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ORIGINAL ARTICLE

Biomechanical Comparison of Locking Versus Non-Locking Plates in Distal Femur Fractures

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ABSTRACT
Background: To compare the 'biomechanical performance, radiographic healing, and functional outcomes of locking versus non-locking plates in the surgical fixation of distal femur fractures'.
Methods: This prospective comparative study was conducted at the Department of Orthopaedic Surgery, Bolan Medical Complex Hospital, Quetta, from January 2022 to June 2023. A total of 57 adult patients with distal femur fractures were included, with 29 managed using locking plates and 28 with non-locking plates. Primary outcome was time to radiographic union. Secondary outcomes included knee range of motion, KOOS score, pain level, malalignment, and complication rates. Data were analyzed using SPSS version 26, with $p < 0.05$ considered statistically significant.
Results: The locking plate group demonstrated a significantly shorter mean time to union (17.3 ± 3.2 weeks vs. 19.5 ± 3.7 weeks, p = 0.02) and greater mean knee flexion at one year '(118.4° ± 8.6° vs. 112.2° ± 9.1°, p = 0.01)'. 'KOOS scores were also higher in the locking plate group (78.6 ± 6.3 vs. 74.1 ± 6.8, p = 0.02)'. There was no significant difference in malalignment, delayed union, or infection rates. Implant failure occurred only in the non-locking plate group.
Conclusion: Locking plates provided faster fracture healing and better functional outcomes compared to non-locking plates, without increasing complication rates. Their use is particularly beneficial in comminuted fractures, poor bone quality, and cases requiring early mobilization.
Keywords: Distal femur fracture, Locking plate, Non-locking plate, Biomechanical stability, Functional outcome, Fracture union

INTRODUCTION
Distal femur fractures account for a small proportion of all femoral fractures but present significant treatment challenges due to their proximity to the knee joint, variable fracture patterns, and frequent occurrence in elderly or osteoporotic patients. High-energy trauma in younger individuals and low-energy falls in older patients are the two most common mechanisms. Optimal management aims to restore anatomical alignment, maintain joint congruency, and enable early rehabilitation to minimize stiffness and functional impairment[1-3].

Conventional non-locking plates, such as dynamic compression plates (DCP) and limited contact dynamic compression plates (LC-DCP), have been widely used for decades. These systems rely on friction between the plate and bone for stability, which may lead to periosteal stripping and compromise blood supply. Furthermore, fixation strength is reduced in osteoporotic bone due to poor screw purchase, increasing the risk of secondary displacement, implant failure, and non-union[4-6].

Locking plate technology was developed to overcome these limitations. By providing fixed-angle stability, locking plates create a rigid construct that maintains alignment even in compromised bone. They function as internal fixators, reducing the need for precise plate-to-bone contact and preserving periosteal blood flow. Several biomechanical and clinical studies have demonstrated improved stability, reduced secondary displacement, and favorable outcomes with locking plates, particularly in comminuted and osteoporotic fractures[7,8]. However, their higher cost and potential for stress shielding have been subjects of debate.

Comparative data between 'locking and non-locking plates' in distal femur fractures remain limited in the local context. Therefore, this study was designed 'to evaluate and compare the biomechanical performance, radiographic healing, and functional outcomes of locking versus non-locking plates in the fixation of distal femur fractures treated at a tertiary care center in Quetta'.

METHODOLOGY
This was a prospective comparative study conducted at the Department of Orthopaedic Surgery, Bolan Medical Complex Hospital, Quetta, over an 18-month period from January 2022 to June 2023. The research was designed to compare the biomechanical performance and clinical outcomes of locking plates versus non-locking plates in the surgical fixation of distal femur fractures. The study was approved by the Institutional Review Board of Bolan Medical Hospital, Quetta. All participants provided informed written consent, and the study adhered to the ethical principles outlined in the Declaration of Helsinki.

A total of 57 adult patients meeting the eligibility criteria were enrolled using a non-probability consecutive sampling technique. Patients were allocated into two groups based on the type of fixation used: Locking Plate group (n = 29) and Non-Locking Plate group (n = 28).

Eligibility Criteria

Inclusion criteria:
- Age ≥ 18 years, both male and female.
- Radiologically confirmed distal femur fractures (AO/OTA classification type A, B, or C).
- Closed fractures or open fractures up to Gustilo–Anderson type II.
- Patients presenting within two weeks of injury.
- Willingness to provide informed consent and comply with follow-up.

Exclusion Criteria:
- Pathological fractures other than those due to osteoporosis.
- Polytrauma with life-threatening injuries.
- Gustilo–Anderson type III open fractures.
- Associated neurovascular injuries requiring repair.
- Pre-existing ipsilateral limb deformities or joint arthroplasty.
- Non-consent or loss to follow-up before 6 months.

All patients underwent detailed history-taking, including demographic data, mechanism of injury, comorbidities, and pre-injury mobility status. Clinical examination included neurovascular assessment of the affected limb. Standard radiographs (anteroposterior and lateral views of the femur including hip and knee joints) were obtained. Fractures were classified according to the AO/OTA classification system.

Routine laboratory investigations (complete blood count, renal profile, fasting blood sugar, coagulation profile) and anesthetic fitness assessment were performed. Informed written consent was obtained from all patients.

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All surgeries were performed under spinal or general anesthesia by experienced orthopedic surgeons following standard aseptic protocols. The choice of implant (locking or non-locking plate) was based on surgeon preference and patient factors.

- Locking Plate Group: Pre-contoured distal femur locking plates were used.
- Non-Locking Plate Group: Dynamic compression plates (DCP) or limited contact dynamic compression plates (LC-DCP) were used.

The surgical approach was either open reduction or minimally invasive plate osteosynthesis (MIPO), depending on fracture type and soft-tissue condition. Reduction quality was assessed intraoperatively using fluoroscopy, aiming for anatomical alignment in both coronal and sagittal planes. Number of screws, type (locking/cortical), and working length were recorded. Bone grafting was performed if deemed necessary.

Postoperatively, all patients received prophylactic antibiotics for 24–48 hours and thromboprophylaxis according to institutional protocol. Early range-of-motion exercises were encouraged within pain limits. Weight-bearing status was guided by fracture stability and radiographic progression of healing.

Follow-up visits were scheduled at 2 weeks, 6 weeks, 3 months, 6 months, and 12 months.

The primary outcome was time to radiographic union, defined as bridging callus across at least three cortices on orthogonal views with no tenderness at the fracture site.

Secondary outcomes included:

- Malalignment (>5° in coronal or sagittal plane)
- Non-union and delayed union
- Knee range of motion (measured with a goniometer)
- Knee injury and Osteoarthritis Outcome Score (KOOS)
- Pain score (VAS)
- Complications (infection, implant failure, reoperation)

Data was recorded using structured forms. Continuous variables were expressed as means with standard deviations (SD) and were assessed between groups with independent-samples t-tests. For categorical variables, data were summarized as frequencies and proportions, and comparisons were made using the Chi-square test or Fisher's exact test when appropriate. A p-value < 0.05 was considered significant. All statistical analyses were conducted using SPSS version 26.

RESULTS

The analysis included 57 patients in total; 29 were treated with locking plates, and 28 with non-locking plates. The mean age was comparable between groups (54.3 ± 12.1 vs. 52.7 ± 11.8 years, p = 0.58), and the proportion of patients aged 60 years or older was similar (41.4% vs. 39.3%, p = 0.88). Gender distribution did not differ significantly, with males representing 58.6% of the locking plate group and 57.1% of the non-locking plate group (p = 0.91). Mean BMI was almost identical between groups (25.6 vs. 25.1 kg/m², p = 0.63). The prevalence of comorbidities such as diabetes, osteoporosis, and smoking history was evenly matched, and there was no significant difference in ASA class distribution (p > 0.05 for all variables)

The distribution of fracture laterality and injury mechanism was similar between groups, with right-sided injuries seen in just over half of patients in both cohorts (p = 0.90) and high-energy mechanisms in approximately 47% overall (p = 0.88). AO/OTA type C fractures accounted for 41.4% in the locking plate group and 35.7% in the non-locking group (p = 0.66). The proportion of open fractures was low and comparable (p = 0.73). Operative time was slightly longer for locking plates but did not reach significance (112.5 ± 18.4 vs. 106.3 ± 17.9 min, p = 0.15), and intraoperative blood loss was similar (p = 0.21). The MIPO technique was more frequently used with locking plates (62.1% vs. 39.3%), but the difference did not achieve statistical significance (p = 0.08). Bone grafting rates were also comparable (p = 0.69).

Radiological assessment revealed a significantly shorter mean time to fracture union in the locking plate group (17.3 ± 3.2 weeks) compared to the non-locking group (19.5 ± 3.7 weeks, p = 0.02). Rates of malalignment in both coronal and sagittal planes were low and did not differ significantly. Delays and non-union phenomena were more prevalent in the group lacking locking plates, but there was no statistical significance in the results (p > 0.05).

Table 1: Demographic and Baseline Characteristics of Patients (n = 57)

Variable	Locking Plate (n=29)	Non-Locking Plate (n=28)	p-value
Mean age (years ± SD)	54.3 ± 12.1	52.7 ± 11.8	0.58
Age ≥ 60 years, n (%)	12 (41.4)	11 (39.3)	0.88
Male sex, n (%)	17 (58.6)	16 (57.1)	0.91
BMI (kg/m² ± SD)	25.6 ± 3.4	25.1 ± 3.2	0.63
Diabetes mellitus, n (%)	8 (27.6)	7 (25.0)	0.82
Osteoporosis, n (%)	9 (31.0)	8 (28.6)	0.84
Smoking history, n (%)	10 (34.5)	9 (32.1)	0.85
ASA class III–IV, n (%)	7 (24.1)	6 (21.4)	0.79

Table 2: Injury and Operative Details

Variable	'Locking Plate (n=29)'	'Non-Locking Plate (n=28)'	p-value
'Right side involved' n (%)	16 (55.2)	15 (53.6)	0.90
High-energy mechanism, n (%)	14 (48.3)	13 (46.4)	0.88
AO/OTA type C fracture, n (%)	12 (41.4)	10 (35.7)	0.66
Open fracture, n (%)	4 (13.8)	3 (10.7)	0.73
Mean operative time (min ± SD)	112.5 ± 18.4	106.3 ± 17.9	0.15
Mean blood loss (mL ± SD)	325 ± 68	348 ± 72	0.21
MIPO technique used, n (%)	18 (62.1)	11 (39.3)	0.08
Bone graft used, n (%)	5 (17.2)	6 (21.4)	0.69

Table 3: Radiographic Outcomes

Variable	Locking Plate (n=29)	Non-Locking Plate (n=28)	p-value
Mean time to union (weeks ± SD)	17.3 ± 3.2	19.5 ± 3.7	0.02*
Malalignment ≥ 5° coronal, n (%)	1 (3.4)	4 (14.3)	0.16
Malalignment ≥ 5° sagittal, n (%)	1 (3.4)	3 (10.7)	0.29
Non-union, n (%)	1 (3.4)	3 (10.7)	0.29
Delayed union (>24 weeks), n (%)	2 (6.9)	5 (17.9)	0.21

*Statistically significant (p < 0.05)

Table 4: Functional Outcomes at 12 Months

Variable	'Locking Plate (n=29)'	'Non-Locking Plate (n=28)'	p-value
Mean knee flexion (° ± SD)	118.4 ± 8.6	112.2 ± 9.1	0.01*
KOOS score (mean ± SD)	78.6 ± 6.3	74.1 ± 6.8	0.02*
VAS pain score (0–10 ± SD)	2.1 ± 0.9	2.6 ± 1.0	0.06
Return to preinjury mobility, n (%)	26 (89.7)	22 (78.6)	0.25

*Statistically significant (p < 0.05)

Table 5: Postoperative Complications

Variable	'Locking Plate (n=29)'	'Non-Locking Plate (n=28)'	p-value
Superficial infection, n (%)	1 (3.4)	2 (7.1)	0.55
Deep infection, n (%)	0 (0.0)	1 (3.6)	0.31
Implant failure, n (%)	0 (0.0)	2 (7.1)	0.15
Reoperation, n (%)	1 (3.4)	3 (10.7)	0.29
DVT, n (%)	1 (3.4)	1 (3.6)	0.97
Mortality within 90 days, n (%)	0 (0.0)	1 (3.6)	0.31

Functionally, patients in the locking plate group achieved significantly greater mean knee flexion at one year (118.4° ± 8.6° vs. 112.2° ± 9.1°, p = 0.01) and higher KOOS scores (78.6 ± 6.3 vs. 74.1 ± 6.8, p = 0.02). Pain levels assessed by VAS were slightly lower in the locking plate group, but the difference did not reach statistical significance (p = 0.06). The proportion of patients returning to their pre-injury mobility status was high in both groups, with no significant difference (p = 0.25).

The incidence of postoperative complications was generally low in both groups. There were no significant differences in superficial or deep infection rates, implant failure, reoperation, thromboembolic events, or short-term mortality. Implant failure occurred only in the non-locking plate group (7.1%), while DVT was reported equally in both groups (p = 0.97).

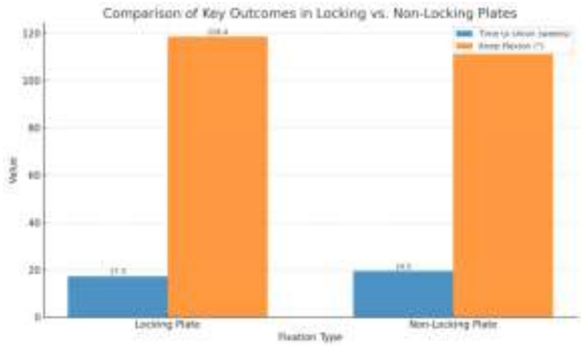

Figure 1: comparative bar graph showing mean time to union and mean knee flexion for locking versus non-locking plates in distal femur fractures.

DISCUSSION

This research analyzed the clinical and biomechanical effects of using ‘locking and non-locking plates’ for fixing distal femur fractures. Patients treated with ‘locking plates’ not only had significantly better outcomes in fracture union and more knee flexion at 12 months but also had greater KOOS scores compared to those managed with ‘non-locking plate’s. While both groups had low complication rates, non-locking plates were associated with an increased rate of implant failure.

The shorter mean time to union in the locking plate cohort (17.3 ± 3.2 weeks vs. 19.5 ± 3.7 weeks) is consistent with previous studies reporting improved healing rates with locking technology. Studies found that locking plates provided better mechanical stability, particularly in osteoporotic bone, by maintaining fixed-angle constructs and reducing the risk of secondary displacement [9-11]. Similarly, studies highlighted the benefit of locking plates in bridging comminuted fractures while preserving periosteal blood supply[12,13].

In terms of functional recovery, the higher mean knee flexion (118.4° vs. 112.2°) and KOOS scores in the locking plate group align with the findings of study, who reported superior postoperative mobility and patient-reported outcomes with locking constructs. The improved range of motion may be attributed to earlier mobilization protocols supported by the increased stability of locking plates[14].

Despite these advantages, our study found no statistically significant difference in rates of malalignment, non-union, or delayed union between groups, which is similar to the observations of studies[15,16]. This suggests that, while locking plates may offer biomechanical superiority, the overall healing process is still influenced by surgical technique, patient biology, and rehabilitation adherence.

Complication rates were low and comparable across groups, with no deep infections reported in the locking plate cohort. This mirrors the results of studies, which found no significant difference in infection or reoperation rates between ‘locking and non-locking plates’. However, our observation of implant failure only in the non-locking plate group reinforces the mechanical advantage of fixed-angle constructs, particularly in comminuted or osteoporotic fractures[17,18].

Cost-effectiveness remains a debated topic. Locking plates are generally more expensive, but their potential to reduce reoperation rates and improve functional recovery may offset initial costs[19,20]. Our study did not include an economic analysis, but future multicenter trials could address this aspect to guide clinical decision-making.

A strength of this study is the prospective design and standardized follow-up, ensuring consistent data collection. However, the relatively small sample size and single-center setting may limit the generalizability of findings. Moreover, the allocation of implant type was not randomized, which could introduce selection bias. Finally, the follow-up period of one year may not capture late complications or post-traumatic arthritis.

CONCLUSION

Locking plates demonstrated superior performance in terms of faster fracture union, greater knee flexion, and improved functional outcomes compared to non-locking plates in the fixation of distal femur fractures. While complication rates were low and similar across groups, implant failure was observed only in the non-locking plate cohort. These findings support the use of locking plates, especially in patients with comminuted fractures, poor bone quality, or when early mobilization is desired. Future large-scale randomized trials with cost analysis are warranted to further validate these results and guide implant selection.

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