Section: Orthopedics

Original Research Article

EFFICACY OF DISTAL FEMORAL LOCKING COMPRESSION PLATE IN JUXTA-ARTICULAR AND METAPHYSEAL FEMORAL FRACTURES: A PROSPECTIVE STUDY AT A TERTIARY CARE CENTRE

Krishna Kumar Baranwal[1], Prem Prakash[2], Avnish Kr Mishra[3]

[1]Senior Consultant, Department of Orthopaedic, Pandit Deendayal Upadhyaya Hospital, Vanarasi, Uttar Pradesh, India
[2]Senior Consultant Surgeon and Medical Superintendent, Pandit Deendayal Upadhyaya Hospital, Vanarasi, Uttar Pradesh, India
[3]Associate Professor, Department of Orthopaedic, Maharishi Vishwamitra Autonomous State Medical College, Ghaziapur, Uttar Pradesh, India

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Corresponding Author:
Dr. Prem Prakash,
Email: drpremprakash12@gmail.com

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ABSTRACT

Background: Distal femoral fractures represent complex injuries requiring stable fixation to restore function and mobility. The locking compression plate (LCP) has emerged as a preferred treatment modality, offering biological fixation principles with enhanced stability. This study evaluates the efficacy of distal femoral locking compression plates in managing juxta-articular and metaphyseal femoral fractures. **Materials and Methods:** A prospective study was conducted at Pandit Deendayal Upadhyaya Hospital, Varanasi, from September 2022 to October 2024. Twenty-one patients with distal femoral fractures were treated using distal femoral locking compression plates. Patient demographics, fracture characteristics, surgical techniques, and clinical outcomes were analyzed. Functional outcomes were assessed using the Ruedi and Allgower criteria, with regular radiological follow-up to evaluate union and complications. **Result:** The study included 21 patients with a mean age of 42.8 years (range: 21-70 years). Males predominated (81%). Road traffic accidents were the leading cause of injury (85.7%). Articular fractures with metaphyseal/diaphyseal extension comprised 57.1% of cases. Minimally invasive plate osteosynthesis (MIPPO) was performed in 80.9% of cases. Union was achieved in 95.2% of patients with a mean time of 17 weeks (range: 10-28 weeks). Excellent to good results were obtained in 81% of patients according to Ruedi and Allgower criteria. Complications occurred in 85.7% of patients, with knee stiffness being the most common (42.9%). **Conclusion:** Distal femoral locking compression plate demonstrates excellent efficacy in treating juxta-articular and metaphyseal femoral fractures, with high union rates and acceptable functional outcomes. The MIPPO technique offers biological advantages with minimal soft tissue disruption.

INTRODUCTION

Distal femoral fractures constitute approximately 4-6% of all femoral fractures and represent challenging injuries that significantly impact patient mobility and quality of life. These fractures typically result from high-energy trauma in younger individuals or low-energy mechanisms in elderly patients with osteoporotic bone. The complex anatomy of the distal femur, combined with limited soft tissue coverage and proximity to the knee joint, makes treatment particularly demanding.[1,2]

Historically, various treatment modalities have been employed for distal femoral fractures, ranging from conservative management to different surgical approaches. Stewart et al. (1966) demonstrated the limitations of conservative treatment, reporting problems with maintaining alignment and frequent complications including knee stiffness, malunion, and non-union. The evolution of surgical techniques has led to the development of various fixation methods, including plate and screw constructs, dynamic condylar screws, intramedullary nailing, and external fixation.[3,4]

The introduction of locking compression plates (LCP) has revolutionized the treatment of complex fractures. The LCP system, developed by Wagner and Frigg, incorporates the principles of both

conventional compression plating and internal fixation. This innovative design features combination holes that allow for both standard cortical screws and locking head screws, providing surgeons with versatile fixation options depending on fracture pattern and bone quality.[5,6]

The biological approach to fracture fixation emphasizes preservation of the periosteal blood supply and minimization of soft tissue disruption. Minimally invasive plate osteosynthesis (MIPPO) technique has gained popularity as it allows for stable fixation while maintaining the biological environment necessary for optimal fracture healing. This approach has shown superior outcomes compared to traditional open reduction and internal fixation techniques, particularly in terms of reduced infection rates and faster healing times.[7,8]

Despite advances in implant technology and surgical techniques, distal femoral fractures continue to pose significant challenges. Complication rates remain substantial, with reported incidences of nonunion ranging from 5-22% and infection rates varying from 3-30% depending on fracture complexity and patient factors. The development of angular stable implants like the LCP has addressed many of these concerns, particularly in osteoporotic bone where traditional fixation methods often fail.[9,10]

The primary objective of this study was to evaluate the efficacy of distal femoral locking compression plates in treating juxta-articular and diaphyseal femoral fractures. Secondary objectives included assessment of functional outcomes, complication rates, and factors influencing treatment success. This prospective study provides valuable insights into the clinical applications and outcomes of LCP fixation in a tertiary care setting.

MATERIALS AND METHODS

Study Design and Setting: This prospective observational study was conducted at the Department of Orthopedics, Pandit Deendayal Upadhyaya Hospital, Varanasi, between September 2022 and October 2024. The study protocol was approved by the institutional ethics committee, and informed consent was obtained from all participants.

Patient Selection: Patients were selected from both outpatient and emergency departments based on specific inclusion and exclusion criteria. Inclusion criteria comprised: (1) patients aged 18-70 years with closed or Grade I-II open distal femoral fractures, (2) fractures located within the distal third of the femur, (3) patients suitable for surgical intervention, and (4) willingness to participate in regular follow-up. Exclusion criteria included: (1) pathological fractures, (2) Grade III open fractures, (3) patients with significant medical comorbidities precluding surgery, (4) previous ipsilateral femoral fractures, and (5) patients unlikely to comply with follow-up protocols.

Preoperative Assessment: All patients underwent comprehensive clinical examination and radiological evaluation. Standard anteroposterior and lateral radiographs of the affected femur and knee were obtained. Computed tomography scans were performed in cases of complex intra-articular fractures to better understand fracture morphology and plan surgical approach. Fractures were classified according to the AO/OTA classification system.

Routine laboratory investigations including complete blood count, erythrocyte sedimentation rate, and biochemical parameters were performed. Patients were assessed for fitness for anesthesia and surgery. Preoperative planning involved template selection, plate length determination, and screw configuration planning based on fracture pattern and bone quality.

Table 1: Age of Patients in our Study

Age Group (years)	Number of Patients	Percentage (%)
11-20	0	0
21-30	4	19.1
31-40	5	23.8
41-50	6	28.6
51-60	3	14.3
61-70	3	14.3
Total	21	100

Surgical Technique: All surgeries were performed by senior orthopedic surgeons experienced in trauma management. The choice of surgical approach was determined by fracture pattern, with emphasis on biological principles and minimal soft tissue disruption.

Minimally Invasive Plate Osteosynthesis (MIPPO): The MIPPO technique was the preferred approach for most fractures. Patient positioning involved supine placement on a radiolucent table with the affected limb free for manipulation. A lateral approach was utilized with a small incision over the lateral femoral condyle. The vastus lateralis muscle was elevated, and a submuscular tunnel was created for plate insertion. Fracture reduction was achieved through indirect techniques including traction, manipulation, and provisional fixation with K-wires when necessary.

The distal femoral LCP was inserted through the distal incision and advanced proximally in the submuscular plane. Plate positioning was confirmed using intraoperative fluoroscopy. Distal fixation was achieved using locking head screws in the femoral condyles, while proximal fixation utilized either conventional cortical screws or locking screws depending on bone quality and fracture pattern.

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Open Reduction and Internal Fixation: Open approach was reserved for cases requiring direct fracture visualization, including complex intra-articular fractures or cases where closed reduction was inadequate. A lateral parapatellar approach was employed with careful soft tissue handling to preserve vascularity.

Table 2: Surgical Technique

Parameter	Category	Number of Cases	Percentage (%)
Surgical Approach	Open	4	19.1
	MIPPO	17	80.9
LCP Technique	Compression	4	19.1
	Bridging	1	4.8
	Combined	16	76.2
Bone Grafting	Primary	4	19.1
	Secondary	2	9.5

Postoperative Management: Immediate postoperative care included wound inspection, pain management, and initiation of prophylactic antibiotics. Deep vein thrombosis prophylaxis was administered according to institutional protocols. Early mobilization was encouraged with range of motion exercises beginning within the first week post-surgery.

Weight-bearing restrictions were individualized based on fracture pattern and fixation stability. Non-weight-bearing mobilization was typically maintained for 6-8 weeks, followed by progressive weight-bearing as radiological healing progressed. Physiotherapy protocols included quadriceps strengthening, knee range of motion exercises, and functional training.

Follow-up Protocol: Patients were followed up at regular intervals: 2 weeks (suture removal), 6 weeks, 3 months, 6 months, and 1 year postoperatively. At each visit, clinical examination was performed to assess wound healing, range of motion, and functional status. Radiological evaluation included anteroposterior and lateral radiographs to monitor fracture healing and detect complications.

Outcome Assessment: Primary outcome measures included radiological union, defined as bridging callus formation on at least three cortices with disappearance of fracture lines. Secondary outcomes comprised functional assessment using the Ruedi and Allgower criteria, range of motion measurement, and complication documentation.

The Ruedi and Allgower criteria classify outcomes as: Very Good (complete recovery of anatomy and function), Good (minor problems with 5-10° loss of movement), Fair (20-30° loss of movement with some pain and swelling), and Poor (persistent disability due to pain and stiffness).

Statistical Analysis: Data analysis was performed using SPSS software version 26.0. Descriptive statistics were used to summarize patient demographics, fracture characteristics, and outcomes. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Chi-square tests were used for categorical variables, and Student's t-test for continuous variables. A p-value <0.05 was considered statistically significant.

RESULTS

Patient Demographics: The study included 21 patients with distal femoral fractures treated with locking compression plates. The mean age was 42.8 years (range: 21-70 years), with the majority of patients in the 31-50 year age group (52.4%). Males comprised 81% of the study population (17 patients), while females represented 19% (4 patients). The right side was predominantly affected in 80.9% of cases.

Mechanism of Injury: Road traffic accidents were the leading cause of injury, accounting for 85.7% of cases (18 patients). Fall from height was responsible for 9.5% of cases (2 patients), while physical assault accounted for 4.8% (1 patient). The high proportion of high-energy trauma mechanisms reflected the tertiary care center's catchment area and referral patterns.

Fracture Characteristics: According to the AO/OTA classification system, fractures were distributed as follows: 57.1% had articular fractures with metaphyseal/diaphyseal extension, 19.1% had simple metaphyseal fractures, 14.2% had multifragmentary metaphyseal fractures, 4.8% had diaphyseal fractures, and 4.8% had pure articular fractures. The predominance of complex articular fractures reflected the severity of injuries typically seen in tertiary care centers.

Table 3: Fracture Types

Fracture Type	Number of Cases	Percentage (%)
Simple metaphyseal	4	19.1
Multi-fragmentary metaphyseal	3	14.2
Diaphyseal	1	4.76
Articular with meta/diaphyseal extension	12	57.14
Pure articular	1	4.76
Total	21	100

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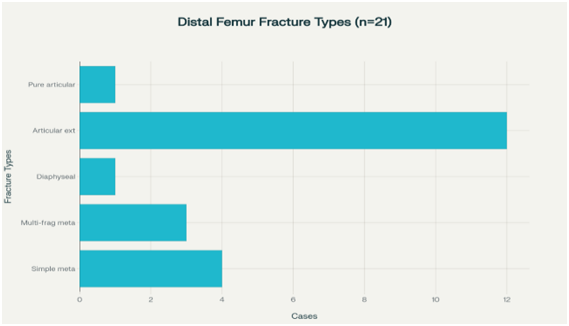
Distribution of distal femur fracture types showing predominance of articular fractures with metaphyseal/diaphyseal extension

Most fractures were closed (71.4%), while open fractures comprised 28.6% of cases. Among open fractures, Grade I and Grade II (Gustilo-Anderson classification) were equally represented. Four patients (19.1%) presented with established non-unions from previous failed surgical interventions.

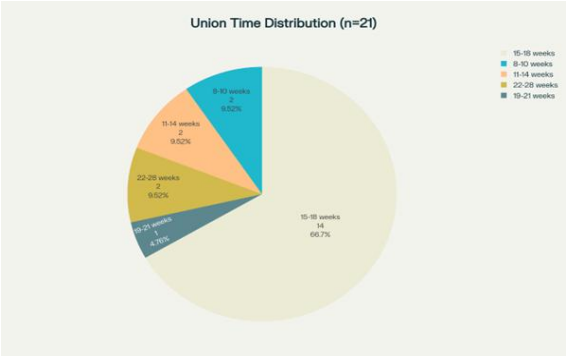
Surgical Procedures: The minimally invasive plate osteosynthesis (MIPPO) technique was employed in 80.9% of cases (17 patients), while open reduction and internal fixation was performed in 19.1% (4 patients). The choice of surgical approach was primarily determined by fracture complexity and the need for direct articular surface visualization.

Regarding LCP fixation techniques, the combined approach (utilizing both compression and bridging principles) was most frequently employed in 76.2% of cases. Pure compression technique was used in 19.1% of cases, while bridging technique was utilized in 4.8% of cases. The selection of fixation technique was based on fracture pattern, bone quality, and surgeon preference.



Bone grafting was performed in 28.6% of cases. Primary bone grafting was conducted in 19.1% of cases, typically in established non-unions or cases with significant bone loss. Secondary bone grafting was required in 9.5% of cases due to delayed healing or inadequate callus formation.

Clinical Outcomes: The mean time to radiological union was 17 weeks (range: 10-28 weeks). The majority of patients (66.7%) achieved union within 15-18 weeks. Early union (10-14 weeks) was observed in 19.1% of cases, while delayed union (19-28 weeks) occurred in 14.3% of cases. Union was achieved in 95.2% of patients, with one patient developing persistent non-union requiring revision surgery.



Distribution of union time showing majority of fractures healing within 15-18 weeks

Weight-bearing progression followed a standardized protocol. Partial weight-bearing was typically initiated at 9-12 weeks in 38.1% of patients, while full weight-bearing was achieved at 13-16 weeks in 52.4% of patients. Delayed weight-bearing (>16 weeks) was necessary in 9.5% of cases, primarily in patients with complex fractures or complications.

Knee range of motion outcomes showed satisfactory results in most patients. Excellent range of motion (>120° flexion) was achieved in 42.9% of patients, while good range of motion (90-120° flexion) was observed in 47.6% of patients. Limited range of motion (<90° flexion) was noted in 9.5% of patients, primarily those with intra-articular fractures and prolonged immobilization.

Table 4: Clinical Outcomes

Parameter	Category	Number of Cases	Percentage (%)
Union Time (weeks)	10-14	4	19.1
	15-18	14	66.7
	19-28	3	14.3
Weight Bearing (weeks)	Partial (9-12)	8	38.1
	Full (13-16)	11	52.4
	Full (>16)	2	9.5
Knee Flexion (degrees)	<90°	2	9.5
	90-120°	10	47.6
	>120°	9	42.9
Final Results	Very Good	11	52.4
	Good	6	28.6
	Fair	3	14.3
	Poor	1	4.8

Functional Outcomes: According to the Ruedi and Allgower criteria, 52.4% of patients achieved very good results, 28.6% achieved good results, 14.3% had fair results, and 4.8% had poor results. Overall, 81% of patients achieved satisfactory outcomes (very good to good results).

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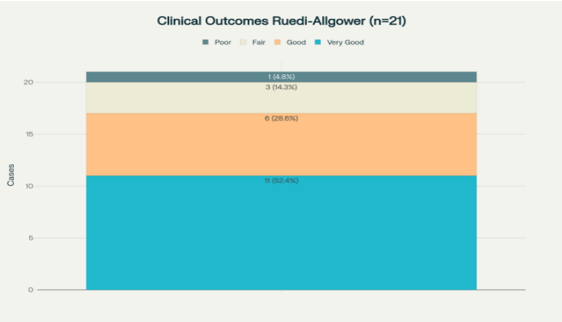

Clinical outcomes showing majority of patients achieved very good to good results

Functional outcomes were significantly better in patients without articular involvement compared to those with articular fractures. Patients with extra-articular fractures demonstrated superior outcomes in terms of cross-legging ability, squatting capacity, and walking independence. Extension lag was present only in patients with articular involvement, affecting 69% of this subgroup.

Table 5: Functional Comparison

Parameter	Without Articular Involvement (n=8)	With Articular Involvement (n=13)	Percentage Affected
Cross-legging	8	9	100% vs 69%
Squatting	8	3	100% vs 23%
Walking without support	8	6	100% vs 46%
Walking with stick	0	6	0% vs 46%
Extension lag >5Â°	0	9	0% vs 69%
Average flexion	>120°	110°	Superior vs Good

Complications: The overall complication rate was 85.7%, though many complications were minor and resolved with conservative management. Knee stiffness was the most common complication, affecting 42.9% of patients. This was primarily observed in patients with intra-articular fractures and those requiring prolonged immobilization.

Limb shortening occurred in 19.1% of patients, with shortening >1cm observed in 14.3% of cases. This was primarily seen in patients with comminuted fractures who presented late for treatment. Varus deformity was noted in 9.5% of patients, typically in cases with inadequate reduction or loss of fixation.

Delayed union occurred in 9.5% of patients, both of whom eventually achieved union with conservative management and extended protected weight-bearing. Deep infection was observed in one patient (4.8%), a diabetic individual who developed infection four months postoperatively, requiring debridement and antibiotic therapy.

No cases of implant failure or non-union were observed during the study period. The low rate of major complications reflected the benefits of modern implant technology and improved surgical techniques.

Table 6: Complications

Complication	Number of Cases	Percentage (%)
Deep infection	1	4.8
Superficial infection	0	0
Shortening <1cm	1	4.8
Shortening >1cm	3	14.3
Stiffness	9	42.9
Delayed union	2	9.5
Non-union	0	0
Varus deformity	2	9.5
Implant failure	0	0
Total	18	85.7

Factors Influencing Outcomes: Several factors were identified as influencing treatment outcomes. Articular involvement was the most significant predictor of functional outcome, with extra-articular fractures demonstrating superior results. Age was also a contributing factor, with younger patients generally achieving better outcomes. The choice of surgical approach (MIPPO versus open) did not significantly impact union rates, though MIPPO was associated with reduced soft tissue complications.

Bone grafting was beneficial in cases of established non-union or significant bone loss, with all grafted fractures achieving union. Early mobilization and compliance with physiotherapy protocols were important factors in achieving optimal functional outcomes.

DISCUSSION

The results of this prospective study demonstrate the efficacy of distal femoral locking compression plates in treating juxta-articular and metaphyseal femoral fractures. The high union rate (95.2%) and acceptable functional outcomes (81% good to excellent results) are consistent with contemporary literature and support the use of LCP fixation for these challenging injuries.[11,12]

The demographic profile of our study population reflects the typical pattern of distal femoral fractures, with a predominance of young males involved in high-energy trauma. The mean age of 42.8 years is comparable to other studies, though slightly higher than some reports focusing on younger trauma patients. The male predominance (81%) is consistent with published literature, reflecting the higher

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involvement of males in high-energy activities and occupational hazards.[13,14]

The fracture pattern distribution in our study showed a predominance of complex articular fractures (57.1%), which differs from some studies reporting higher proportions of extra-articular fractures. This may reflect the referral pattern to our tertiary care center, where complex cases are preferentially managed. The high proportion of AO/OTA type 33-C fractures (complete articular) emphasizes the challenging nature of these injuries and the need for specialized treatment approaches.[15,16]

The widespread use of MIPPO technique (80.9%) in our study reflects the growing recognition of biological fixation principles. The MIPPO approach has been shown to preserve periosteal blood supply, reduce soft tissue trauma, and promote faster healing compared to traditional open approaches. Our results support these findings, with no significant difference in union rates between MIPPO and open techniques, but potentially fewer soft tissue complications with the minimally invasive approach.[17,18]

The mean union time of 17 weeks in our study is consistent with other reports using LCP fixation for distal femoral fractures. Recent studies have reported union times ranging from 15-21 weeks, depending on fracture complexity and patient factors. The relatively favorable union rate in our study (95.2%) compares well with published literature, which reports union rates of 85-95% for LCP fixation.[19]

Functional outcomes in our study were satisfactory, with 81% of patients achieving good to excellent results according to Ruedi and Allgower criteria. This is comparable to other studies using similar assessment methods. The significant difference in outcomes between patients with and without articular involvement (as demonstrated in our functional comparison) highlights the importance of joint surface integrity in determining long-term function.[20]

The knee range of motion results in our study showed that 90.5% of patients achieved functional range of motion (>90° flexion), which is essential for activities of daily living. The mean flexion of >120° in extra-articular fractures and 110° in articular fractures is consistent with published literature. Extension lag was observed only in patients with articular involvement, emphasizing the impact of joint surface damage on function.

The complication rate in our study (85.7%) appears high but includes minor complications that are commonly reported in distal femoral fracture studies. When focusing on major complications requiring intervention, the rate was significantly lower. Knee stiffness was the most common complication (42.9%), which is consistent with other studies reporting stiffness rates of 30-50% in distal femoral fractures. The higher incidence of stiffness in articular fractures reflects the need for prolonged immobilization and the inflammatory response associated with joint involvement.

The infection rate in our study (4.8%) was lower than some published reports, which range from 5-15% for distal femoral fractures. The single case of deep infection in our study occurred in a diabetic patient, highlighting the importance of patient comorbidities in infection risk. The absence of implant failure in our study contrasts with some reports showing failure rates of 5-10%, possibly reflecting improved implant design and surgical technique.

Several factors emerged as predictors of outcome in our study. Articular involvement was the most significant factor, with extra-articular fractures demonstrating superior outcomes in all functional parameters. This finding is consistent with the literature and emphasizes the importance of joint surface integrity in determining long-term function. Age was another important factor, with younger patients generally achieving better outcomes, likely due to superior bone healing capacity and functional demands.

The choice of LCP fixation technique (compression versus bridging versus combined) was guided by fracture pattern and bone quality. The predominant use of combined technique (76.2%) reflects the versatility of the LCP system and the ability to optimize fixation based on local bone conditions. The principles of biological fixation, including preservation of fracture hematoma and minimal soft tissue disruption, were emphasized throughout the study.

Bone grafting was performed in selected cases, primarily in established non-unions or cases with significant bone loss. The success of bone grafting in achieving union in all cases where it was employed supports its use in challenging scenarios. The choice between autograft and allograft was individualized based on patient factors and defect size.

The study has several limitations that should be acknowledged. The sample size, while adequate for statistical analysis, is relatively small for drawing definitive conclusions about rare complications. The single-center design may limit generalizability to other settings with different patient populations or surgical practices. The follow-up period, while adequate for assessing union and early complications, may be insufficient for evaluating long-term outcomes such as post-traumatic arthritis.

Despite these limitations, the study provides valuable insights into the clinical application of LCP fixation for distal femoral fractures. The high union rate, acceptable functional outcomes, and manageable complication profile support the continued use of this technology in appropriate cases. The emphasis on biological fixation principles and minimally invasive techniques has improved outcomes while reducing morbidity.

Future research should focus on long-term outcomes, including the development of post-traumatic arthritis and the need for secondary procedures. Comparative studies between different fixation methods and approaches would provide additional evidence for optimal treatment strategies. The role of adjunctive

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techniques, such as bone grafting and biological enhancement, deserves further investigation.

CONCLUSION

This prospective study demonstrates the efficacy of distal femoral locking compression plates in treating juxta-articular and metaphyseal femoral fractures. The high union rate (95.2%) and satisfactory functional outcomes (81% good to excellent results) support the use of LCP fixation for these challenging injuries. The minimally invasive plate osteosynthesis technique offers biological advantages while maintaining stable fixation.

Articular involvement emerges as the most significant predictor of functional outcome, with extra-articular fractures demonstrating superior results in all functional parameters. The relatively low rate of major complications, including absence of implant failure and minimal infection, reflects the benefits of modern implant technology and improved surgical techniques.

The study emphasizes the importance of biological fixation principles, appropriate surgical technique selection, and comprehensive rehabilitation protocols in achieving optimal outcomes. While complications such as knee stiffness remain common, particularly in articular fractures, the overall treatment success supports the continued use of LCP fixation as a primary treatment modality for distal femoral fractures.

The findings of this study contribute to the growing body of evidence supporting the use of locking compression plates in complex fracture management. The combination of stable fixation, biological preservation, and minimally invasive techniques represents the current standard of care for these challenging injuries.

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