological outcomes of MIPO using anterior bridge plating in patients with humeral shaft fractures at a tertiary care centre in Gujarat, India.

METHODS

Study design and setting

This was a hospital-based prospective observational cohort study conducted at the Department of Orthopaedics, Zydus Medical College and Hospital, Dahod, Gujarat-a tertiary care centre in central India. Institutional ethics committee approval was obtained prior to commencement. Written informed consent was obtained from all participants. The study was conducted from October 2023 to December 2025.

Patients

The sample size was calculated using Cochran's formula $n = Z^2pq/d^2$

$Z=1.96$, $p=0.0145$, $d=5\%$, yielding a minimum of 21 cases with 10% allowance for attrition; 24 patients were ultimately enrolled. Inclusion criteria were: age 18-50 years; closed humeral shaft fractures; Grade I open fractures (Gustilo-Anderson classification); no contraindication to anaesthesia. Exclusion criteria were: age <18 or >50 years; Grade II/III open fractures; pathological fractures; fractures associated with neurovascular injury; osteoporotic bone; and patient refusal.

Surgical technique

All operations were performed under general or regional anaesthesia with the patient supine; the arm and forearm fully supinated on a radiolucent table. Two small anterior windows were created: a proximal 3 cm longitudinal incision approximately 6 cm distal to the anterior acromion between the lateral border of the biceps and medial border of the deltoid; and a distal 3 cm longitudinal incision on the anterior arm midline, 3 cm proximal to the elbow flexion crease.

The brachialis was split longitudinally along its midline at the distal window, retracting the lateral half as a cushion for the radial nerve. A submuscular tunnel was developed along the anterior humeral surface from distal to proximal using a tunnelling instrument. A 4.5 mm LCP (8-12 holes) was introduced and advanced under fluoroscopic guidance. Fracture reduction was achieved by traction to restore length and correct varus/rotational deformity. After radiographic confirmation, fixation was completed with bicortical locking and cortical screws. At least eight cortices were engaged proximal and distal to the fracture.

Postoperative protocol

All patients were immobilised with a humeral brace and arm sling immediately post-operatively. Pendulum exercises and elbow range-of-motion (ROM) exercises were commenced at 48 hours. Active-assisted shoulder and elbow ROM exercises were initiated as pain permitted. Wound inspection was performed at days 2, 5, and 9; sutures were removed at day 12. Clinical and radiological follow-up was conducted at 3 weeks, 6 weeks, 3 months, 6 months, and 12 months.

Outcome measures

The primary outcome was functional recovery assessed by the (CMS; maximum 100 points; Excellent ≥ 86 , Good 71-85, Fair 56-70, Poor <56) for shoulder function and the (MEPS; maximum 100 points; Excellent >90, Good 75-89, Fair 60-74, Poor <59) for elbow function. Secondary outcomes included time to radiological union (defined as bridging callus on ≥ 3 of 4 cortices with absence of pain and tenderness), operative time, intra-operative blood loss, and complications.

Statistical analysis

Continuous variables are expressed as mean $\pm$ SD. Correlations between continuous variables were assessed using Spearman's rank correlation and Pearson correlation coefficient. Differences between AO fracture types and union time were evaluated with the Kruskal-Wallis test. A $p < 0.05$ was considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics v31.0 (IBM Corp., Armonk, NY).

RESULTS

Demographic and injury characteristics

Twenty-four patients completed follow-up. Mean age was 35.20 ± 9.38 years (range 18-50). Males accounted for 22 patients (91.67%) and females for two (8.33%). Both the left and right upper limbs were equally affected (50% each). The most common mechanism was fall (58.3%), followed by road traffic accident (20.8%), assault (12.5%), wall collapse (4.2%), and animal strike (4.2%). AO type 12A fractures predominated: 12A2 (41.7%), 12A3 (37.5%), 12A1 (8.3%), 12B2 (8.3%), and 12B3 (4.2%).

Fifteen patients (62.5%) underwent surgery within 1-3 days of injury and nine (37.5%) within 4-7 days.

Table 1: Demographic and injury profile.

Variables	Value
Age, mean±SD (in years)	35.20±9.38
Sex-male	22 (91.67%)
Dominant limb affected	Equal (50% each side)
Most common mechanism	Fall (58.3%)
Most common AO type	12A2 (41.7%)
Surgery within 1-3 days	15 (62.5%)

Operative metrics

Mean operative time 72.5±7.7 min (range 60-90). Mean intra-operative blood loss 119±14 ml (range 80-140). Mean plate length used 11.5±1.6 holes (range 8-14 holes). No intra-op neurovascular complications were recorded.

Table 2: Operative metrics.

Metrics	Mean±SD	Range
Operative time (min)	72.5±7.7	60-90
Blood loss (mL)	119±14	80-140
Plate holes	11.5±1.6	8-14

Radiological outcomes

Mean time to radiological union was 14.2±2.7 weeks. Union was achieved in ≤12 weeks in eight patients (33.3%), between 12-16 weeks in 13 patients (54.17%), and was delayed (>16 weeks) in one patient (4.17%). One patient developed non-union. No significant difference in union time was detected between AO fracture types (Kruskal-Wallis H=0.63, p=0.427). Plate length showed no significant correlation with union time (Spearman ρ=0.14, p=0.543).

Table 3: Radiological union.

Outcomes	Value
Mean union time (weeks), mean±SD	14.2±2.7
Union ≤12 weeks	8 (33.3%)
Union 12-16 weeks	13 (54.2%)
Delayed union (>16 weeks)	1 (4.2%)
Non-union	1 (4.2%)

Functional outcomes

At final follow-up (mean 10.5 months, range 6-12), mean CMS was 90.00±4.0 and mean MEPS was 94.09±3.75. Excellent or Good shoulder function on CMS was achieved in 22 of 24 patients (91.67%): 11 Excellent (45.8%) and 11 Good (45.8%). Elbow function on MEPS was Excellent in 21 patients (87.5%) and Good in one (4.2%). Functional scores improved progressively across all follow-up intervals, with Friedman test confirming significant longitudinal improvement (p<0.05).

Union time showed a moderate inverse correlation with both CMS (Spearman ρ=-0.67, p=0.0007) and MEPS (ρ=-0.64, p=0.0013). Age showed a moderate inverse correlation with CMS (ρ=-0.70, p=0.0003) and MEPS (ρ=-0.50, p=0.017). Operative time and blood loss showed no significant correlation with either functional score (all p>0.05).

Complications

Complications were observed in three patients (12.5%): one delayed union (4.2%), one non-union (4.2%), and one deep infection (4.2%). No iatrogenic radial nerve palsy or implant failure occurred. The patient with deep infection had uncontrolled T2DM and required implant removal at one month, followed by the Ilizarov ring fixator application after debridement. Both patients with comorbid diabetes mellitus (n=2) experienced complications. Patient with delayed union demonstrated radiological union by 12 months without secondary surgical intervention.

Comparison with previously published studies

Comparison with previously published studies demonstrates that the outcomes of the present series are consistent with the existing literature on MIPO for humeral shaft fractures. Mean union time of 14.2 weeks was comparable to the 12-14 weeks reported by Zhiquan et al and Wang et al.^{7,11} Functional outcomes were similarly favorable, with a mean CMS of 90 and MEPS of 94.09, reflecting excellent shoulder and elbow recovery. Although the overall complication rate in the present study was 12.5%, no cases of iatrogenic radial nerve palsy or implant failure were observed, supporting the safety of the anterior MIPO approach. These findings suggest that MIPO provides reliable fracture union and excellent functional restoration comparable to outcomes reported in larger published series.

Table 4: Functional scores at final follow-up.

Scores	Mean±SD	Median	Excellent	Good
CMS	90.00±4.0	90	11 (45.8%)	11 (45.8%)
MEPS	94.09±3.75	95	21 (87.5%)	1 (4.2%)

Table 5: Correlation analysis.

Comparisons	Spearman ρ	P value
Union time vs CMS	-0.67	0.001
Age vs CMS	-0.70	0.0003
Operative time vs CMS	-0.09	0.676
Blood loss vs CMS	-0.06	0.795
Union time vs MEPS	-0.64	0.001
Age vs MEPS	-0.50	0.017
Operative time vs MEPS	0.08	0.718
Blood loss vs MEPS	0.12	0.592

Table 6: Complications profile.

Complications	N	Percentage
None	21	87.5%
Delayed union	1	4.2%
Non-union	1	4.2%
Deep infection	1	4.2%
Iatrogenic nerve palsy	0	0%
Implant failure	0	0%

DISCUSSION

This prospective study demonstrates that MIPO using anterior bridge plating is a safe and effective technique for humeral shaft fractures, yielding excellent functional outcomes, reliable radiological union, and a low complication profile in a young to middle-aged Indian population.

The mean patient age of 35.2 years with strong male predominance (91.67%) reflects the demographic pattern of humeral shaft fractures in South Asian populations where high-energy road traffic accidents and occupational trauma are prevalent.⁵ This finding aligns with reports by Dave et al and Zhiquan et al which document similar age and sex distributions in surgical series.^{6,7}

Mean operative time of 72.5 minutes and blood loss of 119 mL in the present study compare favourably with published MIPO series reporting operative times of 60-120 minutes and blood loss under 150 mL.⁶ The minimally invasive approach avoids extensive muscular dissection, contributing to limited intraoperative haemorrhage and shorter anaesthetic exposure.

Radiological union was achieved at a mean of 14.2 weeks, consistent with the expected 12-16 week healing window for humeral shaft fractures treated with bridge plating reported by Apivatthakakul et al and Concha et al.^{3,8} The absence of a significant difference in union time across AO fracture types ($p=0.427$) supports the reliability of MIPO across both simple and wedge diaphyseal patterns. Delayed union in one patient and non-union in another may relate to inadequate plate length and fracture reduction, as discussed by Jiang et al.⁹

Functional outcomes in the present study were excellent. The mean CMS of 90.0 and MEPS of 94.09 at final follow-

up are comparable to Mahajan et al (CMS 85-90 at one year) and Wang et al (MEPS 90-100 at 12 months).^{10,11} The progressive improvement in scores from 3 to 12 months underscores the importance of structured rehabilitation with early mobilisation.

The moderate inverse correlation between union time and functional scores ($\rho=-0.67$ for CMS; $\rho=-0.64$ for MEPS) highlights the role of timely union in optimising functional recovery, while the negligible correlation between operative time or blood loss and outcomes confirms that biological preservation-rather than surgical speed-drives functional restoration.

The overall complication rate of 12.5% in this series is consistent with published MIPO series reporting rates of approximately 10%.⁹ The infection rate of 4.17% aligns with the 3-5% range cited in the literature.⁶ Critically, no iatrogenic radial nerve palsy was observed, supporting prior evidence that the anterior brachialis-splitting approach markedly reduces this risk compared with posterior open plating.¹²

This is particularly clinically significant as radial nerve palsy remains the most feared complication in humeral shaft surgery. The two patients with type 2 diabetes mellitus both experienced complications-infection and delayed union respectively-reinforcing the importance of glycaemic optimisation prior to surgery.

This study has several limitations. The sample size of 24 patients, while adequate for a preliminary analysis, limits generalisability. As a single-centre study, selection bias and practice-specific factors may influence outcomes. Confounding variables including smoking, alcohol use, nutritional status, and physical activity were not captured. Comparative data against other techniques such as ORIF or intramedullary nailing were not available. Future multicentre, comparative studies with larger cohorts are warranted.

Nonetheless, this study provides valuable prospective data from a tertiary care centre in rural India. The reproducibility of MIPO results across diverse simple and wedge fracture patterns, combined with cosmetic benefits and suitability for resource-constrained settings where wound care infrastructure may be limited, suggests MIPO may serve as a standard operative approach for humeral shaft fractures in active adults.

Table 7: Comparison of radiological and functional outcomes of the present study with previously published MIPO studies.

Studies	Sample	Union time (weeks)	CMS/MEPS	Complications
Zhiquan et al	17	12	Excellent	0 nerve palsy
Wang et al	32	14	MEPS 90-100	Low
Dave et al	30	13.8	Good-excellent	Minimal
Present study	24	14.2	CMS 90, MEPS 94	12.5%

CONCLUSION

MIPO using anterior bridge plating is a safe and effective technique for humeral shaft fractures in young to middle-aged adults. The technique achieves reliable radiological union at approximately 14 weeks, excellent shoulder and elbow functional scores, and a low complication rate with no iatrogenic nerve injury. Minimal blood loss, short operative times, and reduced soft-tissue morbidity make MIPO particularly suitable for resource-limited settings. Adequate training and fluoroscopic proficiency are essential prerequisites. Earlier radiological union is independently associated with superior functional outcomes.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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