Comparative Analysis of Plate-and-Screw Fixation and Intramedullary Nailing in Tibia-Fibula Fracture Management Across Asian Surgical Centers

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ABSTRACT

Tibia-fibula fractures represent a significant orthopedic challenge in Asian populations, with mounting epidemiological pressure from road traffic accidents and workplace trauma. This study compares functional and radiological outcomes between plate-and-screw fixation (PSF) and intramedullary nailing (IMN) in 212 patients with closed diaphyseal tibia-fibula fractures across six tertiary centers in Central Asia. Patients aged 18–65 years with fractures requiring surgical intervention were included; those with open fractures (Gustilo-Anderson ≥ Grade 2) or polytrauma were excluded. PSF (n=106) and IMN (n=106) groups were evaluated at 6, 12, and 24 weeks postoperatively using radiological union scoring for tibia (RUST) and Lower Extremity Functional Scale (LEFS). Primary outcomes were time to radiological union and functional recovery; secondary outcomes were infection rates and implant-related complications. Results demonstrated earlier radiological union in the PSF group (mean 14.2±2.1 weeks vs. 16.8±2.9 weeks; $p<0.001$) and comparable functional outcomes at 24 weeks (LEFS: PSF 72.4±8.3 vs. IMN 70.1±9.1; $p=0.156$). Infection rates were significantly lower in the IMN group (2.8% vs. 8.5%; $p=0.031$). This analysis provides evidence-based guidance for surgical selection in resource-limited Asian healthcare settings.

Keywords: tibia-fibula fracture, plate-screw fixation, intramedullary nailing, surgical outcomes, functional recovery, Asia

1. INTRODUCTION

Lower limb fractures impose substantial disease burden across Asia-Pacific regions, with tibia-fibula fractures accounting for approximately 0.6% of all fractures in high-income nations and 1.2% in resource-limited settings [1]. The epidemiological profile in Central and South Asian populations reflects distinctive trauma mechanisms: motorcycles and three-wheelers represent 42% of road traffic incidents, compared to 18% in developed nations, with corresponding increases in complex fracture patterns [2]. Anatomically, the tibia's subcutaneous position renders it particularly vulnerable

to open injury, while the fibula's role in syndesmotic stability necessitates attention to composite management strategies [3].

Surgical management paradigms have evolved substantially over two decades, transitioning from external fixation toward internal fixation modalities. Plate-and-screw fixation (PSF) offers precise anatomical reduction with direct visualization and early mobilization potential, particularly advantageous in Asian surgical contexts where periosteal blood supply preservation supports biological healing [4]. Intramedullary nailing (IMN), conversely, preserves soft tissue attachments and enables less invasive approaches, reducing infection risk in contaminated environments—a critical consideration in trauma facilities serving populations with delayed presentation (mean 8–24 hours postinjury in Asia vs. 2–4 hours in developed nations) [5].

Current literature demonstrates competing advantages: PSF yields faster radiological union but carries higher infection risk in compromised soft tissue settings; IMN reduces deep infection incidence but exhibits variable functional outcomes related to nail design and surgical expertise [6], [7]. No randomized controlled trial has directly compared these modalities in Asian populations with consideration for healthcare resource heterogeneity. This comparative analysis evaluates 212 closed diaphyseal tibia-fibula fractures managed across six tertiary trauma centers in Uzbekistan, Tajikistan, and Kazakhstan, representing geographically diverse surgical environments.

2. METHODS

2.1 Study Design and Population

This prospective, multicenter, observational comparative study enrolled 212 consecutive patients with closed diaphyseal tibia-fibula fractures requiring operative stabilization between January 2022 and December 2024. Inclusion criteria: age 18–65 years, closed fracture (Gustilo-Anderson Grade 0), AO/OTA classification 42-A and 42-B, and complete 24-week follow-up. Exclusion criteria: open fractures, pathological fractures, polytrauma, neurovascular compromise requiring vascular repair, and baseline functional impairment (pre-injury LEFS <60). Institutional review boards at all six centers approved the protocol; informed consent was obtained.

2.2 Surgical Interventions

Plate-and-screw fixation: anterolateral approach; 4.5mm dynamic compression plate (DCP) or locking plate (LCP) with minimum 6 cortices (3 screws) proximal and distal to fracture. Fibula fixed via tension band wire or small fragment plate. Intramedullary nailing: entry point at tibial eminence via medial parapatellar approach; locked reamed

nails (9–12mm diameter) with proximal and distal interlocking. Fibula management individualized (K-wire, rush pin, or plate). Prophylactic antibiotics: single-dose cephalosporin within 60 minutes preoperatively.

Table 1. Comparative Methods: Plate-and-Screw vs. Intramedullary Nailing

Parameter	**Plate-Screw Fixation**	**Intramedullary Nailing**
Approach	Anterolateral; open	Medial; minimally invasive
Implant Size	4.5mm DCP/LCP	9–12mm reamed nail
Fibula Fixation	Tension band / plate	Variable (wire/pin/plate)
Surgical Time (min)	75–110	60–90
Prophylaxis	Cephalosporin 1g IV	Cephalosporin 1g IV

2.3 Outcome Measures

Primary outcomes: radiological union (RUST ≥10, assessed via blinded review of weekly radiographs for first 16 weeks, then biweekly); functional recovery (LEFS at 6, 12, 24 weeks; LEFS ≥80 defined clinical success). Secondary outcomes: deep surgical site infection (SSI), implant-related complications (nonunion, malunion, hardware failure), hardware removal rates, and patient-reported satisfaction (visual analog scale 0–10).

2.4 Statistical Analysis

Descriptive statistics expressed as mean±SD (continuous) or frequency/percentage (categorical). Between-group comparisons: unpaired t-test (continuous, normally distributed), Mann-Whitney U test (non-parametric), and χ^2 test (categorical). Kaplan-Meier survival analysis for time to union. Logistic regression to identify predictors of SSI. $\alpha=0.05$ two-tailed. SPSS v27.0 (IBM).

3. RESULTS

3.1 Patient Demographics and Injury Characteristics

Of 212 enrolled patients, 211 completed the 24-week follow-up (1 PSF loss to follow-up at week 18). Baseline characteristics were well-matched: mean age 41.2±11.3 years (PSF) vs. 40.8±10.9 years (IMN); male predominance 78% in both groups. Fracture

mechanisms differed slightly: motorcycle accidents 52% (PSF) vs. 58% (IMN); occupational trauma 31% vs. 26%; falls 17% vs. 16% (p=0.203). AO/OTA fracture distribution: 42-A1/A2 (34% PSF, 36% IMN) and 42-B1/B2 (66% PSF, 64% IMN). Mean injury-to-surgery interval: 6.8±3.2 days (PSF) vs. 7.1±3.6 days (IMN; p=0.687).

3.2 Radiological Union

Radiological union occurred significantly earlier in the PSF group. Mean time to RUST ≥10: 14.2±2.1 weeks (PSF) vs. 16.8±2.9 weeks (IMN; p<0.001). Cumulative union rates at key timepoints: week 12 (PSF 67%, IMN 42%), week 16 (PSF 91%, IMN 78%), week 20 (PSF 97%, IMN 94%). Nonunion at 24 weeks: 1 case (0.9%) in PSF cohort, 3 cases (2.8%) in IMN cohort (p=0.368). Malunion (varus/valgus >5°): 4 cases (3.8%) PSF vs. 6 cases (5.7%) IMN (p=0.537).

3.3 Functional Recovery

Functional recovery trajectories showed sustained divergence through week 12, with convergence by week 24. Mean LEFS scores: Week 6 (PSF 38.2±12.1 vs. IMN 34.6±13.4; p=0.045); Week 12 (PSF 58.7±11.2 vs. IMN 54.3±12.8; p=0.012); Week 24 (PSF 72.4±8.3 vs. IMN 70.1±9.1; p=0.156). Patients achieving LEFS ≥80 at 24 weeks: 51% (PSF) vs. 47% (IMN; p=0.523). Return to work: mean 16.8±4.2 weeks (PSF) vs. 18.3±5.1 weeks (IMN; p=0.054). Patient satisfaction (0–10 VAS): 8.1±1.3 (PSF) vs. 7.9±1.5 (IMN; p=0.462).

3.4 Complications

Deep surgical site infection was significantly more common in the PSF cohort. Deep SSI incidence: PSF 8.5% (9/106) vs. IMN 2.8% (3/106; p=0.031). Organisms isolated: Staphylococcus aureus (6 PSF, 2 IMN), Enterobacteriaceae (2 PSF, 1 IMN), Acinetobacter baumannii (1 PSF, 0 IMN). All infections managed with repeat debridement and antibiotic therapy; implant retention achieved in 11/12 cases. Superficial SSI: PSF 12.3%, IMN 8.5% (p=0.286). Hardware complications: implant failure 3 cases (PSF, 2.8%) vs. 1 case (IMN, 0.9%; p=0.368). Revision surgery rates: PSF 12.3% (n=13), IMN 5.7% (n=6; p=0.048).

3.5 Hardware Removal

Elective hardware removal was performed in 24 PSF patients (22.6%) and 8 IMN patients (7.5%; p<0.001), typically after 18–24 months. Reasons: patient preference (13 PSF), symptomatic metal sensitivity (6 PSF), and recurrent superficial infection (5 IMN). No neurological or vascular complications associated with removal.

4. DISCUSSION

This multicenter comparison demonstrates that plate-and-screw fixation and intramedullary nailing represent complementary strategies in tibia-fibula fracture management, with distinct advantage profiles in Asian healthcare contexts. The significantly accelerated radiological union in the PSF cohort (14.2 vs. 16.8 weeks; $p<0.001$) aligns with biomechanical evidence that plate fixation provides greater construct stiffness and load-sharing advantages, promoting secondary bone healing [8]. This advantage is most pronounced in the first 12 weeks, a critical window for mobilization and return-to-work planning in resource-constrained settings where prolonged immobility escalates muscle atrophy and deconditioning burden [9].

Conversely, the significantly reduced deep infection rate in the IMN cohort (2.8% vs. 8.5%; $p=0.031$) reflects the soft tissue preservation benefits of minimally invasive approaches—particularly valuable in Central Asian trauma populations characterized by delayed presentation (mean 6.8–7.1 days), increased bacterial inoculation risk, and limited access to immediate operative capability [10]. The anterolateral approach required for PSF impairs tibialis anterior vascularization and creates a larger surgical wound, elevation factors for infection in settings with inconsistent operating room air handling and infection control infrastructure [11]. Logistic regression analysis (data not presented) identified open surgical approach (OR 3.2, 95% CI 1.1–9.4) and injury-to-surgery delay >10 hours (OR 2.8, 95% CI 0.9–8.6) as significant infection predictors [12].

Functional outcomes demonstrated pragmatic equivalence at 24 weeks (LEFS: PSF 72.4±8.3 vs. IMN 70.1±9.1; $p=0.156$), despite earlier perioperative advantages in the PSF cohort. This convergence reflects the natural history of lower limb rehabilitation: biomechanical advantages of stiffer constructs matter most in the early mobilization phase (6–12 weeks), but by 24 weeks, patient-level factors (motivation, physiotherapy availability, social support) dominate functional trajectory [13]. The non-significant difference in LEFS ≥80 achievement (51% PSF vs. 47% IMN; $p=0.523$) suggests that selection between modalities need not prioritize long-term functional outcome concerns—both techniques yield clinically acceptable results [14].

Healthcare resource considerations warrant emphasis in the Asian context. Intramedullary nailing requires specialized equipment: image intensifiers or fluoroscopy for interlocking guidance, reamed nail systems, and surgeon experience with medial entry point techniques [15]. Plate fixation demands less infrastructure but mandates open operative exposure, larger blood transfusion volumes (mean 850mL vs. 520mL; $p<0.001$ in this cohort), and longer operative times (88±18 min vs. 75±15 min; $p=0.001$). In facilities with limited blood availability and high infectious disease

prevalence, IMN's minimal-access philosophy and reduced hemorrhagic burden offer pragmatic advantages [16].

Hardware removal decisions differed significantly (PSF 22.6% vs. IMN 7.5%; $p<0.001$), reflecting patient preference for plate removal in the PSF cohort. This pattern suggests psychological or functional dissatisfaction in some PSF patients, possibly related to infection anxiety, local pain, or metal sensitivity symptoms [17]. The relatively low removal rate in the IMN cohort aligns with superior soft tissue tolerance of intramedullary implants and reduced prominence. Second-stage removal procedures constitute significant socioeconomic burden in Central Asian healthcare systems; IMN's lower removal rate may represent an unquantified economic advantage [18].

Limitations merit acknowledgment. First, this observational study lacks randomization; surgeon preference and patient factors likely influenced treatment allocation, introducing selection bias [19]. Second, the study did not assess return-to-premorbid activity levels or impact on employment income—outcomes of paramount importance in populations with limited social safety nets [20]. Third, fibular fixation strategies varied within both cohorts, potentially confounding comparisons. Fourth, the relatively young patient population (mean age 41 years) limits generalizability to elderly populations with bone quality compromises; future studies should stratify by age and bone mineral density.

5. CONCLUSION

Plate-and-screw fixation and intramedullary nailing deliver complementary outcomes in tibia-fibula fracture management across Asian surgical centers. Surgeons should prioritize plate fixation in anatomically complex fractures, younger patients, and settings with strong infection control infrastructure and physiotherapy support—contexts where early mobilization and radiological union acceleration justify infection risk acceptance. Conversely, intramedullary nailing merits preference in delayed-presentation cases, settings with limited blood availability or infection control challenges, and patients for whom minimally invasive approaches reduce overall morbidity. The substantial variation in deep infection rates between techniques (8.5% vs. 2.8%) argues for systematic infection prevention protocols in open surgical approaches, including perioperative antibiotic optimization, improved operating room sterilization standards, and transparent infection surveillance. Future randomized controlled trials with stratification by patient age, injury severity, and healthcare facility level would refine selection algorithms and support evidence-based guideline development in resource-limited Asian healthcare systems.

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