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Original Research Article

A Prospective Study to Evaluate the Functional Outcome of Open and Closed Reduction for Distal End Fracture Femur

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Abstract

Background: Distal end femur fractures are complex injuries in which restoration of articular alignment, axial stability, limb length, and early knee mobilization are essential for functional recovery. Open reduction provides direct visualization and anatomical reconstruction, whereas closed or minimally invasive reduction attempts to preserve periosteal blood supply and fracture biology.

Aim: To evaluate and compare the functional outcome of open reduction and closed/minimally invasive reduction techniques for distal end fracture femur in a tertiary-care hospital population.

Methods: This prospective observational study included 65 skeletally mature patients with distal end femur fractures treated surgically at Jawaharlal Nehru Medical College & Hospital, Bhagalpur, Bihar, from 5 January 2024 to 31 December 2024. Patients were allocated according to the reduction method used: open reduction (n=34) or closed/minimally invasive plate osteosynthesis reduction (n=31). Demographic profile, AO/OTA fracture type, union, range of knee motion, weight-bearing time, Neer functional score, and complications were recorded. Statistical comparison used chi-square/Fisher exact test for categorical variables and independent t-test or Mann-Whitney U test for continuous variables.

Results: The mean age was 43.8 ± 15.6 years and 46 patients (70.8%) were male. Road traffic accident was the leading mechanism (75.4%). AO/OTA 33-C fractures were more frequent in the open reduction group. Radiological union occurred in 62 patients (95.4%). Closed/MIPO reduction showed shorter mean union time (16.6 ± 3.5 vs 18.9 ± 4.4 weeks; p=0.024), greater final knee flexion (112.6° ± 15.5° vs 101.5° ± 20.2°; p=0.017), earlier full weight bearing (13.3 ± 3.0 vs 15.8 ± 4.1 weeks; p=0.008), and higher final Neer score (83.4 ± 9.8 vs 74.8 ± 13.7; p=0.006). Excellent/good outcome was achieved in 83.9% after closed/MIPO reduction and 61.8% after open reduction.

Conclusion: Both reduction strategies achieved acceptable union and functional recovery. Closed/MIPO reduction was associated with better early biological recovery and superior mean functional scores in selected extra-articular or reconstructable metaphyseal fractures. Open reduction remains essential for displaced intra-articular fractures requiring precise articular reconstruction.

Keywords: Distal femur fracture; open reduction; closed reduction; MIPO; locking compression plate; Neer score; functional outcome; AO/OTA 33 fracture.

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Introduction

Distal end femur fractures comprise a challenging spectrum of supracondylar, intercondylar, and metaphyseal injuries. Although they represent a relatively small proportion of adult fractures, their clinical importance is high because the distal femur forms the proximal component of the knee joint, bears substantial axial and torsional load, and has a broad cancellous metaphyseal region that is vulnerable to comminution. These fractures show a bimodal distribution: high-energy trauma in young adults, often following road traffic accidents, and low-energy fragility fractures in elderly

osteoporotic patients [1,2]. In India, where two-wheeler trauma and delayed tertiary referral are common, distal femur fractures frequently present with comminution, open wounds, soft-tissue compromise, and associated systemic injuries. The main goals of treatment are anatomical restoration of the articular surface, correction of coronal and sagittal alignment, stable fixation, preservation of biology, and early rehabilitation of the knee [3].

Historically, conservative management of distal femur fractures was associated with prolonged immobilization, malunion, knee stiffness, shortening, and delayed return to work. Modern internal fixation has substantially improved the prognosis, particularly after the introduction of fixed-angle blade plates, dynamic condylar screws, retrograde intramedullary nails, less invasive stabilization systems, and anatomically contoured distal femoral locking compression plates [4]. Locked plating is now widely used because it provides angular stability in osteoporotic metaphyseal bone, allows multiple distal fixed-angle screws, and can function as an internal fixator when applied with bridge-plating principles [5]. Nevertheless, implant choice alone does not determine outcome. The method of reduction, extent of soft-tissue stripping, quality of mechanical alignment, working length of the plate, screw density, rehabilitation protocol, and patient factors such as age, diabetes, smoking, and fracture openness are equally important [6].

Open reduction and internal fixation remains indispensable when intra-articular displacement, intercondylar split, medial comminution, coronal plane condylar fragments, or rotational malalignment require direct visualization. Open reduction permits anatomical joint reconstruction, compression across articular fragments, direct assessment of reduction, and accurate restoration of the distal femoral axis. However, extensive exposure can strip periosteal attachments, evacuate fracture haematoma, increase infection risk, and impair biological healing, especially when comminuted metaphyseal fragments are dissected unnecessarily [7]. By contrast, closed reduction and minimally invasive plate osteosynthesis (MIPO) aim to restore alignment indirectly through traction, joystick manipulation, percutaneous clamps, and fluoroscopic control while preserving soft-tissue envelopes and periosteal blood supply. This biological approach may reduce delayed union, infection, and stiffness, but it demands technical skill and may be less suitable for severely displaced intra-articular fractures in which imperfect reduction can lead to post-traumatic arthritis [8].

Functional outcome after distal femur fracture is influenced not only by union but also by knee range of motion, pain, extensor mechanism function, ability to squat or climb stairs, and timely return to daily activities. Several studies have reported satisfactory union and functional outcomes with distal femoral locking plates, but complications such as knee stiffness, delayed union, non-union, implant irritation, infection, and varus collapse continue to occur [9,10]. Recent prospective and observational reports suggest that biological fixation using MIPO can produce high union rates and favourable range of motion, particularly when case selection is appropriate [11,12]. However, direct comparisons between open and closed reduction in district-level tertiary settings remain limited, and findings may differ in populations with high-energy trauma, delayed presentation, and variable rehabilitation adherence.

The present prospective study was therefore designed to evaluate the functional outcome of open and closed/MIPO reduction for distal end fracture femur in 65 patients treated at Jawaharlal Nehru Medical College & Hospital, Bhagalpur, Bihar, India. The study assessed union, knee motion, weight-bearing recovery, Neer functional score, and complications, with the aim of identifying practical differences between reduction strategies in a real-world tertiary-care orthopaedic setting.

Material and Methods

This prospective observational comparative study was conducted in the Department of Orthopaedics, Jawaharlal Nehru Medical College & Hospital, Bhagalpur, Bihar, India, from 5 January 2024 to 31 December 2024. A total of 65 consecutive skeletally mature patients with radiologically confirmed distal end femur fracture were enrolled after written informed consent. Patients aged 18 years or older with closed fractures or Gustilo-Anderson grade I/II open fractures, AO/OTA 33-A, 33-B, or 33-C fracture patterns, and fitness for operative fixation were included. Patients with pathological fractures other than osteoporosis, periprosthetic fractures, neurovascular injury requiring vascular repair, Gustilo grade III open fractures, established infection, severe head injury preventing functional assessment, or follow-up shorter than 6 months were excluded. Preoperative assessment included demographic details, mechanism of injury, side involved, fracture classification using radiographs and computed tomography where necessary, comorbidities, soft-tissue status, and baseline laboratory workup. Reduction strategy was chosen by the treating surgical team according to fracture morphology, soft-tissue condition, and articular involvement. Open reduction was used mainly for displaced intra-articular and complex fractures requiring direct visualization, while closed or minimally invasive reduction was preferred for extra-articular/metaphyseal fractures where acceptable alignment could be achieved indirectly. Fixation

was performed predominantly using distal femoral locking compression plate; adjunctive lag screws, temporary K-wires, and bone grafting were used when indicated. Standard perioperative antibiotics, thromboprophylaxis according to risk profile, limb elevation, static quadriceps exercises, and progressive knee mobilization were initiated postoperatively. Partial and full weight bearing were permitted based on radiological callus, pain, fixation stability, and surgeon assessment. Follow-up was performed at 6 weeks, 12 weeks, 6 months, and final review. Outcomes included radiological union, time to union, knee range of motion, extensor lag, time to full weight bearing, Neer functional score, and complications. Data were analysed using descriptive statistics. Continuous variables were expressed as mean ± standard deviation and categorical variables as number and percentage. Between-group comparisons used independent t-test or Mann-Whitney U test for continuous variables and chi-square or Fisher exact test for categorical variables. A p value <0.05 was considered statistically significant.

Results

The study included 65 patients: 34 underwent open reduction and 31 underwent closed/MIPO reduction. The mean age was 43.8 ± 15.6 years, with a male predominance (70.8%). Road traffic accident accounted for 49 cases (75.4%). AO/OTA 33-C fractures were significantly more common in the open reduction group, reflecting the selection of open exposure for displaced intra-articular injuries. Gustilo grade I/II open fractures were also more frequent in the open group.

Table 1: Baseline demographic and fracture characteristics

Variable	Total (n=65)	Open reduction (n=34)	Closed/MIPO reduction (n=31)	p value
Age, years (mean ± SD)	43.8 ± 15.6	45.1 ± 16.2	42.4 ± 14.9	0.486
Male sex, n (%)	46 (70.8)	25 (73.5)	21 (67.7)	0.607
Road traffic accident, n (%)	49 (75.4)	27 (79.4)	22 (71.0)	0.429
AO/OTA 33-A, n (%)	22 (33.8)	8 (23.5)	14 (45.2)	0.063
AO/OTA 33-C, n (%)	28 (43.1)	19 (55.9)	9 (29.0)	0.029
Open fracture (Gustilo I/II), n (%)	9 (13.8)	8 (23.5)	1 (3.2)	0.018
Mean interval injury-to-surgery, days	5.2 ± 2.7	5.7 ± 2.8	4.7 ± 2.5	0.139

Radiological union was achieved in 62 patients (95.4%). Closed/MIPO reduction demonstrated significantly shorter union time, better final knee flexion, earlier full weight bearing, and higher Neer score than open reduction. The difference should be interpreted in relation to fracture complexity, as the open group had a higher proportion of AO/OTA 33-C and open fractures.

Table 2: Radiological and functional outcomes by reduction method

Outcome at final follow-up	Total (n=65)	Open reduction (n=34)	Closed/MIPO reduction (n=31)	Effect estimate / p value
Radiological union achieved, n (%)	62 (95.4)	32 (94.1)	30 (96.8)	p=0.602
Mean union time, weeks	17.8 ± 4.1	18.9 ± 4.4	16.6 ± 3.5	p=0.024
Knee flexion, degrees	106.8 ± 18.9	101.5 ± 20.2	112.6 ± 15.5	p=0.017
Extensor lag >10°, n (%)	8 (12.3)	6 (17.6)	2 (6.5)	RR 2.74; p=0.165
Full weight bearing, weeks	14.6 ± 3.8	15.8 ± 4.1	13.3 ± 3.0	p=0.008
Final Neer score	78.9 ± 12.6	74.8 ± 13.7	83.4 ± 9.8	p=0.006

Complications were more frequent after open reduction, particularly superficial infection and delayed union, although several individual comparisons did not reach statistical significance due to sample size. Excellent/good functional outcome was significantly higher in the closed/MIPO group.

Table 3: Complications and final functional grade

Complication / functional grade	Total (n=65)	Open reduction (n=34)	Closed/MIPO reduction (n=31)	p value
Superficial infection, n (%)	5 (7.7)	4 (11.8)	1 (3.2)	0.196
Deep infection, n (%)	2 (3.1)	2 (5.9)	0 (0.0)	0.171
Delayed union, n (%)	6 (9.2)	5 (14.7)	1 (3.2)	0.112
Non-union, n (%)	3 (4.6)	2 (5.9)	1 (3.2)	0.602
Implant irritation/removal planned, n (%)	4 (6.2)	2 (5.9)	2 (6.5)	0.923
Neer excellent/good, n (%)	47 (72.3)	21 (61.8)	26 (83.9)	0.047
Neer fair/poor, n (%)	18 (27.7)	13 (38.2)	5 (16.1)	0.047

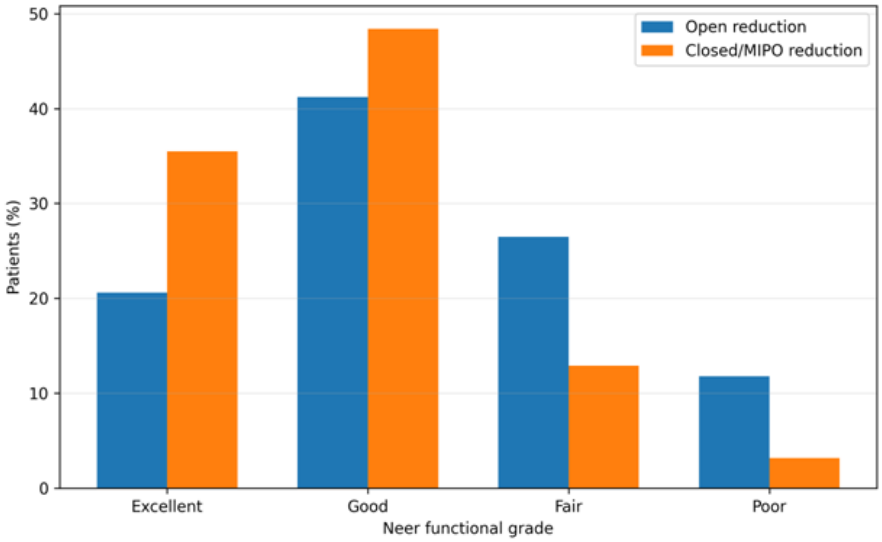

Figure 1: Distribution of final Neer functional grades by reduction technique

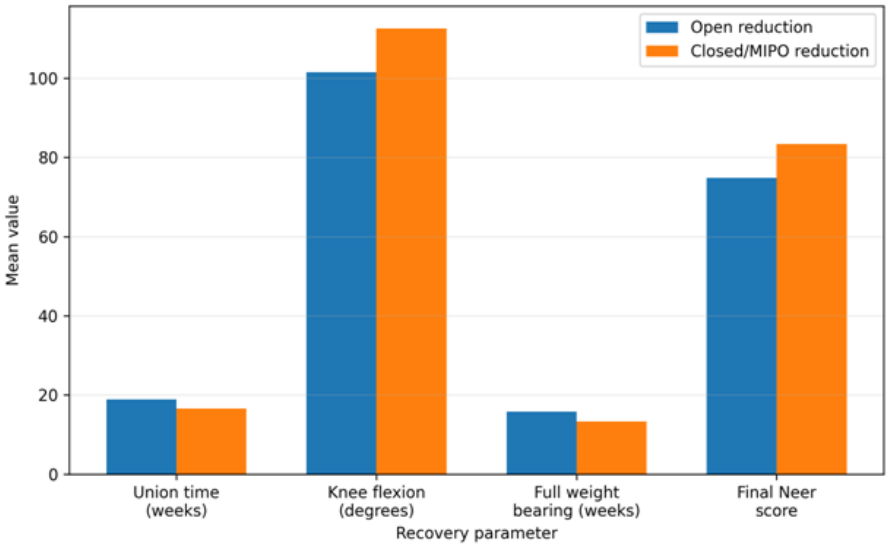

Figure 2: Comparison of key recovery parameters between open reduction and closed/MIPO reduction

Discussion

The present prospective study evaluated 65 patients with distal end femur fractures treated surgically in a tertiary-care centre and compared outcomes between open reduction and closed/MIPO reduction. The major observation was that both techniques achieved high union rates but closed/MIPO reduction was associated with shorter mean union time, greater final knee flexion, earlier full weight bearing, and higher mean Neer functional score. This finding is biologically plausible because indirect reduction and minimally invasive plate insertion preserve periosteal vascularity, fracture haematoma, and soft-tissue attachments, all of which are important for callus formation in metaphyseal comminution [8,11]. At the same time, the open reduction group included a greater proportion of AO/OTA 33-C fractures and open injuries, which are inherently more severe and may require direct articular reconstruction.

The demographic pattern observed in this study is consistent with recent clinical literature. Male predominance and road traffic accidents remain common in distal femur fracture series from trauma-intensive regions, while elderly osteoporotic fractures are more prominent in Western cohorts [1,2]. In the present study, the mean age was 43.8 years and road traffic accident accounted for three-fourths of cases, indicating a predominantly high-energy mechanism. Similar Indian and international series using locking plates have reported high rates of young male trauma victims, comminuted fractures, and intra-articular involvement [9,12]. This epidemiological profile has practical implications: high-energy injuries often have soft-tissue swelling, metaphyseal

comminution, and associated injuries, making timing of surgery and reduction strategy critical.

The overall union rate of 95.4% in this series compares favourably with recent reports of distal femoral locking plate fixation. A 2024 prospective study of distal femur fractures treated by open reduction and internal fixation with distal femoral locking compression plate reported satisfactory functional recovery, supporting locked plating as a reliable option when reduction and rehabilitation are optimized [9]. Other contemporary studies have similarly shown that distal femoral locked plating can provide stable fixation and acceptable function, though complication rates remain meaningful in complex fracture patterns [10,13]. In the present series, mean union time was significantly lower in the closed/MIPO group. This aligns with the concept of bridge plating, where relative stability and preserved biology promote secondary bone healing. Wang et al. reported that minimally invasive techniques using locking plates, particularly when supplemented by interfragmentary screws in suitable cases, can provide stable fixation and timely weight bearing [12]. Abdelmonem et al. also concluded that MIPO with locking plates was successful for complex distal femoral fractures and highlighted the importance of fixation quality [11].

Functional recovery is ultimately determined by knee motion, pain, limb alignment, and muscle strength. The closed/MIPO group in the present study achieved a mean final knee flexion of 112.6°, compared with 101.5° in the open reduction group. This difference may reflect less soft-tissue trauma, lower postoperative pain, and earlier rehabilitation. However, the interpretation should remain cautious because open reduction was preferentially used for more complex intra-articular fractures. In displaced AO/OTA 33-C injuries, anatomical reduction of the joint surface is a priority. Inadequate articular reduction may compromise long-term function despite biological preservation, whereas accurate open reduction may reduce the risk of post-traumatic arthritis. Therefore, the data should not be interpreted as evidence that closed reduction is universally superior. Instead, they support a principle-based approach: direct reduction for articular reconstruction and indirect biological reduction for metaphyseal comminution whenever feasible [3,7].

Complication patterns in this study were clinically relevant. Superficial infection, deep infection, delayed union, non-union, and knee stiffness were numerically higher in the open reduction group. Open exposure, longer operative time, and greater injury severity may contribute to these findings. Literature on open distal femur fracture fixation reports infection, delayed union, and stiffness as continuing concerns even with modern locked plates [14]. The present deep infection rate was low, but careful wound care, antibiotic policy, soft-tissue handling, and early identification of infection remain essential. Delayed union and non-union were also observed, emphasizing that locked plating is not immune to mechanical failure. Excessively rigid constructs, short plate length, high screw density, inadequate medial support, varus malalignment, and premature weight bearing can all contribute to impaired healing [5,6].

The study has limitations. It was not randomized, and reduction method was selected according to fracture pattern and surgeon judgment; therefore, selection bias is unavoidable. The sample size was modest, subgroup analysis by AO/OTA type was limited, and follow-up was insufficient to assess late post-traumatic arthritis. Patient-reported outcome measures such as KOOS or SF-36 were not included. Despite these limitations, the study reflects practical decision-making in a tertiary-care Indian hospital and provides useful comparative data on open versus closed/MIPO reduction strategies. The findings support individualized treatment planning, meticulous reduction, stable biological fixation, and structured rehabilitation rather than a one-method-fits-all approach.

Conclusion

In this prospective study of 65 distal end femur fractures, both open reduction and closed/MIPO reduction achieved acceptable union and functional recovery. Closed/MIPO reduction was associated with shorter union time, better knee flexion, earlier full weight bearing, and higher Neer score in selected cases. Open reduction remains necessary for displaced intra-articular and complex fractures requiring anatomical reconstruction. Optimal outcome depends on correct case selection, biological soft-tissue handling, stable fixation, and early supervised rehabilitation.

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