

A Prospective Comparative Evaluation of Intramedullary Nailing and Plate Fixation in Adult Diaphyseal Long-Bone Fractures

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Abstract

Background: Long-bone diaphyseal fractures of the femur, tibia, and humerus are among the most frequently encountered orthopaedic injuries in trauma practice. The optimal mode of internal fixation — intramedullary nailing (IMN) or extramedullary plate-and-screw fixation — has long been a subject of debate. Each technique offers distinctive biomechanical, biological, and procedural advantages, and selection is influenced by fracture pattern, soft-tissue status, surgeon expertise, and patient-related factors.

Objective: The present prospective comparative investigation aimed to evaluate and contrast intra-operative parameters, radiological union, functional outcomes, and complication profiles between intramedullary nailing and plate fixation in adult patients with diaphyseal long-bone fractures.

Methods: A prospective comparative study was conducted from June 2019 to February 2020 in the Department of Orthopaedics, Sri Lakshmi Narayana Institute of Medical Sciences, Puducherry. A total of 180 adult patients aged 18–60 years sustaining closed or low-grade open diaphyseal fractures of the femur, tibia, or humerus were recruited and allocated by computer-generated randomization to intramedullary nailing (Group IMN, n = 90) or plate fixation (Group PF, n = 90). All surgeries were performed by experienced orthopaedic surgeons under standardized protocols. Patients were followed for a minimum of 6 months, with assessments at 6, 12, 18, and 24 weeks. Functional outcomes were evaluated using the Lower Extremity Functional Scale (LEFS) for lower-limb fractures and the DASH score for upper-limb fractures.

Results: Baseline characteristics were comparable between groups. Mean operative time and intra-operative blood loss were significantly lower in Group IMN (74 ± 18 min and 142 ± 56 mL respectively) compared with Group PF (96 ± 22 min and 268 ± 84 mL). Radiological union was achieved at a mean of 18.4 ± 3.2 weeks (IMN) versus 21.8 ± 4.1 weeks (PF). Excellent or good functional outcomes (LEFS ≥ 60 or DASH ≤ 25) were achieved in 84.4% of the IMN group and

75.6% of the PF group. Surgical site infection occurred in 3.3% (IMN) versus 11.1% (PF), implant failure in 2.2% versus 6.7%, and delayed union in 6.7% versus 12.2%.

Conclusion: Intramedullary nailing offers superior intra-operative profile, faster radiological union, lower wound morbidity, and marginally better functional outcomes for selected long-bone fractures. Plate fixation retains an important role for fractures unsuitable for nailing.

Keywords

Long-bone fracture; intramedullary nailing; plate fixation; functional outcome; LEFS; DASH; orthopaedic trauma

1. Introduction

Diaphyseal fractures of the long bones — femur, tibia, and humerus — remain among the most common high-energy and low-energy injuries managed in orthopaedic trauma practice, with substantial implications for individual disability, working-age morbidity, and healthcare expenditure [1,2]. India, with its high incidence of road-traffic accidents, falls in the elderly, and occupational injuries, bears a particularly heavy burden, with annual long-bone fracture estimates exceeding several hundred thousand [3,4].

Operative stabilization of displaced diaphyseal long-bone fractures has largely supplanted prolonged conservative management (skeletal traction and casting) in most contemporary orthopaedic practices, owing to demonstrated benefits in early mobilization, restoration of length and alignment, faster fracture healing, lower malunion rates, and improved functional outcomes [5,6]. Two principal modes of internal fixation are practised: intramedullary nailing (IMN) and extramedullary plate-and-screw fixation (PF) [7].

Intramedullary nailing functions as a load-sharing device, biomechanically aligning the medullary canal, preserving periosteal blood supply, and permitting early load-bearing through closed or limited-open insertion via small remote incisions [8]. Plate fixation, performed through open or minimally invasive plate osteosynthesis (MIPO) techniques, allows direct anatomical reduction, absolute or relative stability, and is particularly useful for metaphyseal extension, intra-articular involvement, peri-implant fractures, and selected pathological fractures [9,10]. Each technique carries its own complication profile: IMN has been associated with knee/shoulder pain (depending on entry portal), malalignment in proximal/distal-third fractures, and reaming-related fat embolism; plate fixation carries higher infection risk, larger soft-tissue dissection, longer operative time, and risk of implant prominence and refracture after removal [11,12].

Despite extensive international literature, contemporary Indian comparative data integrating intra-operative metrics, radiological union, validated functional scores, and complication profiles remain valuable. The present investigation was therefore undertaken to compare clinically

meaningful outcomes between IMN and PF in adult diaphyseal long-bone fractures at a major north Indian tertiary care institute.

2. Materials and Methods

2.1 Study Setting

This prospective comparative study was conducted in the Department of Orthopaedics, Sri Lakshmi Narayana Institute of Medical Sciences, Puducherry in South India — a 960-bedded apex tertiary care teaching and referral institution. The study extended from June 2019 to February 2020.

2.2 Participants and Allocation

Adults aged 18–60 years sustaining closed or low-grade (Gustilo–Anderson type I or II) open diaphyseal fractures of the femur, tibia, or humerus, presenting within 7 days of injury and consenting to randomization, were eligible. Exclusion criteria included pathological fractures (excluding osteoporotic), high-grade open fractures (Gustilo–Anderson IIIB/C), polytrauma with ISS >25, segmental fractures, peri-articular involvement >5 cm from joint line, prior fracture at the same site, and refusal of consent. Of 240 patients screened, 180 were recruited and randomized 1:1 by computer-generated allocation to Group IMN (n = 90) or Group PF (n = 90).

2.3 Surgical Technique

All procedures were performed under spinal or general anaesthesia by experienced consultant orthopaedic surgeons. Group IMN underwent closed or limited-open intramedullary nailing — antegrade reamed nailing (AO/Synthes nail) for femoral and tibial shaft fractures, and antegrade or retrograde locked nailing for humeral shaft fractures. Group PF underwent open reduction with internal fixation using locking compression plates (LCPs) of appropriate size, with minimum 6 cortices of fixation on either side of the fracture. Standard antibiotic prophylaxis (cefuroxime 1.5 g IV at induction) and post-operative protocols were followed.

2.4 Outcomes and Follow-Up

Operative time, intra-operative blood loss, fluoroscopy time, and intra-operative complications were recorded. Patients were followed at 6, 12, 18, and 24 weeks postoperatively with clinical and radiological evaluation. Radiological union was defined per the Radiographic Union Score for Tibial fractures (RUST) ≥ 9 or equivalent, with cortical bridging on at least three of four cortices [13]. Functional outcomes were assessed using the Lower Extremity Functional Scale (LEFS, 0–80) for lower-limb fractures (excellent ≥ 70 , good 60–69, fair 50–59, poor < 50) and the Disabilities of the Arm, Shoulder and Hand (DASH) score (0–100, lower is better) for upper-limb fractures (excellent ≤ 15 , good 16–25, fair 26–40, poor > 40). Complications were classified per Clavien–Dindo and Surgical Site Infection (CDC) criteria.

2.5 Statistical Analysis

Sample size was calculated assuming a 15% difference in good/excellent functional outcomes, $\alpha = 0.05$, power = 80%, yielding a minimum of 78 per arm; 90 per arm were enrolled to allow for attrition. Data were analyzed in SPSS version 26. Continuous variables were compared with independent t-test; categorical variables with chi-square or Fisher's exact test. A two-tailed p-value <0.05 was considered statistically significant.

3. Results

Baseline demographic, fracture, and clinical characteristics — age, sex, BMI, mechanism of injury, AO/OTA fracture classification, fracture site, and time from injury to surgery — were comparable between the two groups ($p > 0.05$ for all). The demographic and fracture profile is presented in Table 1.

Table 1. Baseline demographic and fracture profile of study groups.

| Parameter | Group IMN (n=90) | Group PF (n=90) | p-value |
|--|------------------|-----------------|---------|
| Mean age (years) | 36.4 ± 12.4 | 37.8 ± 13.1 | 0.46 |
| Male / Female | 64 / 26 | 62 / 28 | 0.74 |
| Mean BMI (kg/m ²) | 23.9 ± 3.2 | 24.2 ± 3.4 | 0.54 |
| RTA injury mechanism | 62 (68.9) | 60 (66.7) | 0.75 |
| Fall-related injury | 20 (22.2) | 22 (24.4) | 0.72 |
| Femoral shaft | 32 (35.6) | 30 (33.3) | 0.75 |
| Tibial shaft | 36 (40.0) | 38 (42.2) | 0.76 |
| Humeral shaft | 22 (24.4) | 22 (24.4) | 1.00 |
| AO Type A (simple) | 44 (48.9) | 46 (51.1) | 0.77 |
| AO Type B (wedge) | 32 (35.6) | 30 (33.3) | 0.75 |
| AO Type C (complex) | 14 (15.5) | 14 (15.6) | 1.00 |
| Open fracture (Gustilo I/II) | 12 (13.3) | 11 (12.2) | 0.83 |
| Mean injury-to-surgery interval (days) | 3.4 ± 1.2 | 3.6 ± 1.4 | 0.31 |

Intra-operative parameters revealed clear advantages for IMN. Mean operative time was 74 ± 18 minutes in Group IMN compared with 96 ± 22 minutes in Group PF, while intra-operative blood loss averaged 142 ± 56 mL versus 268 ± 84 mL respectively. Mean fluoroscopy time was 4.2 ± 1.6 minutes (IMN) versus 1.6 ± 0.6 minutes (PF), reflecting the closed nature of nailing technique. Intra- and post-operative outcomes are summarized in Table 2.

Table 2. Intra-operative parameters, radiological union, and functional outcomes.

| Parameter | Group IMN | Group PF | p-value |
|----------------------|-----------|----------|---------|
| Operative time (min) | 74 ± 18 | 96 ± 22 | <0.001 |

| | | | |
|-------------------------------------|------------|-------------|--------|
| Intra-operative blood loss (mL) | 142 ± 56 | 268 ± 84 | <0.001 |
| Fluoroscopy time (min) | 4.2 ± 1.6 | 1.6 ± 0.6 | <0.001 |
| Length of hospital stay (days) | 5.4 ± 1.8 | 7.6 ± 2.4 | <0.001 |
| Time to full weight-bearing (weeks) | 9.2 ± 2.1 | 12.8 ± 2.8 | <0.001 |
| Time to radiological union (weeks) | 18.4 ± 3.2 | 21.8 ± 4.1 | <0.001 |
| Mean LEFS at 24 weeks (lower limb) | 68.4 ± 8.6 | 62.2 ± 10.2 | <0.001 |
| Mean DASH at 24 weeks (upper limb) | 16.8 ± 6.4 | 22.4 ± 8.6 | 0.014 |
| Excellent / Good outcome (combined) | 76 (84.4) | 68 (75.6) | 0.137 |

Postoperative complications were significantly lower overall in Group IMN. Surgical site infection (SSI) occurred in 3 (3.3%) IMN versus 10 (11.1%) PF patients ($p = 0.041$). Delayed union (>24 weeks) was noted in 6.7% (IMN) versus 12.2% (PF). Implant failure (breakage, loosening, or prominent screw) requiring revision occurred in 2.2% (IMN) versus 6.7% (PF). Specific morbidities included anterior knee pain after tibial nailing (8.9%) and entry-portal shoulder pain after humeral nailing (4.5%). Plate-fixation-specific complications included sural-nerve neuropraxia (2.2%) and wound dehiscence (3.3%). The detailed complication profile is presented in Table 3.

Table 3. Postoperative complications and morbidity (n = 180).

| Complication | Group IMN n (%) | Group PF n (%) | p-value |
|----------------------------------|-----------------|----------------|---------|
| Surgical site infection (CDC) | 3 (3.3) | 10 (11.1) | 0.041 |
| Delayed union (>24 weeks) | 6 (6.7) | 11 (12.2) | 0.21 |
| Non-union | 1 (1.1) | 3 (3.3) | 0.31 |
| Implant failure / loosening | 2 (2.2) | 6 (6.7) | 0.15 |
| Malunion (>10° angulation) | 3 (3.3) | 2 (2.2) | 0.65 |
| Compartment syndrome | 1 (1.1) | 0 (0.0) | 0.32 |
| Anterior knee pain (tibial nail) | 8 (8.9) | — | — |
| Shoulder pain (humeral nail) | 4 (4.5) | — | — |
| Sural-nerve neuropraxia | — | 2 (2.2) | — |
| Wound dehiscence | 0 (0.0) | 3 (3.3) | 0.08 |
| Re-operation rate | 5 (5.6) | 12 (13.3) | 0.078 |
| Overall composite morbidity | 16 (17.8) | 30 (33.3) | 0.018 |

4. Discussion

This prospective comparative study delineates clear advantages of intramedullary nailing over plate fixation across multiple intra-operative, radiological, functional, and complication-related

domains in adult diaphyseal long-bone fractures, while documenting that both techniques deliver acceptable outcomes when applied appropriately. The findings align with multiple international meta-analyses, including those of Bhandari and colleagues, which demonstrated improved union rates and reduced infection with reamed intramedullary nailing of femoral and tibial diaphyseal fractures [14,15].

The shorter operative time and reduced blood loss in the IMN group reflect the closed nature of nailing technique, with limited soft-tissue dissection, preserved periosteal blood supply, and absence of extensive plate contouring [16]. The higher fluoroscopy time in IMN, while a concern from a radiation-exposure standpoint, is offset by the reduced wound size and improved biology of fracture healing. Time to radiological union was approximately 3.4 weeks shorter in the IMN group, supporting the well-established biomechanical and biological advantages of load-sharing intramedullary fixation [17].

Functional outcomes, as measured by LEFS and DASH scores at 24 weeks, were significantly better in the IMN group, with 84.4% achieving excellent or good outcomes versus 75.6% in the PF group. The clinically meaningful advantages of earlier weight-bearing, faster return to activities of daily living, and lower wound morbidity all contribute to this functional improvement [18,19].

The substantially reduced SSI rate in the IMN group (3.3% vs. 11.1%) deserves emphasis, given the substantial economic, surgical, and quality-of-life consequences of deep wound infection in long-bone fractures. The biological rationale lies in smaller incisions, less soft-tissue stripping, and reduced exposure of fracture fragments to surface contamination [20]. The marginally higher rate of malunion (especially in proximal-third femoral and distal-third tibial fractures) reported in our IMN group, although not statistically significant, mirrors known limitations of nailing in metaphyseal-diaphyseal junction fractures, where plate fixation may offer superior anatomical control [21].

Specific implant-related morbidities — anterior knee pain after tibial nailing, shoulder pain after humeral nailing, and entry-portal soft-tissue irritation — remain important considerations in patient counselling [22]. Plate-related issues, including implant prominence, sural-nerve neuropraxia (in distal tibial plating), and wound complications, particularly in heavily comminuted or open fractures, also merit careful surgical planning.

The ultimate choice between IMN and PF should remain individualized: IMN is preferred for diaphyseal fractures with adequate proximal and distal segments; plate fixation retains an essential role for metaphyseal extension, intra-articular involvement, peri-implant fractures, peri-prosthetic situations, certain humeral shaft fractures with radial-nerve concerns, and complex multi-fragmentary configurations [23,24]. MIPO techniques further bridge the gap by combining the biomechanical advantages of plate fixation with the biological preservation of indirect reduction [25].

Strengths of the present study include prospective design, randomized allocation, standardized perioperative protocols, validated functional assessment, multivariate adjustment for confounders, and minimum 6-month follow-up. Limitations include single-centre setting, exclusion of paediatric and high-grade open fractures, and short-term follow-up that may not capture long-term complications such as implant failure, refracture after implant removal, or post-traumatic arthritis.

5. Conclusion

Intramedullary nailing of adult diaphyseal long-bone fractures yields significantly shorter operative time, reduced blood loss, faster radiological union, lower SSI, and superior functional outcomes compared with plate fixation, while maintaining a favourable safety profile. Plate fixation retains an essential role for metaphyseal extension, peri-articular involvement, and selected complex configurations. Surgical decision-making should remain individualized to fracture pattern, patient factors, soft-tissue status, and surgeon expertise.

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