



Original Article

A Study of Functional Outcomes of Distal Femur Fracture Treated with Anatomical Distal Femur Locking Plate

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ABSTRACT

Background: Distal femur fractures are complex injuries associated with significant morbidity and functional impairment. Anatomical distal femur locking plates provide angular stability and have become a preferred fixation method for achieving stable fixation and early mobilisation.

Objective: To evaluate the functional and radiological outcomes of distal femur fractures treated with anatomical distal femur locking plates and to identify factors influencing functional recovery.

Materials and Methods: This prospective observational study was conducted in the Department of Orthopaedics at SMIMER Hospital, Surat, India, from October 2024 to March 2026. Thirty adult patients with distal femur fractures underwent open reduction and internal fixation using an anatomical distal femur locking plate. Patients were followed up at 6, 10, 14, 18, and 24 weeks. Clinical assessment included pain, knee range of motion, weight-bearing status, complications, and functional evaluation using Neer's Knee Score. Radiological assessment evaluated fracture union and implant integrity. Statistical analysis was performed using appropriate tests, with a p-value <0.05 considered statistically significant.

Results: The mean age of the patients was 46.60 ± 19.97 years, with males constituting 53.33% of the study population. Road traffic accidents were the most common mode of injury (73.33%). The average injury-to-surgery interval was 5.8 days, and the mean fracture union time was 12.4 weeks. At the final follow-up, the mean knee flexion was 116.5° , while 46.67% of patients were pain-free. Postoperative complications were observed in 26.67% of patients, with knee stiffness being the most common complication. According to Neer's Knee Score, 36.67% of patients had excellent outcomes, 53.33% had good outcomes, and 10.00% had fair outcomes, resulting in an overall excellent-to-good outcome in 90% of cases. Earlier surgery and shorter union time were significantly associated with better functional outcomes ($p < 0.05$).

Conclusion: Anatomical distal femur locking plate fixation provides stable fracture fixation, reliable union, and excellent functional outcomes with a low complication rate. Early surgical intervention contribute significantly to improved postoperative functional recovery.

Keywords: Distal femur fracture; Locking compression plate; Anatomical distal femur locking plate; Open reduction and internal fixation; Neer's Knee Score; Functional outcome.

INTRODUCTION

Distal femur fractures are relatively uncommon injuries, accounting for approximately 3–6% of all femoral fractures and less than 1% of all fractures in adults.[1] These fractures demonstrate a bimodal age distribution, occurring predominantly in young individuals following high-energy trauma such as road traffic accidents and in elderly patients after low-energy falls associated with osteoporosis.[2] The complex anatomy of the distal femur, proximity to the knee joint, and frequent intra-articular extension make these fractures challenging to manage. Inadequate treatment may result in malunion, nonunion, knee stiffness, post-traumatic osteoarthritis, and long-term functional disability.[3]

The primary objectives of treatment include anatomical restoration of the articular surface, preservation of limb alignment, stable fixation, early mobilization of the knee joint, and restoration of pre-injury functional status.[4] Historically, conservative treatment using skeletal traction and cast bracing was associated with prolonged immobilization, delayed rehabilitation, malalignment, and unsatisfactory functional outcomes.[5] Consequently, operative fixation has become the standard of care for most displaced distal femur fractures.

Several fixation methods have been developed for distal femur fractures, including dynamic condylar screws, condylar buttress plates, retrograde intramedullary nails, Less Invasive Stabilization System (LISS), and distal femur locking compression plates.[6] Among these, the anatomical distal femur locking plate has gained widespread acceptance because of its biomechanical advantages, particularly in osteoporotic bone and comminuted fractures.[7]

Locking compression plates function as fixed-angle constructs that provide angular stability without relying solely on screw purchase within the bone.[8] This design minimizes loss of reduction, preserves periosteal blood supply, allows bridge plating techniques, and facilitates biological fracture healing while maintaining adequate mechanical stability.[9] The pre-contoured anatomical design further reduces intraoperative plate contouring and improves fixation of metaphyseal and intra-articular fragments.[10]

The advent of minimally invasive plate osteosynthesis (MIPPO) techniques has further enhanced the management of distal femur fractures by minimizing soft tissue disruption and preserving fracture biology.[11] Nevertheless, open reduction and internal fixation (ORIF) remains indispensable in fractures requiring direct visualization and anatomical reconstruction of the articular surface. The choice between ORIF and MIPPO depends on fracture morphology, soft tissue condition, and surgeon expertise.[12]

Despite advances in implant technology, postoperative complications such as delayed union, infection, implant failure, varus collapse, knee stiffness, and persistent pain continue to influence functional outcomes.[13] Therefore, assessment of both radiological union and functional recovery using validated scoring systems such as Neer's Knee Score is essential for evaluating treatment success.[14]

The present prospective observational study was undertaken to evaluate the functional and radiological outcomes of distal femur fractures treated with anatomical distal femur locking plates at a tertiary care teaching hospital. The study also aimed to analyze demographic, fracture-related, and treatment-related factors influencing postoperative functional outcomes.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted in the Department of Orthopaedics at SMIMER Hospital, Surat, India, over 18 months from October 2024 to March 2026. A total of 30 consecutive patients with distal femur fractures who fulfilled the predefined eligibility criteria were enrolled. Institutional Ethics Committee approval was obtained before commencement of the study, and written informed consent was obtained from all participants.

Study Population

Adult patients (>18 years) presenting with intra-articular or juxta-articular distal femur fractures were included in the study. Patients with pathological fractures, Gustilo–Anderson type III open distal femur fractures, or those unwilling to provide written informed consent were excluded.

Initial Assessment and Preoperative Evaluation

All patients were initially managed according to the principles of Advanced Trauma Life Support (ATLS). Following hemodynamic stabilization, a detailed history and clinical examination were performed. Particular attention was given to local examination of the injured limb, associated musculoskeletal injuries, and neurovascular status. Standard anteroposterior and lateral radiographs of the affected femur were obtained in all cases. Fractures were classified according to the AO/OTA classification system. Computed tomography (CT) with three-dimensional reconstruction was performed whenever fracture morphology required further delineation.

Open wounds, when present, were managed with sterile dressing, tetanus prophylaxis, intravenous broad-spectrum antibiotics, and early surgical debridement as indicated. Patients were temporarily immobilized using above-knee skin traction or skeletal traction until definitive fixation. Routine preoperative laboratory investigations and anesthetic fitness assessments were completed before surgery.

Surgical Procedure

All fractures were treated by open reduction and internal fixation (ORIF) using a Distal Femur Anatomical Locking Compression Plate (DFLP). Implant size and plate length were selected preoperatively based on fracture configuration and radiographic measurements, aiming for adequate metaphyseal and diaphyseal fixation.

Surgery was performed under spinal or general anesthesia, depending on the anesthesiologist's assessment, with spinal anesthesia being the preferred technique. Patients were positioned supine on a plain operating table, and fracture fixation was performed through the Swashbuckler approach under strict aseptic precautions. Intravenous prophylactic antibiotics were administered before skin incision. After achieving satisfactory reduction, the locking compression plate was applied over the lateral aspect of the distal femur and fixed with appropriate locking screws. Wound closure was performed in layers following confirmation of satisfactory reduction and implant placement. Distal neurovascular status was reassessed before completion of the procedure.

Postoperative Management

The operated limb was elevated to minimize postoperative edema. Intravenous antibiotics were administered for six days, followed by oral antibiotics. Postoperative radiographs were obtained within 48 hours to evaluate fracture reduction and implant position. Early rehabilitation included ankle mobilization and quadriceps strengthening exercises as tolerated. Patients were discharged after suture removal between postoperative days 10 and 15. Partial weight-bearing was initiated following radiological evidence of early fracture union and was gradually progressed to full weight-bearing according to clinical and radiographic healing.

Follow-up and Outcome Assessment

Patients were evaluated at postoperative intervals of 6, 10, 14, 18, and 24 weeks. Each follow-up included detailed clinical and radiological assessment. Clinical evaluation comprised assessment of knee range of motion (flexion and extension), pain, swelling, wound condition, weight-bearing ability, and postoperative complications. Radiological assessment included evaluation of fracture alignment, implant integrity, and progression toward fracture union. Functional recovery was documented throughout the follow-up period.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using appropriate statistical software. Continuous variables were expressed as mean \pm standard deviation (SD), while categorical variables were presented as frequencies and percentages. Associations between categorical variables were analyzed using the Chi-square test. A p-value <0.05 was considered statistically significant.

RESULTS AND OBSERVATIONS

Table 1. Baseline Demographic Characteristics (n = 30)

Variable	Category	n (%)
Age Group (years)	18–20	2 (6.67)
	21–30	5 (16.67)
	31–40	7 (23.33)
	41–50	4 (13.33)
	51–60	5 (16.67)
	>60	7 (23.33)
Sex	Male	16 (53.33)
	Female	14 (46.67)

Mean age: 46.60 \pm 19.97 years

Table 2. Injury Characteristics

Variable	Category	n (%)
Mode of Injury	Road Traffic Accident	22 (73.33)
	Domestic Fall	8 (26.67)
Side Involved	Right	20 (66.67)
	Left	10 (33.33)
Associated Injuries	Same Limb	4 (13.33)
	Opposite Limb	2 (6.67)
	Other Orthopaedic	3 (10.00)

	Non-Orthopaedic	2 (6.67)
	None	19 (63.33)

Table 3. Fracture Characteristics

Variable	Category	n (%)
AO Classification	A1	4 (13.33)
	A2	4 (13.33)
	A3	6 (20.00)
	C1	3 (10.00)
	C2	9 (30.00)
	C3	4 (13.33)
Fracture Status	Closed	27 (90.00)
	Grade I	1 (3.33)
	Grade II	2 (6.67)

Table 4. Surgical Characteristics

Variable	Category	n (%)
Injury-Surgery Interval	<1 Week	23 (76.67)
	1–2 Weeks	4 (13.33)
	2–3 Weeks	2 (6.67)
	>3 Weeks	1 (3.33)
Surgical Procedure	ORIF	18 (60.00)
	MIPPO	12 (40.00)

Average injury-to-surgery interval = 5.8 days

Table 5. Clinical Outcome at Final Follow-up

Variable	Category	n (%)
Pain (VAS)	None	14 (46.67)
	Mild	13 (43.33)
	Moderate	3 (10.00)
	Severe	0
Difficulty in Daily Activity	None	18 (60.00)
	Moderate	11 (36.67)
	Severe	1 (3.33)
Knee Flexion	<90°	2 (6.67)
	90–120°	11 (36.67)
	120–150°	14 (46.67)
	150–180°	3 (10.00)

Mean knee flexion = 116.5°

Table 6. Radiological Outcome

Variable	Category	n (%)
Union Time	8–11 weeks	17 (56.67)
	12–15 weeks	9 (30.00)
	16–19 weeks	3 (10.00)
	≥20 weeks	1 (3.33)
Partial Weight Bearing	8–12 weeks	22 (73.33)
	12–16 weeks	5 (16.67)
	16–20 weeks	3 (10.00)
Full Weight Bearing	8–12 weeks	2 (6.67)
	12–16 weeks	22 (73.33)
	16–20 weeks	4 (13.33)
	20–24 weeks	2 (6.67)

Average union time = 12.4 weeks

Table 7. Post-operative Complications and Functional Outcome

Variable	Category	n (%)
Complications	Superficial Infection	1 (3.33)
	Deep Infection	0

	Knee Stiffness	3 (10.00)
	Varus Deformity	2 (6.67)
	Implant Loosening	1 (3.33)
	Limping	1 (3.33)
	None	22 (73.33)
Neer's Outcome	Excellent	11 (36.67)
	Good	16 (53.33)
	Fair	3 (10.00)
	Poor	0

Excellent + Good = 90%

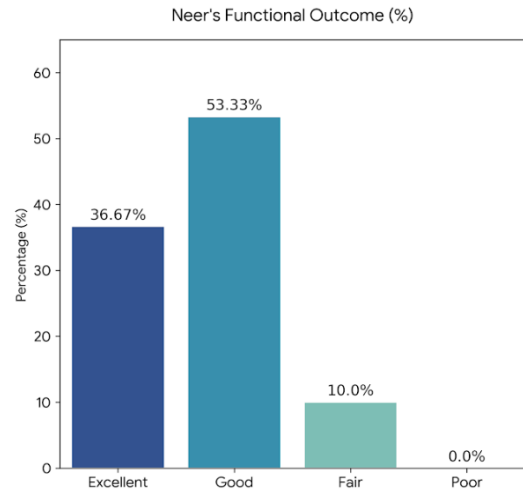
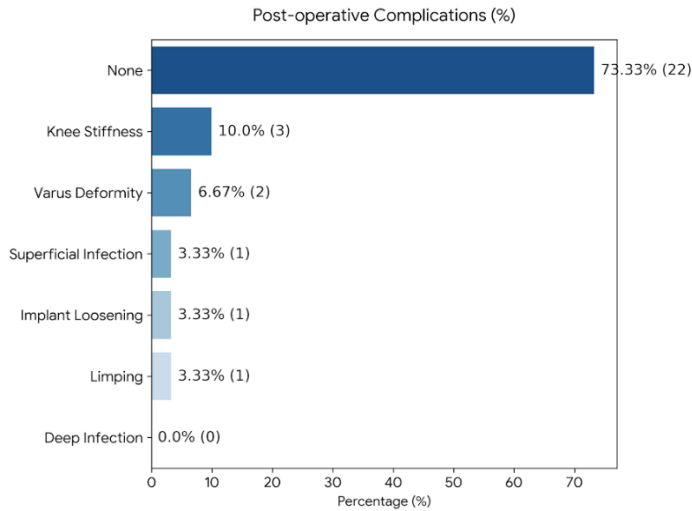


Table 8. Association of Demographic Factors with Neer's Knee Score

Variable	Mean \pm SD	F-value	p-value
Age Group	—	3.482	0.016
Sex	Male 83.19\pm5.64 Female 78.43\pm8.25	3.58	0.069
Mode of Injury	RTA 83.27\pm5.82 Domestic Fall 76.25\pm7.94	6.87	0.014

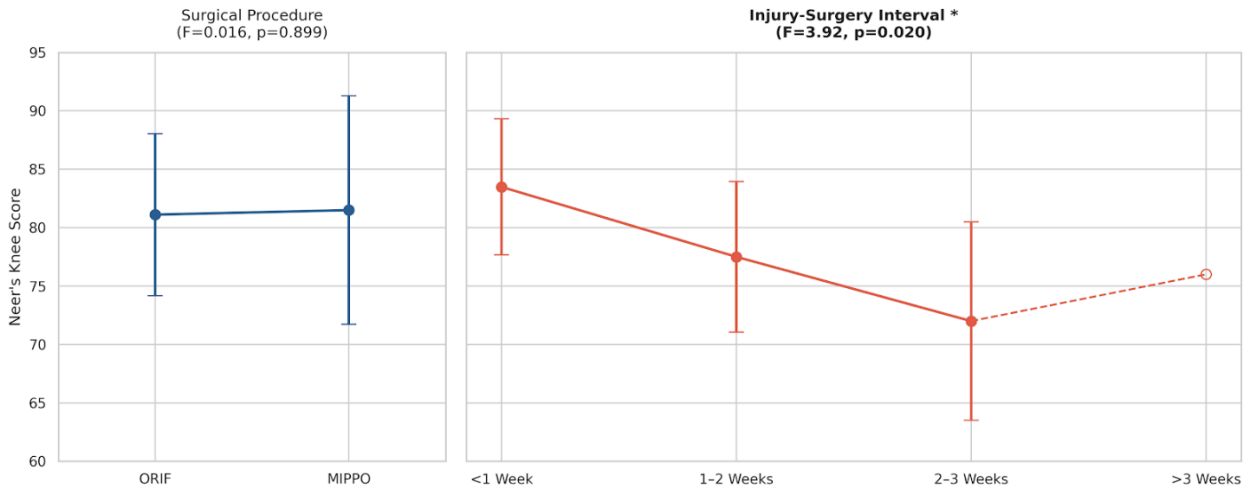
Table 9. Association of Fracture Characteristics with Neer's Knee Score

Variable	Mean \pm SD	F-value	p-value
Fracture Type	Extra-articular 81.57\pm5.93 Complete Articular 80.69\pm7.82	0.125	0.726
Time to Union	84.76\pm5.19 / 79.33\pm4.58 / 70.50\pm6.45	12.456	0.0002
Fracture Status	Closed 81.85\pm6.58 Open 74.67\pm8.50	2.68	0.113

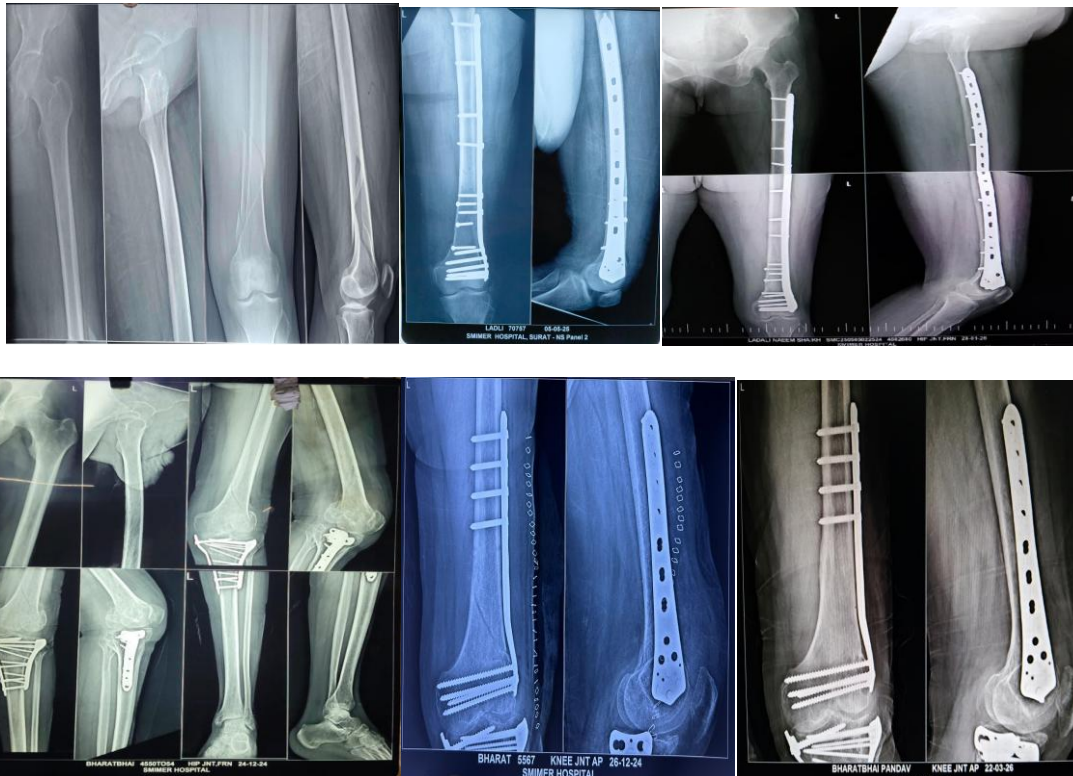
Table 10. Association of Treatment Factors with Neer's Knee Score

Variable	Mean \pm SD	F-value	p-value
Surgical Procedure	ORIF 81.11\pm6.94 MIPPO 81.50\pm9.77	0.016	0.899
Injury-Surgery Interval	<1 Week 83.48\pm5.82 1-2 Weeks 77.50\pm6.45 2-3 Weeks 72.00\pm8.49 >3 Weeks 76.00	3.92	0.020

Association of Treatment Factors with Neer's Knee Score



Case; 1



Case; 2

DISCUSSION

Distal femur fractures remain challenging injuries because of their complex anatomy, frequent intra-articular involvement, and the need to restore both mechanical alignment and knee function. Anatomical distal femur locking plates have become a preferred fixation method owing to their angular stability, especially in comminuted and osteoporotic fractures.[7,8] The present prospective study evaluated the functional outcomes of 30 patients treated with anatomical distal femur locking plates.

The mean age of patients in the present study was 46.60 ± 19.97 years, with the highest incidence observed in the 31–40 years and >60 years age groups, demonstrating the classical bimodal distribution reported in previous studies.[2,15] Younger patients usually sustain these fractures following high-energy trauma, whereas elderly individuals sustain fractures secondary to osteoporotic low-energy falls. Similar age distributions have been reported by Yeap and Deepak,[16] and Hosam et al.[17]

Males constituted 53.33% of cases, which is consistent with studies reporting a slight male predominance because of greater exposure to road traffic accidents and occupational injuries.[16,18] However, the nearly equal gender distribution in the present study also reflects the increasing incidence of osteoporotic distal femur fractures among elderly women.

Road traffic accidents accounted for 73.33% of injuries, making them the predominant mechanism of trauma. Similar observations have been reported by Schutz et al.[19] and Vallier et al.,[20] where high-energy trauma was responsible for the majority of distal femur fractures in younger patients.

According to the AO/OTA classification, C2 fractures (30%) represented the most common fracture type, followed by A3 fractures (20%). The predominance of complete articular fractures is comparable with previous series evaluating surgically managed distal femur fractures.[21] The majority of fractures (90%) were closed injuries, reflecting the relatively lower incidence of severe open distal femur fractures reported in tertiary trauma centres.

Early surgical fixation is widely recommended to facilitate fracture reduction, decrease soft tissue complications, and initiate early rehabilitation.[22] In the present study, 76.67% of patients underwent surgery within one week of injury, with an average injury-to-surgery interval of 5.8 days. Statistical analysis demonstrated significantly better Neer's Knee Scores among patients operated earlier ($p = 0.020$), emphasizing the importance of timely intervention. Similar findings have been reported by Henderson et al.[23]

Both ORIF (60%) and minimally invasive plate osteosynthesis (MIPPO) (40%) were utilized depending on fracture configuration. No statistically significant difference in functional outcome was observed between the two techniques ($p = 0.899$), suggesting that satisfactory outcomes can be achieved when appropriate surgical principles are followed. Similar conclusions were drawn by Kregor et al., who reported excellent outcomes with both techniques using locking plates.[24] The average radiological union time in the present study was 12.4 weeks, with more than half of patients achieving union between 8 and 11 weeks. These findings are comparable with reports by Yeap and Deepak,[16] Kayali et al.,[25] and Weight and Collinge,[26] who documented mean union times ranging between 12 and 16 weeks following locking plate fixation.

Time to fracture union demonstrated a highly significant association with functional outcome ($p = 0.0002$). Patients with earlier union achieved significantly higher Neer's Knee Scores than those with delayed union. Similar observations have been reported in previous studies, indicating that delayed union adversely affects knee rehabilitation and overall functional recovery.[26]

At the final follow-up, 46.67% of patients reported no pain, while only 10% experienced moderate pain. Likewise, 60% of patients reported no difficulty in daily activities. The mean knee flexion achieved was 116.5° , with nearly half the patients obtaining flexion between 120° and 150° . These findings compare favorably with those reported by Vallier et al.[20] and Kregor et al.,[24] who documented mean postoperative knee flexion ranging from 110° to 120° .

The postoperative complication rate was relatively low. Knee stiffness was observed in 10%, varus deformity in 6.67%, superficial infection in 3.33%, implant loosening in 3.33%, and limping in 3.33%, while 73.33% of patients experienced no complications. The low infection rate observed in this study may be attributed to meticulous surgical technique, perioperative antibiotic prophylaxis, and early rehabilitation. Similar complication profiles have been reported by Henderson et al.[23] and Rodriguez et al.[27]

Functional evaluation using Neer's Knee Score demonstrated excellent outcomes in 36.67%, good outcomes in 53.33%, and fair outcomes in 10%, with 90% of patients achieving excellent-to-good functional results. Comparable success rates have been reported in previous studies utilizing distal femur locking plates.[16,24,25]

Age significantly influenced functional outcome ($p = 0.016$), with younger patients demonstrating superior Neer's Knee Scores compared with elderly individuals. Better bone quality, fewer medical comorbidities, and improved rehabilitation compliance likely contributed to these findings. Similarly, patients sustaining road traffic accidents demonstrated significantly better functional scores than those with domestic falls ($p = 0.014$), possibly reflecting differences in baseline physiological reserve and fracture characteristics.

Fracture type (extra-articular versus complete articular) and fracture status (closed versus open) were not significantly associated with final functional outcome, indicating that satisfactory anatomical reduction and stable fixation using locking plates can overcome differences in fracture morphology when appropriate surgical principles are followed.

Overall, the findings of the present study support the growing body of evidence that anatomical distal femur locking plates provide stable fixation, promote reliable fracture union, allow early rehabilitation, and result in excellent functional outcomes with an acceptable complication profile. Careful patient selection, early surgical intervention, accurate fracture reduction, and structured postoperative rehabilitation remain the key determinants of successful treatment.

CONCLUSION

Anatomical distal femur locking plate fixation is an effective treatment for distal femur fractures, providing stable fixation, reliable fracture union, and good functional recovery. In this study, the average union time was 12.4 weeks, and 90% of patients achieved excellent or good functional outcomes according to Neer's Knee Score. Early surgical intervention were associated with significantly better functional results. The complication rate was low, indicating that distal femur locking plates are a safe and reliable option for managing both extra-articular and intra-articular distal femur fractures when combined with appropriate surgical technique and postoperative rehabilitation.

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