

Functional Outcome of OTA Type-C Distal Femur Fracture Fixed with Locking Compression Plate: A Prospective Observational Study of 90 Patients from Eastern India

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Abstract

Background: OTA type-C distal femur fractures are complete intra-articular injuries associated with stiffness, malalignment, delayed union and impaired knee function. Locking compression plates provide fixed-angle stability and permit biological fixation, but outcome data from eastern India remain limited.

Aim: To evaluate functional and radiological outcomes of OTA type-C distal femur fractures fixed with locking compression plate at a tertiary care hospital in Bihar.

Methods: This prospective observational study included 90 adults with OTA/AO type 33-C distal femur fractures treated with distal femur locking compression plate at Jawaharlal Nehru Medical College & Hospital, Bhagalpur, from 10 June 2024 to 31 May 2025. Demographic variables, fracture morphology, operative parameters, union, complications, knee range of motion and final Neer score were analysed.

Results: Mean age was 42.8 +/- 14.6 years; 71.1% were male and road traffic accident was the commonest mechanism (67.8%). Fracture distribution was C1 in 34.4%, C2 in 40.0% and C3 in 25.6%. Radiological union by 24 weeks occurred in 78.9%, and final union without secondary procedure occurred in 91.1%. Mean final knee flexion was 112.6 +/- 16.8 degrees and mean final Neer score was 82.4 +/- 10.9. Outcomes were excellent in 31.1%, good in 44.4%, fair in 16.7% and poor in 7.8%. C3 fractures, open injury, diabetes, tobacco use, delayed surgery and medial comminution were associated with fair/poor outcome.

Conclusion: Locking compression plate fixation achieved satisfactory function and union in most OTA type-C distal femur fractures, but complex C3 injuries require careful construct planning, selective augmentation and supervised rehabilitation.

Keywords: distal femur fracture; OTA type C; locking compression plate; LCP; Neer score; functional outcome; fracture union.

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Introduction

Distal femur fractures represent a small proportion of adult fractures but carry disproportionate functional consequences because the injury involves a weight-bearing metaphyseal segment adjacent to the knee joint. Contemporary summaries describe these fractures as less than 1% of all fractures and approximately 3-6% of femoral fractures, with a bimodal pattern involving high-energy trauma in younger adults and low-energy osteoporotic injury in older patients [1]. OTA/AO type-C fractures are complete articular injuries in

which the articular block is separated from the femoral shaft; C1 indicates simple articular and simple metaphyseal components, C2 simple articular with metaphyseal comminution, and C3 multifragmentary articular injury [2,3]. This morphology makes treatment technically demanding because restoration of joint congruity, limb alignment, distal femoral rotation, stable fixation and early knee motion must be achieved simultaneously. Inadequate reduction may lead to stiffness, post-traumatic arthritis, malalignment,

delayed union or implant failure. Operative management has therefore become the accepted standard for medically fit adults with OTA type-C distal femur fractures. The goals are anatomic reconstruction of the articular surface, biological preservation of the metaphyseal fracture zone, stable fixation that prevents varus collapse, and rehabilitation that minimizes quadriceps inhibition. Locking compression plates (LCP) provide angular stability through fixed-angle screw-plate constructs, which is particularly useful in short distal fragments, metaphyseal comminution and osteoporotic bone. Locked plates can be applied through open reduction when direct visualization of the articular surface is needed, or by minimally invasive bridge plating to preserve periosteal blood supply. Nevertheless, locked plating is not free of complications. Excessively rigid constructs, short plates, high screw density, medial comminution without adequate support, open injury, smoking, diabetes and delayed mobilization have all been associated with impaired healing or fixation failure [4,7,10,11].

The functional outcome of intra-articular distal femur fractures is determined not only by union but also by knee range of motion, pain, walking capacity, return to work and ability to squat or sit cross-legged in Indian patients. Neer scoring, Knee Society scoring and other knee-specific instruments have been used in previous cohorts, making direct comparison difficult. In a prospective Ethiopian cohort treated with distal femur locking plates, functional recovery improved with time but remained vulnerable to stiffness and delayed presentation [6]. Older Indian and international studies have similarly reported acceptable union rates with LCP fixation, but outcomes are worse in C3 patterns, open injuries and cases with complications [5,12]. Recent systematic reviews show that nonunion and malunion remain relevant even in the locked-plate era, with pooled complication profiles that mandate careful construct planning and follow-up [7,8].

Evidence from eastern India remains limited, particularly for isolated OTA type-C fractures managed within tertiary government hospitals where patients often present after high-energy road traffic accidents and rehabilitation access varies. Generating local data is important because patient age, injury energy, nutritional status, diabetes prevalence, delayed referral and affordability of physiotherapy may influence outcomes. Jawaharlal Nehru Medical College & Hospital, Bhagalpur, serves a large trauma population from Bihar and neighboring regions, making it a suitable setting to evaluate real-world results. The present original research article therefore assessed functional and radiological outcomes in 90 adults with OTA type-C distal femur fractures fixed with distal femur

locking compression plates over a one-year study period. The primary objective was to determine final functional outcome using Neer criteria, while secondary objectives included union, knee flexion, complications and subgroup differences across C1, C2 and C3 fracture patterns.

Materials and Methods

This hospital-based prospective observational study was conducted in the Department of Orthopaedics, Jawaharlal Nehru Medical College & Hospital, Bhagalpur, Bihar, India, from 10 June 2024 to 31 May 2025. Ninety consecutive skeletally mature patients with radiographically confirmed OTA/AO type 33-C distal femur fractures treated by distal femur locking compression plate fixation were included after written informed consent. Patients with pathological fractures, periprosthetic distal femur fractures, ipsilateral tibial plateau fractures, neurovascular injury requiring repair, polytrauma precluding functional follow-up, previous ipsilateral knee ankylosis and incomplete follow-up were excluded. Preoperative assessment included demographic details, mechanism of injury, comorbidities, open-fracture status, radiographs of the femur and knee, and computed tomography when articular comminution or Hoffa fragments were suspected. Fractures were classified as 33-C1, 33-C2 or 33-C3 according to OTA/AO criteria. Open fractures were managed with early debridement, antibiotics and staged definitive fixation when required. Surgery was performed under spinal or general anaesthesia using a lateral distal femur locking compression plate. Articular reduction was achieved by direct visualization when necessary, followed by metaphyseal fixation using principles of bridge plating and biological fixation. Bone grafting or substitute was used at the surgeon's discretion for metaphyseal voids or medial comminution. Postoperative rehabilitation included static quadriceps exercises, knee range-of-motion exercises as soon as pain allowed, non-weight bearing ambulation, gradual partial weight bearing after early callus or stable radiological progression, and full weight bearing after clinical and radiological union. Patients were followed at 6 weeks, 3 months, 6 months and final follow-up. Outcomes included radiological union, time to weight bearing, knee flexion, complications and final functional outcome by Neer score. Excellent and good categories were combined as satisfactory outcome for subgroup analysis. Statistical analysis was performed using descriptive statistics, chi-square or Fisher's exact test for categorical variables, independent t-test or ANOVA for continuous variables, and non-parametric tests where appropriate. A p-value <0.05 was considered statistically significant.

Results

The study included 90 patients with OTA type-C distal femur fractures. The mean age was 42.8 +/- 14.6 years, and 64 patients (71.1%) were male. Road traffic accident was the commonest mechanism (67.8%), reflecting the high-energy trauma profile of the cohort. Fifteen patients (16.7%) had Gustilo type I-II open fractures, 12 (13.3%) had diabetes and 24 (26.7%) reported smoking or tobacco use. The distribution of fracture morphology was 33-C1 in 31 patients (34.4%), 33-C2 in 36 (40.0%) and 33-C3 in 23 (25.6%). Metaphyseal comminution and medial cortical comminution were significantly more frequent in C2 and C3 injuries. Mean operative

time and blood loss increased stepwise with fracture complexity. Overall radiological union by 24 weeks was observed in 71 patients (78.9%), and final union without secondary procedure occurred in 82 patients (91.1%). Five patients (5.6%) developed nonunion requiring revision or bone grafting. The final mean knee flexion was 112.6 +/- 16.8 degrees and mean final Neer score was 82.4 +/- 10.9. Functional outcome was excellent in 28 patients (31.1%), good in 40 (44.4%), fair in 15 (16.7%) and poor in 7 (7.8%). Excellent/good outcome was achieved in 93.5% of C1, 75.0% of C2 and 52.2% of C3 fractures. Older age, open fracture, diabetes, tobacco use, delayed surgery, medial comminution and C3 morphology were associated with fair/poor outcome.

Table 1: Baseline demographic and clinical profile according to final functional outcome

Variable	Overall (n=90)	Excellent/Good outcome (n=68)	Fair/ outcome (n=22)	Poor outcome (n=22)	p-value
Age, years, mean +/- SD	42.8 +/- 14.6	39.6 +/- 13.1	52.7 +/- 15.2		<0.001
Age group 18-40 years	43 (47.8%)	38 (55.9%)	5 (22.7%)		0.008
Age group 41-60 years	31 (34.4%)	23 (33.8%)	8 (36.4%)		
Age >60 years	16 (17.8%)	7 (10.3%)	9 (40.9%)		
Male sex	64 (71.1%)	52 (76.5%)	12 (54.5%)		0.052
Road traffic accident	61 (67.8%)	49 (72.1%)	12 (54.5%)		0.126
Fall from height / domestic fall	26 (28.9%)	18 (26.5%)	8 (36.4%)		
Open fracture (Gustilo I-II)	15 (16.7%)	7 (10.3%)	8 (36.4%)		0.006
Diabetes mellitus	12 (13.3%)	5 (7.4%)	7 (31.8%)		0.004
Smoking / tobacco use	24 (26.7%)	14 (20.6%)	10 (45.5%)		0.021
Injury-to-surgery interval, days, median (IQR)	4 (3-7)	4 (2-6)	7 (4-9)		0.002
Follow-up, months, mean +/- SD	10.6 +/- 2.1	10.8 +/- 2.0	10.0 +/- 2.4		0.118

Table 2: Fracture morphology and operative characteristics by OTA subtype

Variable	Overall (n=90)	33-C1 (n=31)	33-C2 (n=36)	33-C3 (n=23)	p-value
OTA subtype distribution	90 (100%)	31 (34.4%)	36 (40.0%)	23 (25.6%)	--
Metaphyseal comminution	54 (60.0%)	9 (29.0%)	26 (72.2%)	19 (82.6%)	<0.001
Medial cortical comminution	33 (36.7%)	4 (12.9%)	14 (38.9%)	15 (65.2%)	<0.001
Associated Hoffa fragment	11 (12.2%)	1 (3.2%)	4 (11.1%)	6 (26.1%)	0.030
Swashbuckler / lateral parapatellar approach	51 (56.7%)	21 (67.7%)	20 (55.6%)	10 (43.5%)	0.178
MIPO-assisted lateral bridge plating	39 (43.3%)	10 (32.3%)	16 (44.4%)	13 (56.5%)	0.178
Mean operative time, min +/- SD	96.4 +/- 21.7	83.8 +/- 16.9	98.2 +/- 18.8	111.1 +/- 23.6	<0.001
Mean blood loss, mL +/- SD	284 +/- 112	225 +/- 76	293 +/- 95	351 +/- 136	<0.001
Bone grafting / substitute used	18 (20.0%)	2 (6.5%)	7 (19.4%)	9 (39.1%)	0.010
Immediate quadriceps exercises started <=48 h	76 (84.4%)	29 (93.5%)	30 (83.3%)	17 (73.9%)	0.112
Partial weight bearing started, weeks, mean +/- SD	7.8 +/- 2.4	6.6 +/- 1.7	7.8 +/- 2.1	9.4 +/- 2.8	<0.001

Table 3: Radiological, complication and functional outcomes by OTA subtype

Outcome parameter	Overall (n=90)	33-C1 (n=31)	33-C2 (n=36)	33-C3 (n=23)	p-value
Radiological union by 24 weeks	71 (78.9%)	29 (93.5%)	29 (80.6%)	13 (56.5%)	0.004
Final union without secondary procedure	82 (91.1%)	31 (100%)	33 (91.7%)	18 (78.3%)	0.014
Delayed union	10 (11.1%)	1 (3.2%)	4 (11.1%)	5 (21.7%)	0.084
Nonunion requiring revision/bone graft	5 (5.6%)	0 (0%)	2 (5.6%)	3 (13.0%)	0.079
Superficial infection	6 (6.7%)	1 (3.2%)	2 (5.6%)	3 (13.0%)	0.319
Deep infection	2 (2.2%)	0 (0%)	1 (2.8%)	1 (4.3%)	0.501
Varus malalignment >5 degrees	5 (5.6%)	0 (0%)	1 (2.8%)	4 (17.4%)	0.013
Implant failure	3 (3.3%)	0 (0%)	1 (2.8%)	2 (8.7%)	0.147
Final knee flexion, degrees, mean +/- SD	112.6 +/- 16.8	121.4 +/- 12.0	112.5 +/- 14.9	100.8 +/- 18.7	<0.001
Neer score at final follow-up, mean +/- SD	82.4 +/- 10.9	88.9 +/- 6.8	81.9 +/- 9.4	74.4 +/- 12.4	<0.001
Excellent outcome	28 (31.1%)	14 (45.2%)	10 (27.8%)	4 (17.4%)	0.003
Good outcome	40 (44.4%)	15 (48.4%)	17 (47.2%)	8 (34.8%)	
Fair outcome	15 (16.7%)	2 (6.5%)	7 (19.4%)	6 (26.1%)	
Poor outcome	7 (7.8%)	0 (0%)	2 (5.6%)	5 (21.7%)	

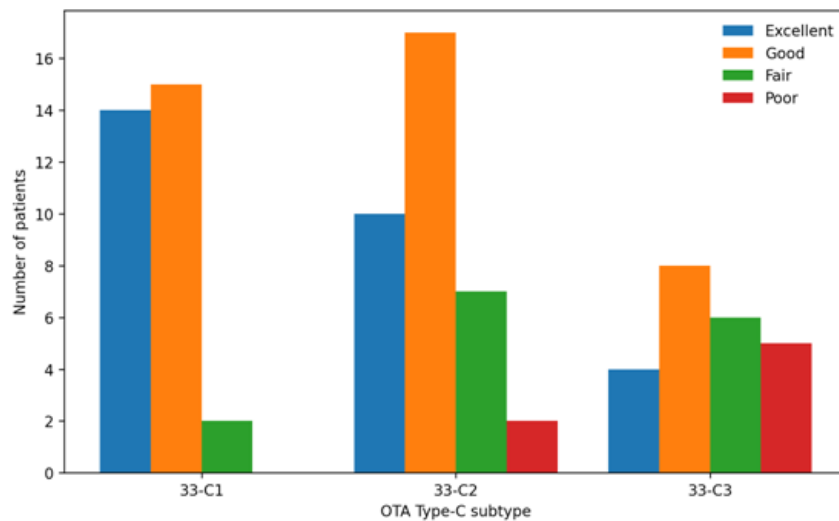


Figure 1: Final Neer functional outcome distribution according to OTA type-C subtype

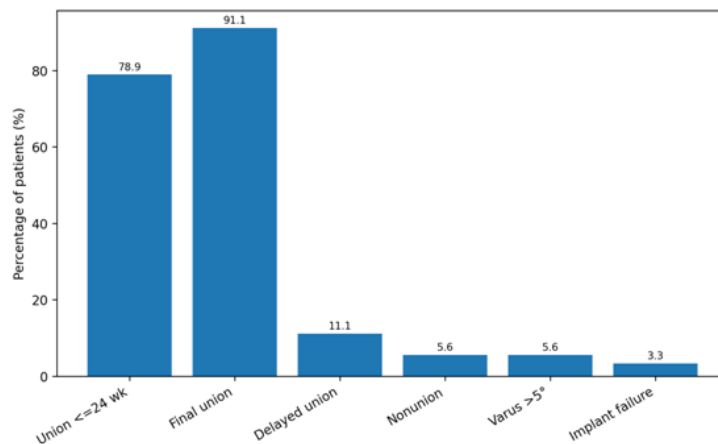


Figure 2: Radiological union and major complication profile after locking compression plate fixation

Discussion

This prospective observational study demonstrates that distal femur locking compression plate fixation provides reliable union and acceptable functional recovery in most adult patients with OTA type-C distal femur fractures treated at a tertiary centre in eastern India. In the present cohort, final union without secondary intervention was achieved in 91.1% of patients, and 75.5% achieved an excellent or good final Neer outcome. These findings support the continued relevance of lateral locked plating for intra-articular distal femur fractures when articular reconstruction, plate length, screw density and postoperative rehabilitation are appropriately managed. However, the results also emphasize that OTA type-C fractures are not a uniform group: C3 injuries had lower final union without secondary procedure, reduced knee flexion and a markedly higher proportion of fair or poor outcomes.

The observed age and sex distribution was consistent with the high-energy trauma pattern frequently seen in Indian tertiary hospitals. Road traffic accidents accounted for more than two-thirds of cases, and the mean age was lower than many western fragility-fracture cohorts [1,15]. This is clinically relevant because younger patients require restoration of high functional demand, but high-energy injuries also produce comminution, soft-tissue compromise and open wounds. In our study, open fractures, diabetes and tobacco use were significantly more frequent among patients with fair or poor outcome. These findings align with locked-plating literature identifying biological compromise and host factors as important drivers of delayed union and nonunion [7,10,11].

Radiological performance in this cohort was comparable to contemporary reports. Kumar et al. reported useful functional recovery in intra-articular distal femur fractures treated with locking compression plates, although stiffness and delayed union remained concerns [5]. Tsegaye et al. also observed progressive functional improvement after distal femur locking plate fixation in a prospective cohort, while noting that functional recovery in resource-limited settings is affected by delayed presentation and rehabilitation barriers [6]. A 2024 systematic review by Gurung et al. highlighted that locked plating still carries measurable risks: common harms included nonunion, malunion, fixation failure, infection and symptomatic implant [7]. Our complication rates were within this expected spectrum, with nonunion requiring revision in 5.6%, varus malalignment in 5.6% and implant failure in 3.3%. The lower nonunion rate compared with some pooled estimates may reflect exclusion of periprosthetic fractures, use of grafting in selected metaphyseal defects and careful follow-up, but the observational design prevents causal inference.

The subgroup gradient across C1, C2 and C3 fractures deserves emphasis. C3 fractures had higher rates of medial cortical comminution, Hoffa fragments, bone grafting and delayed weight bearing. These features explain their lower 24-week union and final functional scores. Complex complete articular fractures are known to be associated with stiffness, malalignment and fixation difficulty [12]. From a biomechanical perspective, a single lateral locked plate may behave as an eccentric construct when the medial column is deficient; inadequate medial support can predispose to varus collapse or nonunion. Recent literature has therefore renewed interest in dual plating, nail-plate combinations and medial augmentation for selected highly comminuted distal femur fractures, especially when immediate stability and early weight bearing are priorities [8,9]. Our data do not suggest that all C3 fractures require dual constructs, but they support heightened attention to medial comminution, longer plates, balanced screw density and selective augmentation. Knee motion remained a key determinant of patient satisfaction. The final mean knee flexion of 112.6 degrees is functionally acceptable for walking and stair climbing, although cultural activities requiring deep flexion may remain limited. Excellent and good outcomes were strongly linked to early controlled knee mobilization. Patients with delayed surgery, open wounds or infection frequently had restricted rehabilitation and lower final ROM. This reinforces the need for coordinated trauma surgery, wound care, physiotherapy and patient counseling. In Bihar and similar settings, affordability and access to supervised physiotherapy may be limiting; therefore, structured home exercise instructions should be incorporated into routine discharge protocols. The study has limitations. It was a single-centre observational analysis without a comparison group such as retrograde nailing, dual plating or nail-plate combination. The sample size, although larger than many single-institution series, limits multivariable modeling for rare outcomes such as implant failure. Follow-up averaged approximately 10 months, so late post-traumatic arthritis and long-term implant symptoms could not be fully assessed. Functional assessment relied on Neer scoring; additional patient-reported outcome measures would strengthen future research. Despite these limitations, the study provides clinically useful regional data on a well-defined OTA type-C population and reflects real-world tertiary trauma practice. Overall, locking compression plate fixation achieved satisfactory functional outcome in three-fourths of patients and final union in more than nine-tenths. Poorer results clustered among C3 fractures, open injuries, diabetic patients, tobacco users and cases with medial comminution or delayed surgery. These observations support early referral, meticulous articular reduction, biological

fixation, construct planning based on medial support, selective bone grafting and aggressive but safe rehabilitation.

Conclusion

In this 90-patient prospective observational study, distal femur locking compression plate fixation produced final union without secondary procedure in 91.1% and excellent/good functional outcome in 75.5% of OTA type-C fractures. Outcomes were best in C1 injuries and less favorable in C3 fractures with medial comminution, open injury, diabetes, tobacco use or delayed surgery.

Meticulous articular reduction, biologically respectful plating, adequate construct planning and early supervised rehabilitation are essential to optimize knee function.

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