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Assessment of rotational stability with intramedullary interlocking nailing for displaced diaphyseal femoral fractures in adults: A prospective observational study.

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Abstract

Background

Diaphyseal femoral fractures are high-energy injuries that require restoration of length, alignment, rotation, and early function. Intramedullary interlocking nailing offers load-sharing fixation and rotational control, particularly in unstable fracture patterns.

Objectives

To assess rotational stability, radiological union, functional recovery, weight-bearing progression, and complications after intramedullary interlocking nailing for displaced diaphyseal femoral fractures in adults.

Methods

This prospective observational study consecutively enrolled 20 adults treated with closed reduction and intramedullary interlocking nailing at the Department of Orthopaedics, Mediciti Institute of Medical Sciences, Ghanpur, Telangana, India. June 2022 to November 2023 represented the recruitment period. Participants were assessed prospectively after surgery for a minimum of 6 months and up to 12 months. Outcomes included alignment, clinical and radiological union, weight-bearing progression, range of motion, pain, swelling, complications, and Thoresen functional criteria.

Results

All 20 enrolled participants completed the minimum follow-up and were analyzed. Males constituted 70.0%, road traffic accidents accounted for 75.0%, and middle-third fractures were the most frequent pattern (45.0%). No participant developed clinically significant rotational deformity greater than 10 degrees, angulation greater than 5 degrees, or shortening greater than 2 cm. Primary union occurred in 18 patients (90.0%). One delayed union required dynamization, and one nonunion required exchange nailing with bone grafting. Excellent Thoresen outcomes were observed in 18 patients (90.0%).

Conclusion

Within the limitations of a small single-centre cohort, intramedullary interlocking nailing provided satisfactory clinical rotational control, maintained alignment, and achieved high union and functional recovery rates in adults with displaced diaphyseal femoral fractures.

Recommendations

Intramedullary interlocking nailing should be performed with careful preoperative planning, accurate fracture-table positioning, appropriate piriformis entry, controlled reduction, sequential reaming, and secure locking. Rotation should be checked repeatedly using cortical width, patellar direction, limb profile, and comparison with the opposite limb.

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Introduction

Femoral shaft fractures are major long-bone injuries in adult orthopaedic trauma. They commonly follow high-energy mechanisms such as road traffic accidents and falls from height, although low-energy fractures may occur in older adults with reduced bone strength. Because the femur is the principal load-bearing bone of the thigh, displacement may cause marked pain, deformity, blood loss, limb shortening, and prolonged disability when stable fixation is delayed. Epidemiological studies indicate that these fractures predominantly affect young adult males, while

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the mechanism of injury and fracture morphology influence treatment planning and outcome [1].

The goals of treatment are restoration of length, axial alignment, rotational profile, and early painless mobilisation. Conservative treatment has historical importance but may result in prolonged hospitalization, joint stiffness, shortening, malunion, and delayed return to activity. Consequently, operative fixation is preferred for most adult diaphyseal femoral fractures. Closed intramedullary nailing preserves fracture haematoma and soft-tissue attachments while providing central load-sharing fixation. Interlocking screws improve control of length and rotation in comminuted, segmental, proximal-third, and distal-third patterns [2,3].

Modern interlocking nails permit static or dynamic locking, early rehabilitation, and high union rates when reduction and implant positioning are appropriate [4,5]. Nevertheless, rotational malalignment remains an under-recognized complication. Although computed tomography provides more precise rotational measurement, careful intraoperative evaluation of cortical thickness, patellar orientation, lesser-trochanter profile, and limb position may reduce clinically relevant malrotation [6].

The timing of fixation, reaming strategy, locking configuration, open-fracture status, associated injuries, and postoperative rehabilitation can influence recovery. Early stabilization may improve pulmonary and rehabilitation outcomes in appropriately selected trauma patients, whereas reamed nailing has shown favourable union profiles in several adult femoral-shaft fracture series [3,5,7-9]. Systematic follow-up is necessary to identify delayed union or nonunion and to institute dynamization, exchange nailing, or bone grafting when indicated.

The present study aimed to assess rotational stability after intramedullary interlocking nailing for displaced diaphyseal femoral fractures in adults. The specific objectives were to evaluate postoperative alignment, clinical and radiological union, functional recovery, weight-bearing progression, and procedure-related complications.

Methodology

Study design

This was a prospective observational study. The term prospective observational indicates that the investigators did not allocate or compare treatments. Adults who received intramedullary interlocking nailing as part of routine orthopaedic care were enrolled before surgery and followed forward in time using predefined clinical, radiological, and functional outcome measures.

Study setting and timeline

The study was conducted in the Department of Orthopaedics, Mediciti Institute of Medical Sciences, Ghanpur, Telangana, India, a tertiary-care teaching hospital that provides emergency trauma assessment, inpatient orthopaedic care, fluoroscopy-guided surgery, radiological services, and postoperative physiotherapy for patients referred from surrounding urban and rural areas. Patient recruitment occurred from June 2022 to November 2023. These dates refer only to recruitment. Each participant was followed for at least 6 months after surgery; patients enrolled earlier were observed for up to 12 months. Therefore, follow-up continued beyond the recruitment period and varied from 6 to 12 months according to the date of enrolment.

Sample size and sampling technique

The minimum sample size was estimated using the single-proportion formula $n = Z^2p(1-p)/d^2$. An expected satisfactory functional outcome proportion of 90% was selected from an earlier interlocking-nailing series [10], with a 95% confidence level ($Z = 1.96$) and 14% absolute precision. The calculated sample was 17.64. After allowing approximately 10% for attrition or incomplete follow-up, the required number was 19.4 and was rounded to 20 participants. Consecutive sampling was used; every patient who met the eligibility criteria during the recruitment period was approached for enrolment until the required sample was reached.

Participants and eligibility criteria

Adults aged 20-70 years with displaced diaphyseal femoral fractures suitable for intramedullary interlocking nailing were eligible. Fractures with or without neurovascular complications and comminuted patterns classified according to the Winquist-Hansen system were considered [2]. Patients with malunited fractures, pathological fractures, an associated fracture of the femoral neck, age below 20 years, or unwillingness to provide consent were excluded.

Measures to address potential bias

Selection bias was reduced through consecutive enrolment using predefined eligibility criteria. Information and measurement bias were limited by prospectively recording data on a structured case-record form, applying the same operative protocol, using prespecified definitions of union and complications, and assessing

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all participants at scheduled clinical and radiological visits. Rotational alignment was evaluated using the same clinical and intraoperative landmarks for every case. Attrition bias was minimized by retaining all enrolled participants in the final analysis after completion of the minimum 6-month follow-up. Because this was a single-arm surgical cohort, blinding and control-group adjustment were not feasible; this limitation was considered during interpretation.

Preoperative assessment

Patients were stabilized according to standard trauma-care principles. Thomas splinting or skeletal traction was applied after clinical and radiological confirmation. Age, sex, mechanism of injury, side, fracture level, open-wound status, associated injuries, and comorbidities were recorded. Anteroposterior and lateral radiographs of the pelvis, femur, and knee were obtained. Open fractures were categorized using the Gustilo-Anderson system, and comminution was categorized using the Winquist-Hansen system [2].

Operative technique

Fixation was performed with the patient supine on a fracture table using a piriformis-entry antegrade nail. Closed reduction was achieved under image-intensifier guidance with traction and manipulation. Sequential reaming was performed, and the nail diameter was selected approximately 1-1.5 mm below the final reamer that produced cortical chatter. Static locking was used in all cases. Rotational alignment was assessed before and after nail insertion by comparing cortical thickness, limb position, patellar orientation, and the rotational profile of the injured and contralateral limbs.

Postoperative protocol and follow-up

Postoperative radiographs were obtained to assess reduction, implant position, and early complications. Antibiotics, analgesics, calcium, and vitamin D were prescribed according to institutional practice. Quadriceps exercises and knee mobilisation were initiated from the second postoperative day. Touch-down or partial weight bearing was individualized according to fracture stability, pain tolerance, associated injuries, and radiographic progression. Follow-up assessments were conducted for 6-12 months after surgery.

Outcome assessment

The outcomes were clinical union, radiological union, time to partial and full weight bearing, knee range of motion, pain, swelling, shortening, angulation, rotational deformity, perioperative complications, and final functional status. Radiological union was defined as bridging callus across at least three cortices together with painless weight bearing. Delayed union was defined as absence of clinical union beyond 24 weeks, and nonunion as absence of progressive callus at 6 months. Final functional outcome was graded using the Thoresen criteria [10].

Statistical analysis

Data were entered into a structured master sheet and analyzed descriptively. Categorical variables were reported as frequencies and percentages. Continuous variables, including delay to nailing, union time, and time to weight bearing, were summarized using means. No inferential comparison was undertaken because the study involved a small, single-arm cohort.

Ethical considerations

Ethical approval was obtained from the Institutional Ethics Committee, Mediciti Institute of Medical Sciences, Ghanpur, Telangana, India, before participant enrolment. Written informed consent was obtained from every participant. Confidentiality was maintained by using coded study records, and clinical management was not altered for research purposes. The study was conducted in accordance with institutional ethical standards and the principles applicable to observational clinical research.

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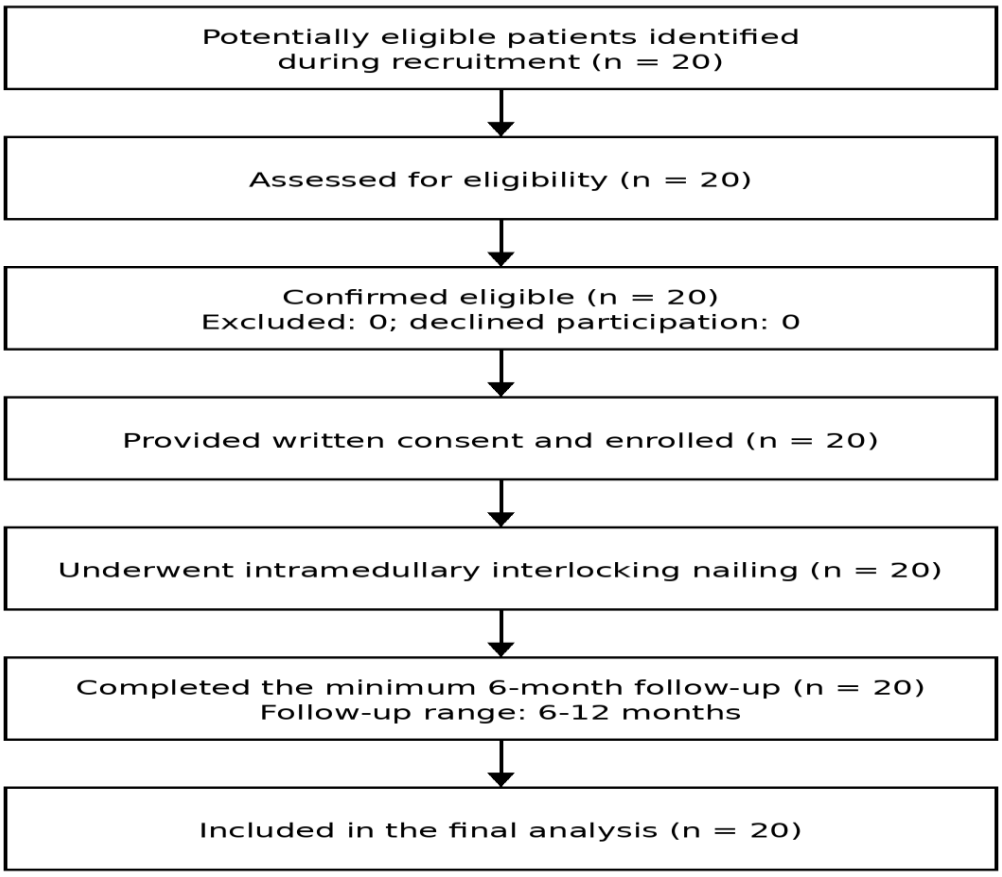
Results

Participant flow

Figure 1. *Participant flow diagram*



Twenty patients were identified as potentially eligible and were examined against the eligibility criteria. All 20 met the criteria, provided written informed consent, underwent intramedullary interlocking nailing, completed the minimum 6-month follow-up, and were included in the final analysis. No patient was excluded after assessment, declined participation, or was lost before the primary outcome assessment (Figure 1).

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Table 1. *Demographic and injury profile of the study participants*

Variable	Category	Number	Percentage
Age group	21-40 years	12	60.0
	41-60 years	6	30.0
	>60 years	2	10.0
Sex	Male	14	70.0
	Female	6	30.0
Mechanism of injury	Road traffic accident	15	75.0
	Fall from height	3	15.0
	Fall of object	2	10.0
Side of fracture	Right	15	75.0
	Left	5	25.0

As shown in Table 1, 12 patients (60.0%) were aged 21-40 years, and 14 (70.0%) were male. Road traffic accidents were the leading mechanism of injury, affecting 15 patients (75.0%). Right-sided fractures were also observed in 15 patients (75.0%).

Table 2. *Fracture level according to open and closed injury status*

Fracture level	Open type I	Open type II	Closed	Total	Percentage
Proximal/middle	1	0	3	4	20.0
Middle	0	1	8	9	45.0
Middle/distal	1	0	2	3	15.0
Distal	1	0	3	4	20.0
Total	3	1	16	20	100.0

Table 2 shows that middle-third fractures were the most frequent anatomical pattern, accounting for 9 cases (45.0%). Sixteen fractures (80.0%) were closed and four (20.0%) were open. Among open fractures, three were Gustilo-Anderson type I and one was type II.

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Table 3. *Winquist-Hansen fracture type according to open and closed injury status*

Winquist-Hansen type	Open	Closed	Total	Percentage
0	3	9	12	60.0
I	1	1	2	10.0
II	0	2	2	10.0
III	0	3	3	15.0
IV	0	1	1	5.0
Total	4	16	20	100.0

Winquist-Hansen type 0 fractures formed the largest group, with 12 patients (60.0%). Types I and II each accounted for 10.0%, type III for 15.0%, and type IV for 5.0% (Table 3). All patterns were managed with static interlocking fixation.

Table 4. *Delay to nailing and associated injuries*

Parameter	Category	Number/Mean
Delay to nailing	Open fractures	1.5 days
	Closed fractures	1.93 days
Associated injuries	Head injury	3 cases
	Rib fractures	2 cases
	Floating knee	2 cases
	Patella fracture	1 case
	Fifth metacarpal shaft fracture	1 case

The mean interval from injury to nailing was 1.5 days for open fractures and 1.93 days for closed fractures. Mild head injury was the most common associated injury, followed by rib fractures and floating-knee injuries (Table 4).

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Table 5: *Perioperative complications*

Period	Complication	Number	Percentage
Preoperative	Fat embolism	1	5.0
Intraoperative	Hypotension	1	5.0
Postoperative	Superficial infection	1	5.0
Postoperative	Knee pain	4	20.0
Postoperative	Minimal knee stiffness	1	5.0

Complications were infrequent and manageable (Table 5). Knee pain was the most frequent postoperative complaint, occurring in four patients (20.0%). One patient each developed preoperative fat embolism, intraoperative hypotension, superficial infection, and minimal knee stiffness. No implant reaction was recorded.

Table 6. *Union status and union time*

Outcome	Number	Percentage	Mean radiological union	Mean clinical union
Primary union	18	90.0	4 months	5.5 months
Delayed union	1	5.0	6 months	7 months
Nonunion	1	5.0	9 months	11 months
Total/overall	20	100.0	4.5 months	-

Primary union occurred in 18 patients (90.0%). One patient with delayed union underwent dynamization, and one patient with nonunion underwent exchange nailing with bone grafting. The overall mean radiological union time was 4.5 months, while mean clinical union among primarily united fractures was 5.5 months (Table 6).

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Table 7. *Functional outcome and postoperative alignment*

Parameter	Excellent	Good	Fair	Poor	Excellent (%)
Overall Thoresen outcome	18	1	1	0	90.0
Varus/valgus alignment	20	0	0	0	100.0
Procurvatum/recurvatum	20	0	0	0	100.0
Internal rotation	20	0	0	0	100.0
External rotation	20	0	0	0	100.0
Shortening	19	1	0	0	95.0
Range of motion	19	1	0	0	95.0
Pain or swelling	18	1	1	0	90.0

Table 7 summarizes the principal objective of rotational stability and the final functional assessment. No patient had clinically significant internal or external rotational deformity, varus-valgus malalignment, or procurvatum-recurvatum. Nineteen patients (95.0%) had excellent shortening and range-of-motion grades. The overall Thoresen outcome was excellent in 18 patients (90.0%), good in one, and fair in one; no poor outcome occurred.

Table 8. *Mean weight-bearing time after intramedullary interlocking nailing*

Weight-bearing stage	Mean time
Partial weight bearing	1.6 months
Full weight bearing with double support	3.06 months
Full weight bearing with single support	5.9 months
Unaided walking	6.0 months

Weight bearing advanced progressively during follow-up (Table 8). Partial weight bearing began at a mean of 1.6 months. Full weight bearing with double support was achieved at 3.06 months, with single support at 5.9 months, and unaided walking at 6.0 months.

Discussion

Key findings

The cohort was predominantly composed of young adult males, and road traffic accidents were the principal mechanism of injury (Table 1). Middle-third and closed fractures were most frequent (Tables 2 and 3). In relation to the primary objective, all 20 patients maintained satisfactory clinical rotational alignment, with no internal or external rotational deformity greater than 10 degrees

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and no angulation greater than 5 degrees (Table 7). Primary union occurred in 90.0%, while one delayed union and one nonunion required secondary procedures (Table 6). Functional recovery was favourable, with 90.0% excellent Thoresen outcomes and progressive restoration of weight bearing (Tables 7 and 8). Complications were uncommon and generally minor (Table 5).

Interpretation of demographic and injury characteristics

The demographic pattern in Table 1 is consistent with the recognized epidemiology of femoral-shaft trauma, in which young men are disproportionately affected by high-energy road traffic injuries [1,11]. This distribution may reflect greater occupational and road exposure among younger adults. The predominance of closed, middle-third fractures (Table 2) is clinically relevant because the central diaphyseal segment generally permits favourable intramedullary load sharing. In contrast, proximal, distal, and highly comminuted patterns require more precise entry-point selection, reduction, and locking to preserve length and alignment.

Interpretation of rotational stability and alignment

The absence of clinically important malrotation or angular deformity in Table 7 suggests that repeated intraoperative assessment of cortical width, patellar orientation, limb position, and contralateral comparison provided acceptable rotational control in this cohort. Rotational malalignment can remain undetected when these landmarks are not systematically checked, and computed tomography is more sensitive than clinical assessment for small rotational differences [6]. Therefore, the present findings should be interpreted as satisfactory clinical and radiographic rotational stability rather than proof of normal computed-tomography torsional measurements.

Interpretation of union and functional recovery

The 90.0% primary union rate shown in Table 6 supports the established role of intramedullary nailing as a load-sharing fixation method for adult femoral-shaft fractures [2,4,7]. The delayed union that responded to dynamization illustrates the benefit of reducing excessive construct stiffness once adequate callus is present, whereas exchange nailing with bone grafting was appropriate for the nonunion case. Evidence from prior studies indicates that reamed intramedullary nailing often provides favourable union characteristics compared with unreamed techniques [5,8,9].

The functional findings in Tables 7 and 8 indicate that maintained alignment and progressive union translated into good recovery of motion and mobility. Eighteen patients had excellent Thoresen outcomes, and no poor result was observed. These results are broadly comparable with previous interlocking-nailing series reporting high proportions of excellent or good outcomes [10,12]. The gradual progression from partial weight bearing to unaided walking reflects the influence of fracture stability, radiographic healing, pain, associated injuries, and rehabilitation rather than a uniform postoperative schedule.

Interpretation of complications

The complications listed in Table 5 were limited and treatable. Superficial infection responded to local care and antibiotics, while knee pain and minimal stiffness improved during follow-up. The low frequency of major shortening, angular deformity, implant-related reaction, and clinically detectable malrotation suggests that careful technique and structured rehabilitation contributed to stable fixation. Nevertheless, the small sample size limits the precision of complication estimates, and uncommon adverse events may not have been captured.

Generalizability

The procedures, implant type, radiographic assessments, and rehabilitation measures used in this study are common in tertiary orthopaedic practice. The findings may therefore be applicable to similar centres treating adult diaphyseal femoral fractures with fluoroscopy-guided antegrade interlocking nailing. Generalization should remain cautious because this was a single-centre cohort of 20 participants without a comparison group and without computed-tomography assessment of rotation.

Conclusion

Intramedullary interlocking nailing achieved satisfactory clinical rotational control, maintained length and alignment, and produced a 90.0% primary union rate in this small cohort of adults with displaced diaphyseal femoral fractures. Functional recovery was predominantly excellent, and complications were limited. These findings support the technique when meticulous reduction, repeated rotational checks, accurate locking, serial radiographic assessment, and structured rehabilitation are applied. Larger comparative studies using objective computed-tomography measurements of femoral rotation are required to confirm these observations.

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Limitations

The study was limited by its small sample size, single-centre design, absence of a comparator group, and descriptive statistical approach. Rotational alignment was assessed clinically and radiographically rather than with postoperative computed tomography. Follow-up duration varied because the stated dates represented recruitment only: all participants completed at least 6 months, whereas earlier recruits were followed for up to 12 months. Long-term gait, return-to-work status, implant removal, and patient-reported outcome measures were not systematically evaluated.

Recommendations

Intramedullary interlocking nailing should be performed with careful preoperative planning, accurate fracture-table positioning, appropriate piriformis entry, controlled reduction, sequential reaming, and secure locking. Rotation should be checked repeatedly using cortical width, patellar direction, limb profile, and comparison with the opposite limb. Patients with open injury, comminution, slow callus formation, or metabolic comorbidity require closer follow-up. Early knee mobilisation, individualized weight-bearing progression, analgesic optimization, and supervised physiotherapy should be incorporated into routine care.

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Conflict of interest:

The authors declare no conflict of interest.

Author contributions:

RR contributed to conceptualization, study design, clinical supervision, data interpretation, literature review, drafting, and critical revision. MAA contributed to study design, data collection, clinical follow-up, interpretation, drafting, and revision. KS contributed to literature review, data organization, statistical summary, drafting, and revision. All authors reviewed and approved the final manuscript.

Data availability

De-identified data supporting the findings of this study are available from the corresponding author upon reasonable request.

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