

Research Article

A Study of Mechanical Axis and Anatomic Lateral Distal Femoral Angle (aLDFA) Deviations in Postoperative Distal Femur Fracture Fixation

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ABSTRACT

Background: Distal femur fractures are complex injuries associated with substantial functional impairment and a high risk of postoperative malalignment. Restoration of the mechanical axis and anatomical lateral distal femoral angle (aLDFA) is essential for achieving optimal clinical outcomes following surgical fixation. This study evaluated postoperative mechanical alignment, radiological parameters, and functional outcomes in patients undergoing distal femur fracture fixation.

Methods: A prospective observational study was conducted among 30 adult patients with distal femur fractures treated surgically at a tertiary care hospital between January 2025 and July 2026. Patients were followed for six months. Clinical evaluation included the Visual Analogue Scale (VAS) for pain and the modified Mize criteria for functional outcome. Radiological assessment comprised Mechanical Axis Deviation (MAD) and Anatomical Lateral Distal Femoral Angle (aLDFA), measured at the final follow-up and compared with the contralateral normal limb. Statistical analysis was performed using SPSS version 20.0, with a p-value <0.05 considered statistically significant.

Results: The majority of patients were males (70.0%) aged 46-60 years (43.3%), with closed fractures accounting for 86.7% of cases. Pain scores improved significantly during follow-up, with the mean VAS decreasing from 4.9 at one month to 0.87 at six months (p<0.001). Excellent and good functional outcomes were achieved in 80% of patients. The mean MAD (5.8 ± 2.6 mm vs. 6.7 ± 3.2 mm; p=0.237) and mean aLDFA ($81.2 \pm 1.8^\circ$ vs. $80.4 \pm 2.3^\circ$; p=0.356) did not differ significantly between the operated and contralateral limbs. Open fractures and complex Müller type C fractures were significantly associated with poorer functional outcomes.

Conclusion: Surgical fixation of distal femur fractures achieved satisfactory restoration of mechanical alignment and anatomical lateral distal femoral geometry, resulting in favorable functional outcomes in most patients. Fracture severity, particularly open and complex fracture patterns, significantly influenced postoperative recovery, whereas minor deviations in MAD and aLDFA did not adversely affect short-term functional outcomes.

Keywords: Distal femur fracture; Mechanical axis deviation; Anatomical lateral distal femoral angle; aLDFA; Modified Mize criteria; Functional outcome; Locking compression plate.

INTRODUCTION

Distal femur fractures occur at an approximately one-tenth rate of proximal femur fractures and they make up 4-6% of all femur fractures. There is a bimodal distribution of fracture depending on age and gender. Most high-energy femur fractures occur in males between 16 and 50 years, while most low-energy fractures occur in osteoporotic women > 50 years. The most common high-energy mechanism of injury is a traffic accident (53%) and the most common

low-energy mechanism is a fall at home (33%).^{1,2}

Fractures of the distal femur are common, It is usually associated with intra articular extension, soft tissue injuries, injury to the quadriceps mechanism, and severe comminution. This remains firmly fixed, from those involving component loosening and knee joint replacement. Distal femur fractures are managed surgically, using methods of osteosynthesis with a dynamic compression plate (DCP), angle condylar plate, or a short

retrograde-inserted retrograde (supracondylar) intramedullary nail.

An LCP offers all advantages of angle-stable implants. It osteoporotic bone locking compression plate is more effective than a Dynamic compression plate implant or a condylar plate because LCP provides stable fixation for the distal fragment.³

Despite all these modalities, treatment of distal femur fractures are not without complications, since most of these fractures lie close to traversing neurovascular structures, hence popliteal vessels are more prone to injury and severely comminuted fragments and bone loss, displacement of fragments these make fractures hard to fix. Since fractures are juxta-articular concerning the knee joint, the movement of this joint is affected earlier and recovery of the lost knee range of movement is delayed unless followed with good physiotherapy and gradual mobilization Significant advances have been made in the treatment of femur fractures in the past 30 years.

Neer in 1967 concluded that distal femur fractures were not fitted for internal fixation and were treated conservatively with traction & cast bracing. "It is accepted that operative fixation with the ability to maintain anatomical reduction of the joint surface, reimpose axial alignment and early mobilization presents clear advantages over closed means of treatment". Numerous implants/devices have been put forwarded for the treatment of distal femur fractures.⁴ These include anatomical reduction of the distal femoral articular surface, minimal soft tissue stripping, stable internal fixation, and early mobilization.

The purpose of this study is to study and analyse the mechanical axis and anatomic lateral distal femoral angle (aLDFA) deviation in post-operative distal femur fracture fixation. This study aimed to compare the functional and radiological outcome following distal femur fracture using mechanical axis and aLDFA in post-operative patient.

MATERIAL AND METHODS

Study Design and Setting: A prospective observational study was conducted at BIRRD Trust Hospital, Tirupati, over 18 months from January 2025 to July 2026.

Study Population and Sampling: The study included patients presenting with distal femur fractures who underwent surgical fixation at the study center. We used purposive sampling and enrolled 30 eligible patients.

Eligibility Criteria: Patients aged 18 years or older with distal femur fractures managed surgically were included in the study. Patients with pathological fractures due to causes other than osteoporosis were excluded.

Study Instrument: Data were collected using a predesigned and pretested proforma that recorded patients' demographic details, clinical history, physical examination findings, laboratory investigations, and preoperative and postoperative radiological parameters.

Ethical Considerations: The study protocol was approved by the Institutional Human Ethics Committee before participant recruitment. Written informed consent was obtained from all participants prior to enrolment. Participant confidentiality was maintained throughout the study by assigning inpatient (IP) numbers instead of recording patient names.

Study Procedure: Following ethical approval, patients fulfilling the eligibility criteria were recruited after obtaining written informed consent. At admission, demographic information, clinical history, physical examination findings, laboratory parameters (haemoglobin and total leukocyte count), and radiological findings were documented using the standardized proforma.

All patients underwent surgical management according to standard treatment protocols, including open reduction and internal fixation or closed reduction and internal fixation, as appropriate. Clinical and radiological follow-up evaluations were performed at 1, 3, and 6 months postoperatively. Radiological assessment included measurement of Mechanical Axis Deviation (MAD) and Anatomical Lateral Distal Femoral Angle (aLDFA). At the final follow-up (6 months), the MAD and aLDFA values of the operated limb were compared with those of the contralateral normal limb.

Statistical Analysis: The collected data were entered into Microsoft Excel 2019 and analyzed using the Statistical Package for the Social Sciences (SPSS) version 20.0. Categorical variables were summarized as frequencies and percentages and presented using tables and graphical representations. Associations between categorical variables and functional outcome, assessed using the modified Mize criteria, were evaluated using the Chi-square test or Fisher's exact test, as appropriate. The unpaired Student's *t*-test was used to compare the mean MAD and aLDFA between the affected and contralateral normal

limbs. Changes in Visual Analogue Scale (VAS) scores across the 1-, 3-, and 6-month follow-up visits were analyzed using Friedman's chi-square test. One-way analysis of variance (ANOVA) was performed to compare the mean

MAD and aLDFA across the different categories of the modified Mize outcome. A two-tailed p value of <0.05 was considered statistically significant.

RESULTS

Table 1: Distribution of sociodemographic factors, details of fracture, comorbidities, and Mize outcome

Variable		Frequency	Percentage
Age group (years)	21-30	7	23.3
	31-45	8	26.7
	46-60	13	43.3
	61-70	2	6.7
Gender	Male	21	70
	Female	9	30
Side of fracture	Left	16	53.3
	Right	14	46.7
Type of fracture	Closed	26	86.7
	Open	4	13.3
Mullers classification	A1	10	33.3
	A2	7	23.3
	B1	5	16.7
	B2	4	13.3
	C1	1	3.3
	C2	2	6.7
	C3	1	3.3
Comorbidities	DM	4	13.3
	HTN	4	13.3
	DM&HTN	1	3.3
	Bronchial Asthma	1	3.3
	Nil	20	66.7
Mize score	Excellent	12	40
	Good	12	40
	Fair	4	13.3
	Failure	2	6.7

Among the 30 patients included in the study, the majority (43.3%) were aged 46–60 years, with a mean predominance of males (70.0%). Left-sided fractures (53.3%) were slightly more common than right-sided fractures (46.7%). Most fractures were closed injuries (86.7%). According to Müller's classification, type A1 fractures constituted the largest proportion (33.3%), followed by A2 fractures

(23.3%). Two-thirds of the patients (66.7%) had no associated comorbidities, while diabetes mellitus and hypertension were each present in 13.3% of patients. Functional outcome assessed using the modified Mize criteria demonstrated excellent and good outcomes in 40.0% of patients each, whereas fair and failure outcomes were observed in 13.3% and 6.7% of patients, respectively.

Table 2: Visual analogue score at 1month, 3month, 6 months

VAS score	Mean	Median	IQR	Friedman Chi-square test	P value
At 1 month	4.9	5	4.00-6.00	58.513	<0.001
At 3 months	2.93	3	2.00-3.25		
At 6 months	0.87	1	0-1.25		

Pain intensity assessed using the Visual Analogue Scale (VAS) showed a significant reduction over the follow-up period. The mean VAS score decreased from $4.9 \pm$ at 1 month to

2.93 at 3 months and further to 0.87 at 6 months. Friedman's test demonstrated a statistically significant improvement in pain scores across the three follow-up visits ($\chi^2 =$

58.513, $p < 0.001$), indicating progressive postoperative pain relief.

Table 3: Mechanical axis deviation and aLDFA at 6 months

Variable		Mean (SD)	Mean difference	T value	P value
MAD at 6 months	Affected limb	5.8 (2.6)	-0.9	-1.195	0.237
	Normal limb	6.7 (3.2)			
aLDFA at 6 months	Affected limb	81.2 (1.8)	0.5	-0.93	0.356
	Normal limb	80.4 (2.3)			

At six months postoperatively, the mean mechanical axis deviation (MAD) was 5.8 ± 2.6 mm in the operated limb compared with 6.7 ± 3.2 mm in the contralateral normal limb. Similarly, the mean aLDFA measured $81.2 \pm 1.8^\circ$ in the affected limb and $80.4 \pm 2.3^\circ$ in

the normal limb. Neither MAD ($p = 0.237$) nor aLDFA ($p = 0.356$) demonstrated statistically significant differences between the affected and unaffected limbs, indicating satisfactory restoration of lower limb alignment following fixation.

Table 4: Association of Mize modified criteria outcome with variables

Variable		Outcome (Mize classification)				Fisher's exact test	P value
		Excellent No. (%)	Good No. (%)	Fair No. (%)	Failure No. (%)		
Age group (years)	21-30	1 (14.3)	4 (57.1)	2 (28.6)	0 (0)	10.156	0.255
	31-45	5 (62.5)	3 (37.5)	0 (0)	0 (0)		
	46-60	6 (46.2)	4 (30.8)	2 (15.4)	1 (7.7)		
	61-70	0 (0)	1 (50)	0 (0)	1 (50)		
Gender	Male	8 (38.1)	8 (38.1)	3 (14.3)	2 (9.5)	0.882	1.000
	Female	4 (44.4)	4 (44.4)	1 (11.2)	0 (0)		
Side of fracture	Left	5 (35.7)	6 (42.9)	1 (7.1)	2 (14.3)	2.822	0.501
	Right	7 (43.8)	6 (37.5)	3 (18.8)	0 (0)		
Type of fracture	Closed	0 (0)	0 (0)	2 (50)	2 (50)	14.166	<0.001
	Open	12 (46.2)	12 (46.2)	2 (7.7)	0 (0)		
Mullers classification	A	8 (47.1)	8 (47.1)	1 (5.9)	0 (0)	13.596	0.008
	B	4 (44.4)	4 (44.4)	1 (11.1)	0 (0)		
	C	0 (0)	0 (0)	2 (50)	2 (50)		
Comorbidities	Present	5 (50)	4 (40)	1 (10)	0 (0)	1.777	0.666
	Absent	7 (35)	11 (55)	1 (5)	1 (5)		

The modified Mize functional outcome showed a statistically significant association with fracture characteristics. Open fractures were associated with significantly poorer outcomes compared with closed fractures ($p < 0.001$). Likewise, Müller fracture classification demonstrated a significant association with

postoperative functional outcome ($p = 0.008$), with more complex fracture patterns exhibiting poorer results. In contrast, age group ($p = 0.255$), gender ($p = 1.000$), side of fracture ($p = 0.501$), and presence of comorbidities ($p = 0.666$) were not significantly associated with the functional outcome.

Table 5: Mize criteria outcome with MAD and aLDFA

Variable	Outcome – Mize classification				F value	P value
	Excellent Mean (SD)	Good Mean (SD)	Fair Mean (SD)	Failure Mean (SD)		
MAD at 6 months	6.3 (2.4)	5.7 (3.2)	4.8 (1.7)	5.8 (2.1)	0.378	0.770
ALDFTA at 6 months	81 (2.8)	78.3 (2.2)	79	78	0.231	0.874

The mean mechanical axis deviation and anatomical lateral distal femoral angle were

comparable across different modified Mize outcome categories. Patients with excellent

outcomes had a mean MAD of 6.3 ± 2.4 mm, while those with good, fair, and failure outcomes had mean values of 5.7 ± 3.2 mm, 4.8 ± 1.7 mm, and 5.8 ± 2.1 mm, respectively. Similarly, the mean aLDFA ranged from 78° to 81° across outcome categories. Analysis of variance showed no statistically significant association between postoperative MAD ($F = 0.378$, $p = 0.770$) or aLDFA ($F = 0.231$, $p = 0.874$) and functional outcome according to the modified Mize criteria.

DISCUSSION

Distal femur fractures are complex injuries that account for approximately 3–6% of all femoral fractures and present significant challenges because of their proximity to the knee joint, frequent intra-articular involvement, and risk of postoperative malalignment. The primary goals of treatment are anatomical reduction, restoration of limb alignment, stable fixation, early mobilization, and satisfactory functional recovery. The present prospective observational study evaluated the clinical and radiological outcomes of 30 patients who underwent surgical fixation for distal femur fractures, with particular emphasis on Mechanical Axis Deviation (MAD) and Anatomical Lateral Distal Femoral Angle (aLDFA).

The mean age of the study participants was 45.7 years, with the highest proportion of patients (43.3%) belonging to the 46–60-year age group. Similar findings have been reported by Nirav et al., suggesting that distal femur fractures are more common among middle-aged and older adults because of age-related reduction in bone strength and increased susceptibility to trauma.⁵ Males constituted 70% of the study population, yielding a male-to-female ratio of 2.3:1. This male predominance is consistent with previous studies and may be attributed to greater exposure to road traffic accidents and occupational injuries.^{6,7} In contrast, fractures among female patients are often associated with osteoporosis and low-energy falls.

Closed fractures accounted for 86.7% of cases, while only 13.3% were open fractures. According to the AO/OTA Müller classification, type A fractures were the most common, followed by type B and type C fractures. These findings are comparable with previous reports demonstrating that extra-articular fractures are encountered more frequently than complex intra-articular injuries.^{8,9} Road traffic

accidents were the predominant mechanism of injury (70%), reflecting the increasing burden of high-energy trauma in developing countries. Postoperative pain improved significantly during follow-up. The mean Visual Analogue Scale (VAS) score decreased from 4.9 at one month to 2.93 at three months and further to 0.87 at six months ($p < 0.001$). Patients with AO type A fractures experienced faster pain relief than those with type C fractures, while patients with open fractures continued to report mild pain during movement at the final follow-up. These findings indicate progressive fracture healing and successful postoperative rehabilitation.

The average knee flexion achieved at six months was 112.3° , which is comparable to values reported by Rademaker et al. and Ru et al. Patients with type A fractures achieved better knee mobility than those with complex type C fractures. Reduced range of motion among patients with intra-articular and open fractures is likely related to greater soft tissue injury, prolonged immobilization, and extensive articular involvement. Nevertheless, most patients achieved knee flexion sufficient for performing routine daily activities.

Only one patient developed a superficial surgical site infection following fixation of an open fracture. The infection responded well to antibiotics and regular wound care without requiring additional surgery. This low complication rate may be attributed to meticulous surgical technique, appropriate perioperative antibiotic prophylaxis, and standardized postoperative care. However, the occurrence of infection exclusively in an open fracture highlights the increased risk associated with severe soft tissue injury.

Functional outcome assessed using the modified Mize criteria demonstrated excellent or good results in 80% of patients, while fair and failure outcomes were observed in 13.3% and 6.7%, respectively. Statistical analysis revealed that fracture type and open fractures were significantly associated with poorer functional outcomes, whereas age, gender, side of injury, and associated comorbidities showed no significant association. These findings suggest that fracture severity rather than patient demographics is the principal determinant of postoperative recovery.

Restoration of the mechanical axis is essential for maintaining physiological load distribution across the knee joint. In the present study, the mean MAD at six months was 5.8 ± 2.6 mm in the operated limb compared with $6.7 \pm$

3.2 mm in the contralateral normal limb, with no statistically significant difference between the limbs ($p=0.237$). Furthermore, MAD did not differ significantly among the modified Mize outcome categories ($p=0.770$). Although patients with AO type C fractures and open fractures demonstrated relatively greater coronal malalignment, the deviations remained within clinically acceptable limits and did not significantly influence short-term functional outcomes. Similar observations have been reported by Heather V et al., who found that significant varus deformity was primarily associated with more complex fracture patterns.¹⁰

The mean aLDFA was $81.2 \pm 1.8^\circ$ in the operated limb and $80.4 \pm 2.3^\circ$ in the normal limb, with no statistically significant difference ($p=0.356$). Likewise, no significant association was observed between aLDFA and functional outcome ($p=0.874$). Although patients with complex fractures exhibited mild residual varus alignment, the mean aLDFA remained within the accepted physiological range. These findings are consistent with studies by Schutz M et al.¹¹, who reported greater varus collapse in AO type C fractures, and Michael Z et al.¹², who established normal radiographic values of distal femoral alignment in the Indian population.

An important finding of the present study is that minor variations in postoperative MAD and aLDFA did not adversely affect short-term clinical outcomes. Most patients achieved satisfactory pain relief, acceptable knee range of motion, and good functional recovery despite minimal radiological deviations. This observation suggests that restoration of alignment within physiological limits may be sufficient to achieve favourable early outcomes following distal femur fracture fixation. However, long-term follow-up is necessary to determine whether these minor deviations predispose patients to progressive varus collapse or post-traumatic osteoarthritis.¹³

The strengths of the present study include its prospective design, standardized follow-up, and comprehensive evaluation of both clinical and radiological outcomes. Nevertheless, certain limitations should be considered. The relatively small sample size and single-centre design may limit the generalizability of the findings. In addition, the follow-up period of six months was insufficient to assess long-term complications, including implant failure, secondary osteoarthritis, and late deformity.

Larger multicentre studies with longer follow-up are therefore warranted.

In conclusion, surgical fixation of distal femur fractures achieved satisfactory restoration of mechanical alignment and distal femoral anatomy, resulting in excellent or good functional outcomes in the majority of patients. Although complex AO type C fractures and open injuries were associated with relatively poorer outcomes, restoration of MAD and aLDFA comparable to the contralateral limb was achieved in most patients. Accurate anatomical reduction, stable fixation, and structured rehabilitation remain the key determinants of successful clinical and radiological outcomes following distal femur fracture fixation.

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