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Original Article

Orthopaedics Section

Clinical Outcomes of Single Lateral versus Dual Plating in Isolated Comminuted Intra-articular Distal Femur Fractures among Adults: A Retrospective Study

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ABSTRACT

Introduction: Distal femur fractures are relatively rare compared to hip fractures. Distal femur fractures, particularly Arbeitsgemeinschaft für Osteosynthesefragen (AO) 33-C2 and C3 types with multiple fragments, pose significant treatment challenges. Complex comminution and articular extension markedly increase the difficulty of achieving stable fixation.

Aim: To compare the effectiveness of Single Lateral Plating (SLP) and Dual Plating (DP) techniques in treating comminuted distal femur fractures, with a focus on clinical improvement and complication rates.

Materials and Methods: The present hospital-based retrospective study was conducted on 50 cases of comminuted intra-articular distal femur fractures managed surgically at a tertiary care medical institute in eastern India between January 2020 and December 2022. Patients were divided into two groups: Group A (n=25) received SLP, while Group B (n=25) underwent DP. Key outcomes were evaluated at the level of functional recovery and union time, with additional data collected on the intraoperative blood loss, surgical time and frequency of complications. Clinical outcomes were assessed based on functional recovery, as measured by the Knee Society Scores (KSS). Statistical analyses were conducted using unpaired t-tests and Chi-square tests. A p-value of <0.05 was considered statistically significant.

Results: Fifty adults were analysed (SLP, n=25; 16 men/9 women; 53.2±9.8 years) and (DP, n=25; 15 men/10 women; 50.0±10.9 years). The DP cohort showed higher KSSs at every follow-up- one month: 64.5±5.0 vs 54.0±6.0 (p<0.001); three months: 75.4±5.6 vs 62.5±6.8 (p<0.001); six months: 82.1±6.1 vs 66.3±6.2 (p=0.003); 12 months: 87.3±4.9 vs 69.0±5.7 (p=0.021); 15 months: 89.0±4.5 vs 70.2±5.1 (p=0.047). Radiographic union occurred earlier with DP (p<0.0001). No significant between-group differences were observed in intraoperative blood loss (p=0.21) or operative time (p=0.12), while implant failure and non-union were less frequent with DP; surgical-site infection occurred in one patient per group.

Conclusion: The DP group showed superior functional outcomes, faster healing, and fewer complications, with no significant increase in blood loss or operative duration.

Keywords: Bone plates, Functional outcome, Internal fixation, Treatment outcome

INTRODUCTION

Distal femur fractures account for approximately 3 to 7% of all femoral fractures and are often associated with significant morbidity, particularly when they involve the articular surface or present with a comminuted pattern. Excluding hip fractures, nearly one-third of femoral fractures involve the distal femur. These injuries exhibit a bimodal age distribution, occurring in younger individuals due to high-energy trauma (for example road traffic accidents), and in older adults with osteoporotic bone from low-energy falls [1]. In particular, AO/OTA 33-C2 and 33-C3 types represent complex, comminuted, intra-articular fractures that pose formidable challenges to both reduction and fixation due to metaphyseal comminution, joint surface involvement, and inherent instability [2].

Historically, non-operative management of such fractures often led to complications such as malunion, non-union, and joint stiffness, arthritis, deformities due to muscle forces (e.g., gastrocnemius-induced posterior sag and quadriceps induced anterior spike displacement). Hence, operative fixation has become the standard of care. Among various surgical options, SLP with a locking compression plate has gained popularity due to its relative simplicity, less surgical exposure, and preservation of soft-tissues. However, SLP has limitations, especially in comminuted intra-articular fractures where medial column support is compromised. In such cases, reliance on a lateral plate alone may results in varus collapse, implant failure, or delayed union [3].

To address these limitations, DP involving both lateral and medial stabilisation has been proposed for providing enhanced biomechanical stability, especially in fractures with significant medial comminution. Several recent biomechanical studies have shown that DP offers superior stability under axial and torsional loads [4-6]. Similarly, clinical studies have demonstrated improved healing rates, lower failure rates, and faster mobilisation with DP [7,8]. Nevertheless, concerns remain regarding increased operative time, soft-tissue dissection, and infection risk due to the second surgical approach.

Despite the increasing use of DP in complex distal femur fractures, there is no clear consensus on its routine application, particularly in cases where medial comminution is marginal. Moreover, many existing studies are limited by small sample sizes, heterogeneity in fracture types, or are based on Western populations, where the demographic and trauma patterns may differ from those in developing countries like India [9-12]. Comparative studies between SLP and DP, particularly in isolated AO 33-C2 and C3 fractures with long-term follow-up, are scarce [11,12].

Hence, the present retrospective comparative study aimed to bridge this gap by evaluating clinical and functional outcomes of SLP versus DP in isolated comminuted intra-articular distal femur fractures in adults, based on a uniform follow-up protocol and objective scoring using the KSS [13]. The study also seeks to clarify whether the theoretical advantages of DP translate into significantly improved clinical results, without increasing surgical morbidity. By

contributing data from an Indian tertiary care center, this study added meaningful evidence from a region underrepresented in the orthopaedic trauma literature.

MATERIALS AND METHODS

The present hospital-based retrospective study was conducted on 50 cases at a tertiary-level medical institute in Kolkata, West Bengal, Eastern India operated between January 2020 and December 2022 and data analysis was performed from August 2023 and August 2024. Ethical approval was obtained from the institutional ethics committee prior to the commencement of the study (Approval No.: IPGMER/IEC/2023/893).

Inclusion and Exclusion criteria: Patients were included in the study if they were aged between 18 and 80 years, skeletally mature, and medically fit for surgery (ASA Grade I or II). Eligible patients had comminuted intra-articular distal femur fractures classified as AO/OTA type 33-C2 or 33-C3 with either closed fractures or Gustilo-Anderson Type I open fractures [14]. Only patients who consented to regular follow-up for at least 15 months were included. Patients were excluded if they had pathological fractures (e.g., secondary to malignancy), sustained polytrauma requiring external fixation as the definitive treatment, or had pre-existing knee arthritis or significant deformities. Additional exclusion criteria included inability to adhere to post-operative rehabilitation protocols, as well as the presence of spinal injuries or neurological deficits.

Sample size selection: Sample size was determined retrospectively based on the number of patients who met the inclusion and exclusion criteria within the study period. A post-hoc power analysis using a clinically significant difference of 10 points in KSS, standard deviation of 11.5, 95% confidence level, and 80% power indicated a minimum of 21 patients per group. A total of 50 patients were included, with 25 in the SLP group and 25 in the DP group [15].

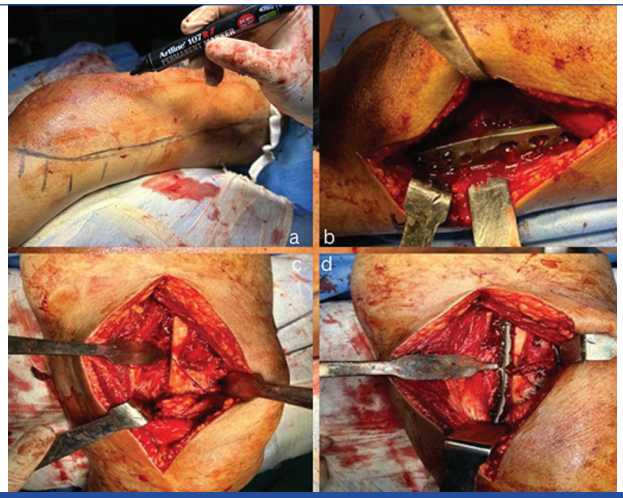
Study Procedure

All patients underwent preoperative radiographic evaluation, including anteroposterior and lateral views of the distal femur, along with computed tomography scans in selected cases to assess intra-articular involvement. Surgical intervention either SLP or DP was performed using standardised techniques by experienced orthopaedic surgeons. Intraoperative variables such as surgical time (minutes) and estimated blood loss (milliliters) were recorded. Clinical data including demographic profile, Co-morbidities, and mechanism of injury (e.g., road traffic accident, fall from height) were documented. Postoperatively, all patients followed a uniform rehabilitation protocol and follow-ups were scheduled at 1, 3, 6, 12, and 15 months. Key outcome parameters studied included time to radiological union (in weeks, mean±SD), KSS for functional evaluation, and the incidence of complications such as infection, implant failure, non-union, or reoperation. The data were systematically extracted from operative records, inpatient charts, and follow-up assessments for comparative analysis between the SLP and DP groups. KSS which evaluates knee pain stability, and motion along with walking ability and stair climbing on a 0-100 scale. Scores of 80-100 are graded excellent, 70-79 good, 60-69 fair, and <60 poor.

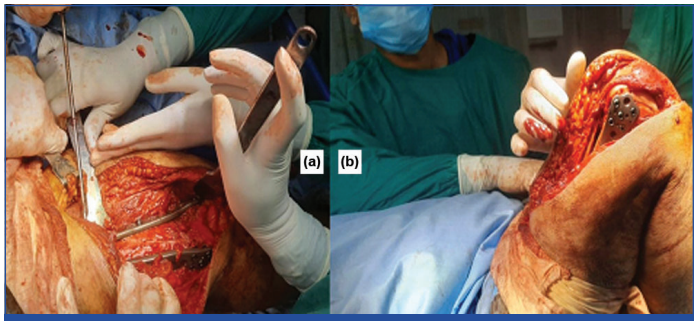
Study procedure: All patients underwent a standardised clinical evaluation and necessary investigations at the time of admission, as documented in the institutional proforma. Surgical procedures were performed under either spinal or general anaesthesia, based on patient suitability and surgeon preference, as recorded in the operative notes. Postoperative functional outcomes were assessed at regular intervals over a minimum duration of 15 months. Each visit included documentation of clinical recovery, radiographic union, and complications. Functional assessment was based on the KSS, as recorded in follow-up charts by treating orthopaedic consultants. Only cases with complete records and a minimum of 15 months of follow-up were included in the final analysis.

All patients were positioned supine on a radiolucent table with supportive positioning to facilitate reduction and intraoperative access. Patients were assigned to the SLP or DP group based on standardised institutional criteria considering the degree of medial comminution, and intraoperative stability. The choice between SLP and DP was guided by intraoperative assessment of medial comminution and fracture stability. DP was typically performed in cases where there was complete disruption of the medial cortex, a medial metaphyseal void greater than 1.5 cm, or when medial support was lost after applying a lateral plate. It was also favoured when gross instability or varus angulation was observed following provisional fixation. Conversely, SLP was selected when the medial cortex could be anatomically restored, the comminution was minimal (less than 1.5 cm), and a stable reduction was achieved. Intraoperative fluoroscopy was used to confirm the absence of varus collapse or construct instability, and adequate bone quality was considered essential. All surgeries were performed by Orthopaedic Trauma Surgeons with a minimum of three years of post-fellowship experience. The lateral approach was used for SLP, the swashbuckler (extended anterolateral) approach for complex intra-articular fractures, and a dual approach for DP.

Articular reduction preceded metaphyseal fixation using K-wires, lag screws, and Herbert screws as appropriate. A lateral distal femoral Locking Compression Plate (LCP) was applied in all cases, and a medial buttress plate was added in the DP group for enhanced stability. The medial plate was kept shorter to reduce stress risers [Table/Fig-1,2].



[Table/Fig-1]: a) Preoperative skin marking on the lateral aspect of the distal femur; b) Lateral Locking Compression Plate (LCP) fixed to the lateral femoral cortex; c) Anteromedial exposure showing the medial cortex of the distal femur; d) The fracture has been anatomically reduced and stabilised using a medial plate.

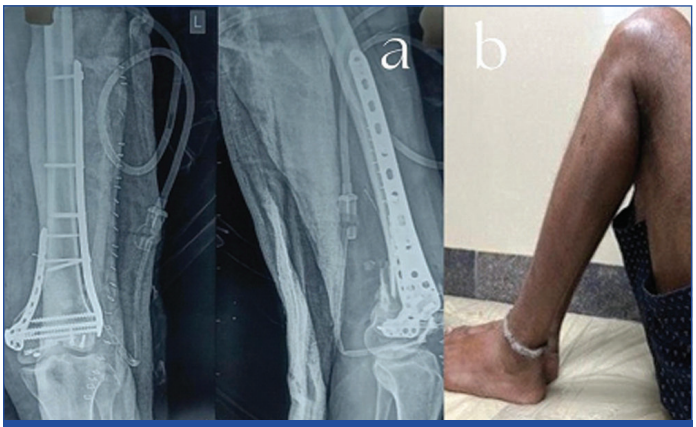


[Table/Fig-2]: a) Modified Swashbuckler approach was used to fix the distal femur with a dual-plating construct; b) Intraoperative assessment of construct stability following dual-plating fixation.

Postoperative rehabilitation was carried out according to a standardised institutional protocol under the supervision of the experienced physiotherapy team to ensure uniformity and adherence. During the first two weeks, patients were initiated on passive and active assisted knee range of motion exercises along with partial weight-bearing using walker support as tolerated.

From the third to the sixth week, rehabilitation progressed to active knee flexion-extension and quadriceps strengthening while maintaining partial weight-bearing. Between six and twelve weeks postoperatively, patients were gradually transitioned to full weight-bearing as tolerated, supplemented by proprioceptive and balance training. After twelve weeks, patients were encouraged to resume normal daily activities, and higher-impact movements reintroduced gradually based on radiological evidence of fracture healing.

Suture removal was documented in patient records to have been done between 12-14 days postoperatively in all cases. Follow-up was conducted at 1, 3, 6, 12 and 15 months postoperatively. Postoperative radiographic assessments were independently conducted by orthopaedic senior residents with over three year of clinical training and discrepancies were resolved by consensus in consultation with a supervising Orthopaedic surgeon to minimise assessment bias. At each follow-up, functional assessment was recorded using the KSS [Table/Fig-3].



[Table/Fig-3]: a) Anteroposterior and lateral X-rays of the left distal femur show fixation with a lateral distal femoral Locking Compression Plate (LCP) and a short medial plate; b) The patient is shown sitting cross-legged, indicating good functional knee range of motion after 1 year.

STATISTICAL ANALYSIS

Data collected during the study were initially organised using Microsoft Excel and subsequently analysed using Statistical Package for Social Sciences (SPSS) version 27.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed as mean values with corresponding standard deviations, while categorical variables were summarised as frequencies and percentages. Statistical comparisons of continuous data between independent groups were performed using two-sample (unpaired) t-tests. Mean differences were reported along with corresponding 95% Confidence Intervals (CIs) to reflect the precision of estimates. Effect sizes were calculated using Cohen's d to quantify the magnitude of between-group differences, with thresholds interpreted as small (0.2), medium (0.5), and large (≥0.8). A p-value ≤0.05 was considered statistically significant [16].

RESULTS

A total of 50 patients diagnosed with distal femur fractures were selected based on predefined inclusion criteria. The cohort was evenly divided, with 25 patients having undergone SLP and 25 treated with DP.

In this study, Group A (SLP) had a mean age of 53.2±9.8 years, while Group B (DP) had a mean age of 50.0±10.9 years, with no statistically significant difference (p=0.34). The gender distribution was comparable between groups, with males comprising 64% of Group A and 60% of Group B (p=0.78). Female representation was 36% in Group A and 40% in Group B. The right-side was more frequently affected in both groups- 56% in Group A and 52% in Group B- while the left-side accounted for 44% and 48%, respectively. There was no significant difference in the laterality of fractures between the two groups (p=0.79). [Table/Fig-4].

Variables		SLP (n=25)	DP (n=25)	p-value
Gender	Male (%)	16 (64%)	15 (60%)	0.78
	Female (%)	9 (36%)	10 (40%)	
Age (mean±SD)		53.2±9.8	50.0±10.9	0.34
Side	Left (%)	11 (44%)	12 (48%)	0.79
	Right (%)	14 (56%)	13 (52%)	
Fracture type AO	33-C2 (%)	14 (56%)	12 (48%)	0.77
	33-C3 (%)	11 (44%)	13 (52%)	

[Table/Fig-4]: Comparison of baseline demographics and fracture patterns between SLP and DP groups, showing no significant differences.

The mean surgical duration was 112±10 minutes in the SLP group and 116±9 minutes in the DP group, with a mean difference of four minutes (95% CI: -1.41 to 9.41; p=0.12; Cohen's d=0.42). Mean intraoperative blood loss was 420±30 mL in the SLP group and 430±25 mL in the DP group, with a difference of 10 mL (95% CI: -5.7 to 25.7; p=0.21; Cohen's d=0.36), indicating no statistically significant difference between the groups. Co-morbidity distributions (no Co-morbidity, hypertension, diabetes) did not differ significantly between the SLP and DP cohorts (p=0.650). Mechanism-of-injury distributions (road-traffic accident, fall, other) did not differ significantly between the SLP and DP cohorts (p=0.56) [Table/Fig-5].

Parameters	SLP group	DP group	p-value	Mean difference (95% CI)	Cohen's d
Surgical time (min, mean±SD)	112±10	116±9	0.12	4 (-1.41 to 9.41)	0.42
Blood loss (mL, mean±SD)	420±30	430±25	0.21	10 (-5.7 to 25.7)	0.36
Comorbidities (N)	No: 7 | HTN: 15 | DM: 3	No: 10 | HTN: 12 | DM: 3	0.650	-	-
Mechanism of injury (N)	RTA: 15 | Fall: 8 | Others: 2	RTA: 18 | Fall: 5 | Others: 2	0.56	-	-

[Table/Fig-5]: Comparison of intraoperative parameters and baseline variables between SLP and DP groups.
HTN: Hypertension; DM: Diabetes mellitus; RTA: Road traffic accident

DP (22.4±2.76 weeks) achieved significantly faster fracture union than SLP (25.5±3.04 weeks), with a mean difference of 3.1 weeks (95% CI: 1.60-4.60; p=0.001), corresponding to a large effect size (Cohen's d=1.07) [Table/Fig-6].

At the 1-month postoperative period, the DP group demonstrated significantly better early functional status (mean KSS: 64.5±5.0) compared to the SLP group (mean KSS: 54.0±6.0), with a highly significant p-value (<0.001). This trend of superior functional outcomes in the DP group continued at all follow-up intervals. However, as time progressed, the difference between the two groups narrowed, and the statistical significance of the difference gradually diminished. Here DP offered better early functional outcomes, This supports the use of DP for early mobilisation and function [Table/Fig-7].

Mechanical complications such as non-union, malunion, and implant failure were more frequent in the SLP group. Infection rates were equal, while knee stiffness was observed only in the DP group [Table/Fig-8].

DISCUSSION

The present retrospective comparative study evaluated the clinical and functional outcomes of SLP versus DP in the management of comminuted intra-articular distal femur fractures (AO/OTA 33-C2 and 33-C3). The key findings demonstrate that DP is associated with faster fracture union, higher KSS at each follow-up interval, and fewer mechanical complications such as implant failure, non-union, and malunion, without a significant increase in operative time or blood loss.

Outcome variable	SLP (Mean±SD)	DP (Mean±SD)	Mean difference (weeks)	95% CI (weeks)	p-value	Effect size (Cohen's d)
Time to fracture union	25.5±3.04	22.4±2.76	3.1	1.60 to 4.60	0.001**	1.07 (large)

[Table/Fig-6]: Comparison of fracture union time between SLP and DP groups showing significantly faster healing with Dual Plating (DP).

Follow-up time	SLP (Mean±SD)	DP (Mean±SD)	p-value	Mean difference (95% CI)	Effect size (Cohen's d)
1 month	54.0±6.0	64.5±5.0	<0.001**	7.44 to 13.56	1.90
3 months	62.5±6.8	75.4±5.6	<0.001**	9.45 to 16.35	2.07
6 months	66.3±6.2	82.1±6.1	0.003**	12.39 to 19.21	2.57
12 months	69.0±5.7	87.3±4.9	0.021	15.35 to 21.25	3.44
15 months	70.2±5.1	89.0±4.5	0.047	16.13 to 21.47	3.91

[Table/Fig-7]: Comparison of functional outcomes (KSS) over time showing consistently higher scores in the DP group across all follow-ups.

Complications	SLP group (n=25)	DP group (n=25)
Non-union	2 (8%)	0 (0%)
Malunion	1 (4%)	0 (0%)
Implant failure	2 (8%)	0 (0%)
Knee stiffness	0 (0%)	1 (4%)
Infection	2 (8%)	2 (8%)

[Table/Fig-8]: Comparison of postoperative complications between SLP and DP groups showing fewer mechanical complications in the DP group.

The consistently higher KSS across all follow-up intervals in the DP group- especially within the first six months- highlight the clinical advantage of enhanced construct stability. Early mobilisation and functional recovery are critical in preventing knee stiffness, particularly in elderly or osteoporotic patients. In The present study, data align with those of Ma J et al., who reported significantly improved outcomes with DP in bicondylar and comminuted distal femur fractures, including earlier weight-bearing and lower rates of non-union [17]. Similarly, Zhang Y et al., demonstrated, via finite element analysis that DP provides superior biomechanical stability under axial and torsional loads compared to lateral plating alone [6].

The fracture union time was significantly shorter in the DP group (22.4±2.76 weeks vs. 25.5±3.04 weeks; p=0.001), corroborating the findings of José E et al., who reported markedly earlier radiological union (13 vs. 28 weeks) and earlier weight-bearing with DP in metaphyseal comminuted distal femur fractures [18]. In this study, the rate of implant failure and non-union in the SLP group (8% each) underscores the limitations of relying solely on lateral plating in fractures with compromised medial cortical integrity.

Importantly, despite concerns in the literature regarding increased soft-tissue dissection with DP, this study observed no significant difference in infection rates (8% in both groups). This supports findings by Park H et al., who emphasised that meticulous surgical technique and proper patient selection can mitigate soft-tissue complications [19].

Despite the common perception that DP increases operative time and blood loss, this study found no statistically significant difference between DP and SLP in either parameter. This suggests that DP can be performed without additional surgical burden, making it a viable option even in resource-limited settings associated with medial plating [20].

From a clinical decision-making perspective, this results support the use of DP in complex intra-articular fractures with medial cortical disruption, metaphyseal void >1.5 cm, or intraoperative instability after lateral fixation [21]. While SLP may remain appropriate for less comminuted patterns with preserved medial support, relying solely on lateral constructs in unstable configurations may compromise outcomes. Despite these encouraging results, the non-randomised treatment allocation introduces the potential for selection bias, as more complex fractures may have been preferentially treated with DP. However, this also reflects real-world surgical judgment, where intraoperative findings guide construct choice.

An important strength of the current study was its contribution to data from the Indian subcontinent, where geographic, demographic, and infrastructural factors may differ from Western cohorts. This adds value to the existing body of literature, which is largely based on data from developed countries.

Limitation(s)

The present study has several limitations that should be acknowledged. The retrospective design inherently limits control over treatment allocation, introducing the possibility of selection bias. Patients were assigned to either SLP or DP based on intraoperative assessments such as medial comminution and fracture stability, which, while standardised, were ultimately at the discretion of the operating surgeon. This non-randomised allocation may have resulted in the DP group being preferentially used in more complex fractures, potentially confounding outcome comparisons. Blinding of outcome assessors was not feasible due to the retrospective nature of the study. Although efforts were made to minimise bias- such as using independent assessments and verification by consultants- the lack of formal blinding may still introduce observer bias, particularly in functional outcome scoring.

The long-term follow-up beyond 15 months was not uniform for all patients. Additionally, potential confounding factors such as bone quality, comorbidities were not controlled through multivariate analysis. Further, radiographic assessments were not standardised through Computed Tomography at union, which might affect precision in detecting delayed union or malalignment. Future prospective, multicentric studies with larger cohorts are recommended for more definitive conclusions.

CONCLUSION(S)

The present study demonstrates that DP offers superior clinical outcomes compared to SLP in the management of comminuted intra-articular distal femur fractures, particularly in terms of faster union rates, improved functional scores, and fewer mechanical complications. While both techniques achieved acceptable results without significant differences in intraoperative blood loss or surgical duration, the consistent functional advantage observed with DP-especially during early follow-up-suggests a meaningful clinical benefit in select patients. However, these findings must be interpreted within the context of potential selection bias, as treatment allocation was guided by intraoperative assessment. The absence of randomisation and a relatively small sample size may also limit the generalisability of the results. Nonetheless, this study reinforces the biomechanical rationale for dual-column support in complex distal femoral fractures and supports the tailored use of DP in fractures with medial cortical disruption or metaphyseal voids. Further prospective randomised studies are warranted to validate these findings and refine surgical decision-making algorithms.

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