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Radiological Outcome Analysis of Comminuted Femoral Shaft Fractures: Locking Plate Versus Open Interlocking Intramedullary Nail

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Abstract: ***Background:*** Comminuted femoral shaft fractures present significant challenges in orthopedic trauma management, particularly in low-resource settings where minimizing complications is essential. This study compares the radiological and functional outcomes of locking compression plates (LCP) and open interlocking intramedullary nails (IMN) in such fractures. ***Methods:*** This experimental clinical trial included 36 patients with comminuted femoral shaft fractures, treated with either IMN (n=18) or LCP (n=18). Baseline characteristics, injury profile, surgical details, hospital stay, time to union, radiological outcomes (assessed by the Radiographic Union Score for Tibial fractures [RUST], adapted for femur), and postoperative complications were analyzed. Radiographs were evaluated at 1.5, 3, and 6 months. ***Results:*** At 1.5 months, most patients were in the fair RUST category, but by 3 months, half of both groups had achieved good union, and excellent outcomes were more common in the LCP group (33.33% vs. 27.77%). During the 6 months, most patients in both groups achieved good or excellent radiological union, with the LCP group showing a higher proportion of excellent scores (44.44% vs. 33.33%). Functional outcomes for six months also favored LCP, with 44.44% achieving excellent results compared to 33.33% in IMN. Complications were more frequent in the IMN group (11.11% infection, 11.11% non-union), while none were reported in the LCP group. Time to union and hospital stay were comparable between groups. ***Conclusion:*** Locking compression plates provide superior radiological healing, fewer complications, and better functional outcomes compared to open interlocking nails in comminuted femoral shaft fractures. These advantages support the use of LCP in resource-limited settings where reliable healing and complication avoidance are essential.

Keywords: Comminuted Femoral Shaft Fractures, Locking Compression Plate, Intramedullary Nailing, Radiological Outcomes, RUST Score, Functional Outcomes.

Original Research Article

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INTRODUCTION

Femoral shaft fractures are one of the most significant long bone injuries encountered in orthopedic trauma, often resulting from high-energy trauma such as road traffic accidents, which are notably prevalent in lower-middle-income countries, including Bangladesh. The high impact of femoral fractures on mobility and quality of life is well-documented, with studies indicating prolonged recovery periods and challenges in fracture stabilization and healing, especially in cases of comminuted fractures, where the bone is fragmented into multiple pieces, complicating the repair process.[1,2] In Bangladesh, femoral shaft fractures constitute a significant portion of orthopedic cases in trauma centers, with road traffic accidents contributing to over 40% of such traumatic injuries, underscoring the need for effective, resource-suited surgical interventions.[3] Risk factors like falls and physical labor in high-risk occupations further compound the prevalence of these fractures, making femoral fracture management a critical area of focus within the country's healthcare framework.[4]

Various surgical options are available for the treatment of femoral shaft fractures, primarily focusing on stabilizing the fracture to allow for proper healing and prevent complications like malunion or nonunion. The two main techniques for treating comminuted femoral fractures are locking plate fixation and intramedullary nailing, each with unique mechanics and advantages. Locking plate fixation involves using a plate with multiple screws that lock into the plate, forming a fixed-angle structure that provides stability across the fracture. This method offers excellent control over fracture alignment, especially in cases of severe comminution, where precise anatomical reduction is necessary. However, the locking plate technique often requires a more invasive approach, which can increase the risk of infection and soft tissue damage, making it less ideal in settings where postoperative care is limited.[5] Intramedullary nailing (IMN), on the other hand, involves inserting a nail along the medullary cavity of the bone, providing central stabilization with less invasive access. IMN is associated with shorter operative times and reduced infection risks, particularly favorable for low-resource settings where healthcare access may be inconsistent, allowing for early weight-bearing and faster recovery.[6]

Radiological outcomes play a pivotal role in assessing the success of orthopedic interventions for femoral fractures, providing objective measures of healing and stability essential for guiding treatment decisions. Radiological assessments of fracture union time, alignment, hardware stability, and complications like malunion or nonunion offer valuable insights into the effectiveness of a chosen treatment method. Parameters like the Radiographic Union Score for Tibia Fractures (RUST) have been adapted for similar use in femoral fractures, helping clinicians evaluate callus formation and alignment, which are critical indicators of successful bone healing.[7] Studies comparing radiological outcomes between locking plate fixation and intramedullary nailing highlight the variable healing and complication rates associated with each technique, with IMN generally favoring shorter union times, while locking plates provide better alignment control, particularly in complex fractures.[8,9] This variability underscores the need for evidence-based guidelines tailored to specific populations, particularly in low-resource settings like Bangladesh, where limited access to follow-up care can influence long-term outcomes.

Existing literature on the comparative effectiveness of locking plates versus intramedullary nails reveals a complex picture. For instance, a meta-analysis examining the treatment of distal femur fractures post-total knee arthroplasty (TKA) found similar rates of nonunion and revision between locking plates and retrograde intramedullary nails, though IMN exhibited a lower infection rate, suggesting a possible advantage in settings with constrained postoperative care.[10] Moreover, research has shown that minimally invasive locking plates can provide better reduction quality in complex supracondylar fractures, whereas IMN offers benefits such as reduced blood loss and faster operative times, which are advantageous for trauma settings.[11] Additionally, a study on femoral shaft fractures with multiple injuries indicated that dual plating provided enhanced stability but at the cost of a longer radiographic union time, underscoring the need for a balanced approach based on individual case requirements and available resources.[12] Given the high burden of femoral fractures in Bangladesh and the limitations in healthcare resources, this study aims to provide data on radiological outcomes following treatment with locking plates versus intramedullary nails in a Bangladeshi population. By assessing key radiological outcomes, such as union rates, alignment, and hardware stability, this study seeks to identify the most suitable surgical intervention for improving patient outcomes in resource-limited environments. This focus on radiological markers will not only contribute to the local orthopedic knowledge base but may also provide a foundation for guiding treatment strategies in similar settings globally, where high trauma incidences and limited postoperative support necessitate the most effective and contextually appropriate surgical approaches.

METHODS

This experimental clinical trial was conducted at the Department of Orthopaedic Surgery, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh, from July 2010 to June 2012. The study protocol was

reviewed and approved by the Ethical Committee of BSMMU. Written informed consent was obtained from all patients prior to inclusion. A total of 36 patients diagnosed with comminuted femoral diaphyseal fractures were included and allocated into two groups: Group I (n=18), treated with open interlocking intramedullary nailing, and Group II (n=18), treated with a locking compression plate (LCP). Inclusion criteria comprised patients aged 20–70 years of both sexes, with comminuted femoral shaft fractures located between 5 cm distal to the lesser trochanter and 9 cm proximal to the knee joint line, with fracture duration between 2 and 28 weeks. Exclusion criteria included recent fractures (<1 week), pathological fractures, infected non-unions, persistent open wounds, fractures in children, or medically unstable patients. Data was collected using a predesigned, validated questionnaire, and statistical analysis was performed using SPSS v16.0. A p-value <0.05 was considered statistically significant.

Radiological Outcome Assessment by RUST Score

Radiological union was assessed using the Radiographic Union Score for Tibial fractures (RUST), adapted for femoral shaft fractures. This scoring system evaluates callus formation and visibility of the fracture line at four cortices: anterior, posterior, medial, and lateral. Each cortex is scored from 1 to 3:
1 = No callus, visible fracture line
2 = Callus present, visible fracture line
3 = Callus present, no visible fracture line

The total score ranges from 4 to 12, with higher scores indicating greater radiographic healing. For interpretive purposes, scores were categorized as:
4–6 = Poor/Fair
7–9 = Good
10–12 = Excellent

Radiological assessments were performed at three postoperative intervals:
Around 1.5 months (POD 40–49 days)
Around 3 months (POD 85–94 days)
Around 6 months (POD 185–194 days)

A good-quality digital radiograph with both anteroposterior and lateral views was obtained at each assessment. It should be noted that in cases of LCP fixation, the lateral view may sometimes be misleading due to the presence of the plate obscuring callus visualization.

Additionally, radiological outcomes guided postoperative rehabilitation. Patients with a RUST score ≥6 were allowed partial weight-bearing with double axillary crutches, while those with a RUST score ≥9 were permitted full weight-bearing with a single walking aid. This approach minimized the risk of premature weight-bearing, which could disrupt fracture alignment and callus formation.

RESULTS

Table 1: Distribution of the Participants by Baseline Characteristics (N=36)

Baseline Characteristics	Group 1 (n=18)		Group 2 (n=18)	
	n	%	n	%
Age				
20-29	2	11.11%	6	33.33%
30-39	6	33.33%	4	22.22%
40-49	4	22.22%	2	11.11%
50-59	2	11.11%	2	11.11%
60-69	4	22.22%	4	22.22%
Mean±SD	34.4±8.3		42.7±11.5	
Gender				
Male	14	77.78%	12	66.67%
Female	4	22.22%	6	33.33%
Occupation				
Farmer	2	11.11%	4	22.22%

Businessman	2	11.11%	4	22.22%
Housewife	2	11.11%	6	33.33%
Day Laborer	4	22.22%	2	11.11%
Service holder	2	11.11%	2	11.11%
Driver	4	22.22%	0	0.00%
Student	2	11.11%	0	0.00%

The baseline characteristics show that Group 1 participants have a mean age of 34.4 ± 8.3 years, while Group 2 participants are older, with a mean age of 42.7 ± 11.5 years. In Group 1, the largest age group is 30-39 (33.33%), whereas, in Group 2, the 20-29 age range is most common (33.33%). Males dominate both groups, making up 77.78% of Group 1 and 66.67% of Group 2. Occupationally, Group 1 has a higher representation of drivers (22.22%) and day laborers (22.22%), while Group 2 consists mainly of housewives (33.33%), followed by farmers and businessmen (22.22% each). Group 1 includes students and drivers, whereas Group 2 has none in these occupations.

Table 2: Distribution Of the Participants by Injury Related Characteristics (N=36)

Injury related characteristics	Group 1 (n=18)		Group 2 (n=18)	
	n	%	n	%
Cause of Injury				
Motor vehicle accident	10	55.56%	12	66.67%
Fall from height	4	22.22%	2	11.11%
Assault	2	11.11%	2	11.11%
Blunt Trauma (others)	2	11.11%	2	11.11%
Side of Involvement				
Right	6	33.33%	8	44.44%
Left	12	66.67%	10	55.56%
Fracture site				
Proximal Third	8	44.44%	2	11.11%
Middle Third	10	55.56%	10	55.56%
Distal Third	0	0.00%	6	33.33%

Injury-related characteristics show that motor vehicle accidents are the most common cause of injury in both groups, accounting for 55.56% in Group 1 and 66.67% in Group 2. Falls from height caused 22.22% of injuries in Group 1 but only 11.11% in Group 2. Both groups have similar proportions of injuries from assault and blunt trauma (11.11% each). Regarding the side of involvement, left-sided injuries are more frequent in both groups, affecting 66.67% in Group 1 and 55.56% in Group 2. Fracture site distribution shows differences; in Group 1, fractures are primarily located in the middle third (55.56%) and proximal third (44.44%) of the femur, with no distal fractures. Conversely, Group 2 has fractures distributed across the proximal (11.11%), middle (55.56%), and distal thirds (33.33%) of the femur.

Table 3: History of Previous Treatment (N=36)

Treatment History	Group 1 (n=18)		Group 2 (n=18)	
	n	%	n	%
Upper tibial skeletal traction	14	77.78%	12	66.67%
Others (by kabiraz)	4	22.22%	6	33.33%

The treatment history of participants shows that the majority in both groups had previously undergone upper tibial skeletal traction, with 77.78% in Group 1 and 66.67% in Group 2. Additionally, a smaller portion of participants in each group had received alternative treatments

from local healers (kabiraz), representing 22.22% in Group 1 and 33.33% in Group 2.

Table 4: Distribution of Subjects by Time Interval Between Injury and Surgery (N=36)

Treatment related characteristics	Group 1 (n=18)	Group 2 (n=18)	t value	p value
Time interval between Injury and Surgery				
Mean±SD	12.3±2.5	14.4±4.6	1.203	0.246
Range	9-20	8-20		
Post-operative hospital stays				
Mean±SD	10.4±2.54	10.5±2.95	0.694	0.497
Range	8-15	9-15		
Time taken to union				
Mean±SD	14.41±2.50	13.72±1.98	0.64	0.525
Range	12-24	10-20		

The time interval between injury and surgery shows a slightly shorter mean for Group 1 (12.3 ± 2.5 days) compared to Group 2 (14.4 ± 4.6 days), though this difference is not statistically significant (t = 1.203, p = 0.246). Post-operative hospital stays are similar between the groups, with Group 1 having a mean stay of 10.4 ± 2.54 days and Group 2 10.5 ± 2.95 days (t = 0.694, p = 0.497). The time taken to achieve union is also comparable, with a mean of 14.41 ± 2.50 weeks in Group 1 and 13.72 ± 1.98 weeks in Group 2, showing no significant difference (t = 0.64, p = 0.525).

Table 5: Distribution Of Participants by Radiological Outcome (N=36)

Radiological Outcome	Group 1 (n=18)		Group 2 (n=18)	
	n	%	n	%
Limb Length Discrepancy				
0 cm	14	77.78%	14	77.78%
<1 cm	4	22.22%	2	11.11%
1-3 cm	0	0.00%	2	11.11%
>3 cm	0	0.00%	0	0.00%
Mean±SD	2.25±3.30		2.25±3.20	
Hip flexion of the affected limb				
>90°	16	88.89%	14	77.78%
71°-90°	2	11.11%	4	22.22%
41°-70°	0	0.00%	0	0.00%
0°-40°	0	0.00%	0	0.00%
Mean±SD	97.67°±14.39°		94.56°±15.39°	
Hip abduction of the affected limb				
>30°	12	66.67%	14	77.78%
21-30°	4	22.22%	2	11.11%
11-20°	2	11.11%	2	11.11%
0-10°	0	0.00%	0	0.00%
Mean±SD	33.33°±8.02°		34.67°±10.54°	
Knee flexion of affected limb				
>90°	16	88.89%	18	100.00%
61°-90°	2	11.11%	0	0.00%
0°-60°	0	0.00%	0	0.00%
Mean±SD	105.22°±14.24°		106.67°±12.32°	

The radiological outcomes for participants in both groups reveal similar results across key measurements. Limb length discrepancy shows that most participants (77.78%) in both Group 1 and

Group 2 had no discrepancy (0 cm), with minor discrepancies (<1 cm) present in 22.22% of Group 1 and 11.11% of Group 2. In terms of hip flexion, a large majority achieved >90° in both groups (88.89% in Group 1 and 77.78% in Group 2), with the remaining participants showing flexion between 71° and 90°. Mean hip flexion was slightly higher in Group 1 (97.67° ± 14.39°) compared to Group 2 (94.56° ± 15.39°). For hip abduction, 66.67% of Group 1 and 77.78% of Group 2 achieved >30°, while smaller percentages in both groups achieved abduction between 21° and 30° or 11° and 20°. Mean hip abduction was relatively comparable, with Group 1 at 33.33° ± 8.02° and Group 2 at 34.67° ± 10.54°. Knee flexion of the affected limb showed favorable outcomes, with all participants in Group 2 (100%) and most in Group 1 (88.89%) achieving >90° flexion. The remaining 11.11% of Group 1 had knee flexion between 61° and 90°. Mean knee flexion was similar between the groups, with 105.22° ± 14.24° in Group 1 and 106.67° ± 12.32° in Group 2.

Table 6: Post-Surgery Complications (N=36)

Complications	Group 1 (n=18)		Group 2 (n=18)	
	n	%	n	%
Infection	2	11.11%	0	0.00%
Non-Union with implant failure (loosening)	2	11.11%	0	0.00%
Sciatic nerve palsy	0	0.00%	0	0.00%
None	14	77.78%	18	100.00%

Post-surgery complications reveal a higher incidence in Group 1 compared to Group 2. In Group 1, 11.11% of participants experienced infections, and another 11.11% had non-union with implant failure (loosening), while no cases of sciatic nerve palsy were reported. In contrast, Group 2 showed no reported complications, with 100% of participants experiencing a complication-free recovery. Overall, 77.78% of Group 1 participants had no complications, underscoring a more favorable outcome in Group 2.

Table 7: Distribution Of Functional Outcome At 6-Month Follow-Up

Outcome	Group 1 (n=18)		Group 2 (n=18)	
	n	%	n	%
Excellent	6	33.33%	8	44.44%
Good	8	44.44%	8	44.44%
Fair	2	11.11%	2	11.11%
Poor	2	11.11%	0	0.00%

At the 6-month follow-up, functional outcomes were favorable in both groups, with Group 2 showing slightly higher rates of excellent outcomes. In Group 1, 33.33% of participants achieved an excellent outcome, while 44.44% of Group 2 reached this level. Both groups had an equal percentage of good outcomes, with 44.44% in each. Fair outcomes were reported in 11.11% of participants in both groups. Notably, poor outcomes were only present in Group 1 (11.11%), with no poor outcomes recorded in Group 2.

Table 8: Assessment Of RUST Score At 1.5 Months Follow-Up (POD 40–49 Days)

RUST Score	Group I (n=18)	Group II (n=18)
Fair (4–6)	10 (55.55%)	8 (44.44%)
Good (7–9)	6 (33.33%)	7 (38.88%)
Excellent (10–12)	2 (11.11%)	3 (16.66%)

At approximately six weeks postoperatively, the majority of patients in both groups remained in the fair category (RUST 4–6), with 55.55% in Group I and 44.44% in Group II. A moderate proportion of patients demonstrated good radiological union (33.33% in Group I and

38.88% in Group II). Only a small number of patients achieved excellent healing at this early stage, comprising 11.11% in Group I and 16.66% in Group II.

Table 9: Assessment Of RUST Score At 3 Months Follow-Up (POD 85–94 Days)

RUST Score	Group I (n=18)	Group II (n=18)
Fair (4–6)	4 (22.22%)	3 (16.66%)
Good (7–9)	9 (50.00%)	9 (50.00%)
Excellent (10–12)	5 (27.77%)	6 (33.33%)

By three months postoperatively, radiological healing had progressed in both groups. The proportion of patients in the fair category decreased to 22.22% in Group I and 16.66% in Group II. Half of the patients in each group (50.00%) were classified as good, while the proportion achieving excellent union increased to 27.77% in Group I and 33.33% in Group II. These findings suggest steady progression of callus formation and fracture healing across both treatment methods.

Table 10: Assessment Of RUST Score At 6 Months Follow-Up (POD 185–194 Days)

RUST Score	Group I (n=18)	Group II (n=18)
Fair (4–6)	4 (22.22%)	2 (11.11%)
Good (7–9)	8 (44.44%)	8 (44.44%)
Excellent (10–12)	6 (33.33%)	8 (44.44%)

At six months, the majority of patients in both groups demonstrated favorable radiological union. In Group I, 22.22% of patients remained in the fair category, while 44.44% were classified as good and 33.33% as excellent. In Group II, only 11.11% of patients remained in the fair category, while 44.44% were good and an equal 44.44% were excellent. These results indicate that by six months, most patients in both groups had achieved either good or excellent radiological union, with slightly better outcomes observed in the LCP group.

DISCUSSION

This study compared the radiological outcomes, functional recovery, and complication rates of locking compression plates (LCP) and open interlocking intramedullary nails (IMN) in the treatment of comminuted femoral shaft fractures, aiming to identify the optimal approach for patients in resource-limited settings.[13] The results demonstrated that LCP provided a more favorable outcome in terms of reduced complications and higher functional scores at six-month follow-up, aligning with findings from various comparative studies. The demographic baseline showed a slight age difference between groups, with Group 1 having a younger average age. Although this was not statistically significant, it reflects demographic trends in femoral fracture cases where younger patients are often involved in high-energy trauma such as road traffic accidents, which were the predominant cause in both groups. This aligns with other studies that note motor vehicle accidents as a major cause of femoral fractures, especially in low- to middle-income countries with high trauma rates due to inadequate traffic safety measures.[13,14]

In terms of preoperative treatment, most participants initially received skeletal traction, with a minority seeking traditional healer interventions. The use of skeletal traction aligns with findings from Chokotho *et al.*, who highlighted traction as a common initial treatment in resource-limited settings, although outcomes often favor early definitive fixation techniques for improved recovery.[15] The time interval between injury and surgery was not significantly different between groups, reflecting findings by Nyholm *et al.*, who also showed that while shorter intervals may benefit recovery, the timing must be balanced with patient stabilization and resource availability.[16] Postoperative hospital stays were comparable across both groups, with no statistically significant difference, which aligns with findings from other studies indicating that IMN and LCP treatments generally lead to similar hospitalization durations

when complications are minimal.[17,18] The time to union was also similar between groups, which is consistent with the study by Ekwunife *et al.*, who found that both intramedullary and extramedullary fixation techniques can provide reliable union in femoral fractures given adequate post-operative management and follow-up.[19]

Radiologically, limb length discrepancies were minimal in both groups, with the majority achieving no discrepancy or less than 1 cm. This outcome is supported by Kohli *et al.*, who found that LCP can maintain excellent limb alignment even in cases of complex comminuted fractures due to its fixed-angle stability.[20] Hip and knee range of motion outcomes were also favorable in both groups, but knee flexion was marginally better in the LCP group. This aligns with Gill *et al.*, who found that patients treated with locking plates often achieve better functional outcomes in knee flexion compared to those treated with retrograde nailing due to reduced soft tissue interference.[21]

When radiological union was assessed using the RUST score at sequential follow-up points, a clear trend of progressive healing was observed in both groups, though outcomes were consistently more favorable in the LCP group. At 1.5 months, the majority of patients in both groups remained in the *fair* category, reflecting the expected early stage of callus formation. By three months, the proportion of patients achieving *excellent* scores increased substantially, particularly in the LCP group. At six months, most patients in both groups demonstrated either *good* or *excellent* union, but the LCP group had a higher proportion of patients in the *excellent* category (44.44% vs. 33.33% in the IMN group). These findings reinforce that while both fixation methods provide reliable union, locking plates may promote more consistent progression toward radiological healing, which is crucial for guiding safe weight-bearing and rehabilitation. This pattern aligns with prior evidence that standardized radiological scoring systems such as RUST provide an objective measure of healing progression and may highlight subtle differences in outcomes between fixation techniques. In terms of complications, Group 1 showed a higher rate of infections and non-union cases compared to Group 2, which reported no complications. This difference supports findings by Aggarwal *et al.*, who observed that locking compression plates had lower complication rates in distal femoral fractures, likely due to better stability and fewer incidences of implant-related failures.[22] Similarly, Shamma *et al.*, noted that while IMN is effective, LCP provides additional benefits in terms of reduced infection rates and better outcomes in complex fractures, particularly in resource-limited settings where infection control is challenging.[23]

At the six-month follow-up, functional outcomes were notably better in Group 2, with a higher percentage achieving excellent ratings and none classified as poor, as compared to Group 1. This finding resonates with results from Veeragandham *et al.*, who demonstrated that LCP provides enhanced early functional outcomes due to its rigid fixation, enabling early mobilization and weight-bearing.[24] In summary, this study's findings underscore the advantages of locking compression plates in treating comminuted femoral shaft fractures, particularly in settings with limited resources for postoperative follow-up and infection control. While both LCP and IMN provide adequate stability and union rates, LCP shows a lower complication rate and better functional outcomes, supporting its use as a preferred treatment in similar patient populations. These results are consistent with multiple studies suggesting that LCP may offer a safer and more effective alternative for managing complex femoral fractures, particularly when infrastructure for extensive post-surgery care is limited.

Limitations of the Study

The study was conducted in a single hospital with a small sample size. So, the results may not represent the whole community.

CONCLUSION

In this study, locking compression plates (LCP) demonstrated superior outcomes compared to open interlocking intramedullary nails (IMN) in the treatment of comminuted femoral shaft fractures. Radiological assessment with the RUST score showed progressive union in both groups, but a higher proportion of patients in the LCP group achieved excellent scores by six months. LCP also provided better functional results at six-month follow-up, with fewer postoperative complications and comparable time to union, hospital stays, and

range of motion outcomes. These findings suggest that LCP may be a more favorable option, particularly in resource-limited settings where minimizing complications and ensuring reliable radiological healing are critical. Future multicenter studies with larger sample sizes and longer follow-up periods are recommended to further validate these results.

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