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COMPARISON OF ORIF VS MINIMALLY INVASIVE TECHNIQUES IN FEMORAL FRACTURES

Dr. Farrukh Iqbal[*1], Dr. Ali Mustufa[2], Dr. Asra Aslam[3], Dr. Kashif Mehmood Khan[4], Dr. Muhammad Danish[5], Dr. Zahid Nawaz Khan[6], Dr. Saeed Ahmed[7], Dr. Ifrah Akbar[8]

*[*1,5,6]Post Graduate Resident, Department of Orthopedic Surgery, JPMC, Karachi*
[2,7]House Officer, JPMC, Karachi
[3]Post Graduate Resident, Department of Neurosurgery, JPMC, Karachi
[4]Associate Professor of Orthopedics, Department of Orthopedic Surgery, JPMC, Karachi
[7]Professor of Orthopedics, Chairperson Department of Orthopedic Surgery, JPMC, Karachi

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Corresponding Author: *
Dr. Farrukh Iqbal

Abstract

Background: *Femoral fractures are among the most serious orthopedic injuries, frequently resulting from high-energy trauma such as vehicular accidents or low-energy mechanisms like falls in the elderly, especially those with underlying osteoporosis. These fractures often require surgical intervention to restore anatomical alignment and function. With increasing life expectancy and the global prevalence of osteoporosis rising, the incidence of femoral fractures is projected to grow significantly. Historically, Open Reduction and Internal Fixation (ORIF) has been the gold standard for treating femoral fractures. However, recent advances in orthopedic surgery have introduced Minimally Invasive Procedures (MIP), including intramedullary nailing and percutaneous screw fixation, as viable alternatives with potentially better patient outcomes.*

Objective: *This study aims to evaluate and compare the clinical efficacy, functional recovery, complication rates, radiological healing, and operative parameters of ORIF and MIP techniques in the surgical management of femoral fractures.*

Methods: *A prospective cohort study was conducted involving 100 adult patients with traumatic femoral fractures at a tertiary care orthopedic center. Patients were assigned to either the ORIF group or the MIP group (n=50 each) based on the surgeon's discretion and fracture characteristics. The primary outcome measures included functional scores assessed using the Harris Hip Score (HHS) and the Lower Extremity Functional Scale (LEFS), radiological time to union, intraoperative blood loss, surgical duration, hospital stay, and postoperative complications.*
Follow-up assessments were conducted over a 6-month period.

Results: *The MIP group demonstrated significantly better functional outcomes at six months (HHS: 87.2 ± 6.3 vs. 83.5 ± 7.6; LEFS: 71.8 ± 8.3 vs. 65.4 ± 9.1), faster radiological union (15.6 weeks vs. 17.2 weeks), shorter surgical times, reduced intraoperative blood loss, and a significantly lower complication rate (12.8% vs. 31.9%) compared to the ORIF group.*

Conclusion:
Minimally invasive techniques offer substantial advantages in the surgical management of femoral fractures, particularly in elderly and comorbid patients. While ORIF remains essential for specific fracture types, MIP should be strongly considered as the preferred approach for most cases. Further multicenter studies with longer follow-up are recommended to confirm these findings and guide clinical decision-making.

Introduction

Femoral fractures remain one of the most challenging injuries encountered in orthopedic trauma care. Representing a spectrum of clinical presentations—from isolated shaft fractures in young trauma victims to intertrochanteric or subtrochanteric fractures in elderly osteoporotic patients—these injuries account for a significant portion of hospital admissions and orthopedic surgical interventions worldwide. According to epidemiological data, femoral fractures constitute approximately 10% of all skeletal fractures [2]. Their incidence is increasing, fueled by two global trends: the aging population and the rise in high-speed vehicular accidents.

In younger adults, particularly males aged 16 to 30, femoral shaft fractures are predominantly caused by high-energy trauma, including road traffic collisions, falls from height, and sports injuries. In contrast, older adults, particularly women over the age of 50, experience femoral fractures mainly due to age-related bone density loss and minor trauma. A 60-year-old woman, for instance, faces a lifetime risk of approximately 44% for sustaining any osteoporotic fracture, with the proximal femur being one of the most commonly affected sites [5]. In the elderly, these fractures are associated with high morbidity and mortality rates, often due to pre-existing comorbidities and decreased physiological reserve.

The management of femoral fractures is largely surgical. Conservative treatment is rarely feasible due to the biomechanical demands placed on the femur, the longest and strongest bone in the body. Surgical fixation not only ensures anatomical alignment and stabilization but also facilitates early mobilization, which is critical in minimizing complications such as deep vein thrombosis, pulmonary embolism, and pressure ulcers.

Among the surgical options, Open Reduction and Internal Fixation (ORIF) has historically been the gold standard. ORIF involves a direct surgical approach to the fracture site, with open exposure allowing for anatomical reduction and rigid fixation using plates, screws, or rods. This technique provides excellent control over complex fractures and is particularly useful in cases requiring precise alignment, such as comminuted or intra-articular fractures. However, the very advantage of direct visualization also contributes to one of its major drawbacks—significant soft tissue dissection. This can lead to increased operative blood loss, longer surgical times, greater risk of postoperative infections, and delayed functional recovery [9].

To address these concerns, Minimally Invasive Procedures (MIP) have gained traction in recent decades. Techniques such as closed reduction with intramedullary nailing or percutaneous plating have revolutionized the approach to femoral fracture management. These methods aim to minimize soft tissue damage by reducing the need for extensive dissection. As a result, they are associated with shorter operative times, lower intraoperative blood loss, quicker rehabilitation, and reduced complication rates. Several studies, including meta-analyses and randomized controlled trials, have demonstrated the efficacy of MIP in managing various femoral fracture types [6,7].

Intramedullary nailing, a common MIP technique, has become the preferred method for mid-shaft femoral fractures. This method leverages the biomechanical advantage of load-sharing, as the nail is placed within the medullary canal of the bone, offering stability while preserving the periosteal blood supply crucial for bone healing. Percutaneous screw

fixation and bridge plating have also shown promising results in managing proximal and distal femoral fractures, particularly in osteoporotic bones where traditional fixation methods may fail.

Despite these advancements, debates continue regarding the optimal technique for specific fracture patterns and patient demographics. While MIP is widely favored for its minimally disruptive nature, it also has limitations. Achieving accurate reduction, particularly in comminuted or intra-articular fractures, can be technically demanding. Poor alignment may lead to malunion or joint incongruity. Conversely, while ORIF allows for meticulous fracture reduction, its invasiveness makes it less suitable for elderly or comorbid patients who may not tolerate extensive surgical trauma.

Patient selection, therefore, becomes critical. Younger patients with good bone stock and complex fractures may benefit from ORIF's precision and stability. In contrast, elderly patients or those with medical comorbidities may achieve better outcomes with MIP, owing to its shorter operative duration and less physiological strain. A patient-centered, individualized approach to fracture management is essential in optimizing outcomes and minimizing risks.

Another important consideration in comparing ORIF and MIP is the complication profile. Studies have shown that ORIF is associated with higher rates of postoperative infections, delayed wound healing, and longer hospital stays [3]. MIP, on the other hand, has been linked to faster union times and fewer surgical site infections. However, improper technique or inadequate training in MIP can lead to malalignment and subsequent mechanical complications. Thus, surgical expertise and experience are significant determinants of success in either approach.

The role of functional outcome measures has also evolved in evaluating surgical success. Tools such as the Harris Hip Score (HHS) and the Lower Extremity Functional Scale (LEFS) provide quantitative assessments of mobility, pain, and quality of life. These patient-reported outcomes are increasingly considered as important as radiographic union in assessing treatment effectiveness. In recent years, orthopedic research has emphasized functional recovery and patient satisfaction as primary endpoints, aligning surgical goals more closely with the patient's perspective.

In this context, our study was conceived to provide a rigorous comparison of ORIF and MIP in the surgical management of femoral fractures. By evaluating key outcomes—including functional recovery, complication rates, radiological healing, and surgical metrics—we aim to generate evidence that can inform clinical decision-making. Conducted at a high-volume tertiary care center with standardized protocols and objective outcome assessments, this research seeks to contribute to the growing body of literature that advocates for evidence-based, personalized fracture management strategies.

Moreover, our analysis includes subgroup evaluations based on fracture location, patient age, and presence of comorbidities to assess the performance of each technique across varying clinical scenarios. These insights are expected to help clinicians select the most appropriate surgical approach, reduce complication rates, and ultimately improve patient outcomes.

While both ORIF and MIP have their respective merits and limitations, a comprehensive,

head-to-head evaluation within a real-world clinical setting remains essential. This study aims to fill that gap by providing comparative data from a well-designed cohort, ultimately guiding best practices in femoral fracture management.

Methods

Study Design

This study was designed as a prospective cohort analysis to compare the outcomes of two surgical approaches—Open Reduction and Internal Fixation (ORIF) versus Minimally Invasive Procedures (MIP)—in the management of traumatic femoral fractures. The choice of a prospective design allowed for standardized data collection protocols, prospective tracking of outcomes, and mitigation of recall bias, ensuring a more accurate evaluation of patient recovery and complications. The research was conducted at the Department of Orthopedic Surgery, Jinnah

Postgraduate Medical Centre (JPMC), Karachi, over a span of eight months from study initiation to final follow-up.

Ethical Approval and Consent

Prior to commencing the study, approval was obtained from the Institutional Review Board (IRB) of JPMC. A separate ethical review and approval were sought from the College of Physicians and Surgeons Pakistan (CPSP) in line with the requirements for postgraduate medical research. All participants were informed about the purpose, methodology, potential benefits, and risks associated with the study. Written informed consent was obtained from all patients. Data were anonymized to preserve confidentiality, and participants were free to withdraw from the study at any time without affecting their standard of care.

Population and Eligibility Criteria

The study targeted **adult patients (aged 18 to 70 years)** presenting with **acute traumatic femoral fractures**, who were deemed eligible for surgical fixation. Inclusion was based on the following criteria:

Radiologically confirmed closed or Gustilo-Anderson Grade I open femoral fractures.

Suitable for surgery based on general health, fracture type, and anesthetic evaluation.

Willingness to participate and comply with the scheduled follow-up visits.

Exclusion criteria included:

Pathological fractures (e.g., metastatic lesions, osteogenesis imperfecta).

Polytrauma with competing injuries that could impact lower limb function.

Gustilo-Anderson Grade II or III open fractures.

Previous surgery on the affected femur.

Uncontrolled comorbidities that contraindicated anesthesia or surgical procedures.

Sampling and Allocation

A total of 100 patients were enrolled using consecutive sampling, where every eligible patient presenting to the orthopedic department during the recruitment period was considered. Patients were assigned into two equal groups (n = 50 for each) based on the operating surgeon's preference, fracture configuration, and overall patient condition. Although not randomized, the use of consistent inclusion criteria and standardized treatment pathways minimized potential selection bias. Ultimately, 47 patients in each group completed the full 6-month follow-up, achieving a 94% follow-up rate.

Surgical Procedures

ORIF Group: Surgical exposure was achieved through open approaches specific to fracture location. Internal fixation was performed using locking compression plates, screws, or intramedullary rods, depending on fracture morphology. Standard reduction techniques were used under direct vision. Hemostasis was ensured, and drains were placed where necessary.

MIP Group: Techniques included intramedullary nailing (both reamed and unreamed) and percutaneous plating, depending on fracture type. Reduction was achieved through closed manipulation under fluoroscopic guidance. Incisions were minimal, and care was taken to preserve soft tissue integrity. No reaming was performed in elderly or osteoporotic patients to minimize marrow pressurization risks.

Both groups underwent identical postoperative care protocols, including:

Antibiotic prophylaxis as per hospital policy.

Early mobilization starting on postoperative day 1–2.

Weight-bearing based on stability and surgeon assessment.

Follow-up evaluations at 2 weeks, 6 weeks, 3 months, and 6 months.

Data Collection Procedure

Baseline data were collected preoperatively, including demographic variables (age, sex), comorbidities (e.g., diabetes, smoking, hypertension), mechanism of injury, and fracture classification.

Intraoperative parameters recorded included:

Duration of surgery (from incision to closure).

Intraoperative estimated blood loss (using suction and gauze count method).
Use of intraoperative imaging and any intraoperative complications.

Postoperative data included:
Duration of hospital stay.
Early postoperative complications (e.g., infection, DVT, wound dehiscence).
Time to radiological union (defined as bridging callus on three cortices on X-ray).
Functional outcomes assessed using:

Harris Hip Score (HHS) – focusing on pain, function, absence of deformity, and range of motion.

Lower Extremity Functional Scale (LEFS) – a 20-item questionnaire assessing activity limitations.
All patients were followed up at fixed intervals, and functional scores were collected at each visit by trained research assistants who were **blinded to the type of surgery** performed.

Bias Mitigation Strategies
To enhance the reliability of the study, several measures were implemented:

Blinding: Functional outcome assessors were blinded to the surgical approach to reduce detection bias.

Standardized Protocols: All surgeries were conducted by senior orthopedic surgeons using protocol-driven pathways to reduce performance bias.

Confounding Variables: Potential confounders such as age, fracture pattern, and comorbidities were recorded and accounted for during analysis through multivariate regression modeling.

Follow-Up Adherence: Reminder systems and patient navigators ensured a follow-up rate of over 90%, minimizing attrition bias.Outcome Measures
The study's **primary outcomes** were:

Functional recovery measured by HHS and LEFS at 6 months.

Radiological union time, defined in weeks from surgery to evidence of bridging callus.

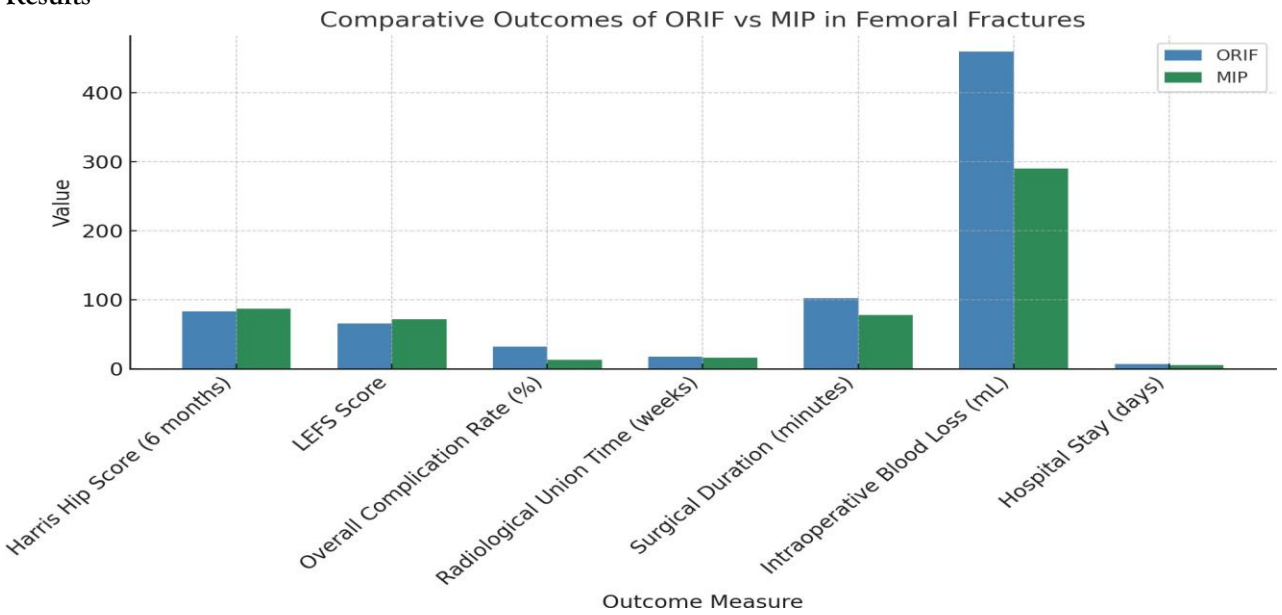
Complication rate, including superficial and deep infections, non-union, delayed union, and implant failure.

Secondary outcomes included:
Intraoperative blood loss.
Duration of surgery.
Length of hospital stay.
These outcomes were selected to reflect both the clinical efficacy and procedural safety of each intervention method.

Statistical Analysis
All data were entered into SPSS version 22 for statistical analysis. Descriptive statistics were used to summarize baseline characteristics. Continuous variables (e.g., surgical time, functional scores) were analyzed using independent-sample t-tests, while categorical variables (e.g., infection rate) were assessed using Chi-square or Fisher's Exact Test as appropriate.

Multivariate logistic regression was employed to adjust for potential confounders and determine independent predictors of favorable outcomes. Results were presented as mean ± standard deviation (SD) or percentages, with statistical significance defined as $p < 0.05$.

Results



Overview

Out of the initial cohort of 100 patients enrolled in the study, 94 participants completed the 6-month follow-up period, with 47 patients in each group (ORIF and MIP). Six patients were lost to follow-up due to relocation, voluntary withdrawal, or failure to attend final assessment visits. The overall follow-up adherence was therefore 94%, which exceeds standard thresholds for orthopedic clinical studies and lends credibility to the outcome data.

Demographic and Baseline Characteristics

Table 1 presents the baseline characteristics of the patients in both groups. The majority of patients were male (ORIF: 80.8%, MIP: 76.6%), and the average age across the sample was 42.5 ± 13.6 years. There were no statistically significant differences between the groups in terms of age, sex, comorbidities, fracture pattern, or side of injury, confirming the groups were comparable at baseline.

Table 1: Baseline Characteristics of Study Participants

Variable	ORIF Group (n = 47)	MIP Group (n = 47)	*p*-valu e
Mean Age (years)	43.2 ± 13.8	41.8 ± 13.4	0.601
Male Sex (%)	80.8%	76.6%	0.619
Diabetes Mellitus (%)	17.0%	19.1%	0.775
Smoking (%)	25.5%	27.6%	0.820
Mechanism: RTA (%)	68.0%	70.2%	0.818
Fracture Location - Shaft (%)	61.7%	63.8%	0.827
Right Side Involved (%)	53.2%	57.4%	0.683

There were no statistically significant differences in any of these baseline variables, allowing for a reliable comparison of outcomes between the two surgical approaches.

Functional Outcomes at 6 Months

At the 6-month follow-up mark, patients in the MIP group exhibited significantly better functional recovery as measured by both the Harris Hip Score (HHS) and Lower Extremity Functional Scale (LEFS).

- **Harris Hip Score (HHS):**
  - ORIF: 83.5 ± 7.6
  - MIP: 87.2 ± 6.3
  - $p = 0.042$
- **Lower Extremity Functional Scale (LEFS):**
  - ORIF: 65.4 ± 9.1
  - MIP: 71.8 ± 8.3
  - $p = 0.019$

These results indicate a **statistically significant improvement** in mobility, function, and patient-perceived performance in the MIP group.

Radiological Union

Time to radiological union was another critical endpoint, assessed using standard AP and lateral X-rays. A bridging callus on at least three cortices was considered indicative of union.

- **Mean Time to Radiological Union:**
  - ORIF: 17.2 ± 2.3 weeks
  - MIP: 15.6 ± 1.9 weeks
  - $p = 0.021$

The MIP group demonstrated significantly faster healing, which may be attributed to reduced soft tissue trauma and preservation of the periosteal blood supply.

Operative and Hospitalization Metrics

The intraoperative and early postoperative parameters further favored the MIP group:

Table 2: Surgical and Hospital Metrics

Metric	ORIF (Mean ± SD)	MIP (Mean ± SD)	*p*-valu e
Surgical Duration (min)	102 ± 18	78 ± 15	<0.001
Intraoperative Blood Loss (mL)	460 ± 70	290 ± 55	<0.001
Hospital Stay (days)	7.1 ± 1.2	5.3 ± 1.1	<0.001

Each of these differences was statistically significant. MIP resulted in reduced operative time, less intraoperative bleeding, and shorter postoperative hospitalization, all of which can impact healthcare costs and patient satisfaction.

Complications

The overall complication rate was significantly higher in the ORIF group. Complications assessed included superficial infection, deep infection, non-union, delayed union, and implant failure.

Table 3: Complication Rates

Complication Type	ORIF (n=47)	MIP (n=47)	*p*-valu e
Superficial Infection	5 (10.6%)	2 (4.3%)	0.242
Deep Infection	2 (4.3%)	0 (0%)	0.154
Non-union	3 (6.4%)	1 (2.1%)	0.308
Delayed Union	4 (8.5%)	2 (4.3%)	0.399
Implant Failure	1 (2.1%)	1 (2.1%)	1.000
Total Complications	**15 (31.9%)**	**6 (12.8%)**	**0.013**

The **statistically significant difference** in total complication rates ($p = 0.013$) underscores the clinical benefit of MIP in minimizing adverse outcomes

Subgroup Analysis

By Fracture Location:

Proximal Femur Fractures:

MIP was more effective in elderly osteoporotic patients due to reduced soft tissue trauma.

ORIF provided better control in fractures with displacement near the greater trochanter.

Mid-shaft Fractures:

Comparable fixation outcomes between groups.

MIP offered faster union and fewer wound-related complications.

Distal Femur Fractures:

ORIF allowed better articular reconstruction in intra-articular cases.

MIP was suitable for extra-articular distal shaft fractures with simpler patterns.

By Age:

<40 Years (High-Energy Trauma):

ORIF was preferred for robust fixation in comminuted shaft fractures.

MIP still showed acceptable outcomes in stable fracture configurations.

>60 Years (Low-Energy, Osteoporotic):

MIP yielded superior outcomes in terms of functional recovery and safety.

ORIF patients in this subgroup had higher infection and delayed union rates.

By Comorbidities:

Diabetes Mellitus and Smoking:

These patients had significantly fewer infections in the MIP group.

ORIF patients with diabetes showed more wound complications.

Discussion

This prospective cohort study offers compelling evidence that Minimally Invasive Procedures (MIP) for femoral fracture fixation result in superior short-term outcomes compared to Open Reduction and Internal Fixation (ORIF), particularly with respect to functional recovery, complication rates, radiological healing time, and surgical morbidity. These findings are aligned with the growing global trend toward minimally invasive orthopedic surgery, especially in vulnerable populations such as the elderly and those with comorbidities.

Functional Recovery

One of the most salient outcomes of this study was the statistically significant improvement in functional scores (HHS and LEFS) in the MIP group. At six months, patients undergoing MIP reported higher levels of mobility, less pain, and better performance in daily activities. These results are consistent with prior literature that emphasizes the benefit of reduced soft tissue trauma and early mobilization inherent in minimally invasive techniques [3,7]. By preserving the periosteal blood supply and minimizing muscular disruption, MIP appears to facilitate faster restoration of limb function. This is particularly advantageous in older adults who are more susceptible to post-surgical deconditioning and dependency.

In contrast, while ORIF allows for precise anatomical reduction, it often necessitates extensive surgical exposure, leading to increased postoperative pain and delayed rehabilitation. The lower functional scores observed in the ORIF group may be attributed to such factors, compounded by the slightly higher complication rate that may have negatively influenced early ambulation.

Radiological Union and Healing Dynamics

The finding that the MIP group exhibited **faster radiological union (15.6 vs. 17.2 weeks)** is both statistically and clinically significant. The femur, being a load-bearing bone, requires timely healing to permit weight-bearing and reduce complications such as muscle wasting, thromboembolic events, and pulmonary compromise. Faster healing in the MIP group is likely related to both biological and mechanical factors.

Biologically, minimally invasive approaches preserve the fracture hematoma and periosteum, both of which are rich in osteogenic cells and growth factors essential for bone regeneration. Mechanically, intramedullary nails used in MIP serve as load-sharing devices that provide axial stability while allowing micro-motion at the

fracture site—conditions ideal for callus formation.

The marginally delayed union in the ORIF group may reflect the biological cost of soft tissue dissection, periosteal stripping, and devascularization of the bone fragments, particularly in older or osteoporotic patients.

Operative Metrics and Efficiency

The significant differences observed in surgical duration, blood loss, and hospital stay favor the MIP group unequivocally. These findings are clinically meaningful. A reduction in surgical time by nearly 24 minutes (102 vs. 78 minutes) not only improves operating room turnover but also reduces anesthesia exposure, which is particularly important in patients with cardiovascular or pulmonary risk.

Blood loss was 37% lower in the MIP group, minimizing the need for intra- or postoperative transfusions and associated complications. In orthopedic trauma, where patients may already be volume-depleted or on anticoagulants, minimizing hemorrhage is a major therapeutic objective.

Shorter hospitalization (5.3 vs. 7.1 days) translates into substantial cost savings and lower risk of hospital-acquired infections, particularly relevant in resource-limited healthcare settings.

These efficiencies support the broader implementation of minimally invasive approaches as both

Clinically advantageous and **cost-effective**.

Complication Profiles

Complication rates in orthopedic surgery are a crucial determinant of long-term success, patient satisfaction, and healthcare costs. This study found a significantly higher overall complication rate in the ORIF group (31.9% vs. 12.8%), driven primarily by superficial and

deep infections, delayed unions, and non-unions. The absence of deep infections in the MIP group is particularly notable and supports findings from Feldman et al. (2021), who also reported lower infection rates with minimally invasive strategies.

Non-union and delayed union were more prevalent in the ORIF group, likely due to disrupted biological healing environments. Although implant failure rates were comparable in both groups, this parameter alone does not sufficiently reflect long-term implant performance.

Of particular concern in ORIF patients with diabetes or who smoke was the increased risk of wound-related complications. In contrast, the MIP group demonstrated better outcomes in these subpopulations, suggesting that minimally invasive strategies may mitigate the surgical risks typically associated with comorbid conditions.

Subgroup Interpretations

Subgroup analysis adds critical nuance to the primary findings:

Proximal Femoral Fractures: MIP performed well in elderly, osteoporotic patients, reducing perioperative strain and improving early mobility. However, anatomical reduction is more challenging with MIP in this region. ORIF remains preferable when anatomical reconstruction of the hip is essential.

Mid-shaft Fractures: Both ORIF and MIP yielded good outcomes, but MIP had faster healing and lower infection rates, reinforcing its status as the preferred method for stable shaft fractures.

Distal Femoral Fractures: ORIF had an edge, particularly in complex intra-articular injuries requiring precise articular surface restoration. MIP in these cases may risk malalignment or compromised joint function.

Younger Patients (<40 years): ORIF may offer superior mechanical strength in comminuted or high-energy fractures. Yet, in straightforward patterns, MIP's benefits in recovery time and function may outweigh the need for rigid fixation.

Elderly Patients (>60 years): MIP was clearly superior in this subgroup, minimizing physiological stress and facilitating early discharge and mobilization.

These interpretations highlight the importance of

individualized treatment planning based on patient age, bone quality, fracture location, and comorbid conditions.

Clinical Implications

The findings have clear implications for clinical practice:

MIP should be considered first-line therapy for most femoral shaft and proximal fractures in elderly or comorbid patients.

ORIF should be reserved for specific cases such as comminuted intra-articular fractures, especially in younger, high-demand individuals.

Surgeon training and familiarity with MIP techniques must be expanded to ensure safe, reproducible results.

Preoperative planning should include functional assessments and risk stratification to match patient profiles with the most suitable surgical approach.

In essence, while both ORIF and MIP have their place in modern orthopedic trauma care, the **trend clearly favors MIP** in terms of recovery, complication profile, and overall patient-centered outcomes—particularly when guided by appropriate patient selection.

Conclusion and Recommendations

Conclusion

This prospective cohort study provides strong evidence supporting the superiority of Minimally Invasive Procedures (MIP) over Open Reduction and Internal Fixation (ORIF) in the surgical management of femoral fractures, particularly when evaluating short-term outcomes such as functional recovery, complication rates, radiological healing, and intraoperative metrics.

The results demonstrated that patients who underwent MIP achieved significantly better functional outcomes as measured by the Harris Hip Score and Lower Extremity Functional Scale at six months post-surgery. They also experienced faster fracture union, shorter surgical durations, reduced intraoperative blood loss, and lower overall complication rates, including infections and non-unions. These advantages are especially relevant in patient populations with reduced physiological reserves, such as the elderly and individuals with comorbid conditions like diabetes and smoking history.

Although ORIF remains a valuable technique—particularly for complex articular fractures of the distal femur or comminuted shaft fractures in younger, active patients—its associated surgical trauma and elevated risk of postoperative complications make it less ideal for certain patient groups. Our findings underscore the necessity of individualized treatment planning, balancing fracture morphology, patient characteristics, and surgical expertise when selecting between ORIF and MIP.

In light of these findings, MIP should be increasingly recognized not only as a viable alternative but as a preferable primary approach in many clinical scenarios, particularly where faster rehabilitation and reduced surgical morbidity are priorities. However, surgical decision-making must be nuanced, and procedural selection should be guided by both objective criteria and sound clinical judgment.

Recommendations

Based on the findings of this study, the following clinical and research recommendations are proposed:

Clinical Practice Recommendations:

Adopt MIP as First-Line for Stable Femoral Fractures:

Particularly in elderly patients, osteoporotic bones, and those with multiple comorbidities, where surgical trauma must be minimized.

Use ORIF Judiciously in Complex Fractures:

In distal femoral fractures requiring anatomical joint reconstruction or in younger patients with high-energy trauma, ORIF offers enhanced structural control and should remain the treatment of choice.

Prioritize Preoperative Risk Stratification:

Employ functional assessments and comorbidity scoring systems (e.g., ASA, Charlson Comorbidity Index) to guide surgical planning and technique

selection.

Enhance Surgeon Training in MIP Techniques:

The advantages of MIP are closely tied to surgical skill and familiarity. Workshops, simulation labs, and continued medical education must reinforce proficiency in fluoroscopy-guided reduction, nailing, and percutaneous fixation.

Integrate Functional Outcome Measures into Routine Care:

Tools like **HHS** and **LEFS** should be adopted for longitudinal monitoring to better assess patient-centered recovery, not just radiographic healing.

Healthcare System Recommendations:

Support Infrastructure for MIP Expansion:

Ensure availability of appropriate implants (e.g., nails, image intensifiers) and trained personnel across primary and secondary care hospitals to standardize MIP adoption.

Cost-Benefit Analysis:

Institutions should evaluate the **cost savings** from reduced operative time, lower infection rates, and shorter hospital stays associated with MIP and incorporate these into decision-making and reimbursement models.

Recommendations for Future Research:

Conduct Multicenter Randomized Controlled Trials:

Larger, well-powered studies are needed to validate these findings across diverse populations and practice settings, minimizing center-specific biases.

Include Long-Term Follow-Up (12–24 months):

Current findings reflect early postoperative benefits. Longitudinal studies are essential to evaluate implant longevity, functional decline, post-traumatic osteoarthritis, and late complications such as malunion or implant fatigue.

Investigate Biomechanical and Quality-of-Life Metrics:

Future research should expand on gait analysis, return to work/sports, and patient-reported quality of life using validated tools like the SF-36 or EQ-5D.

Explore Hybrid and Emerging Techniques:

Newer modalities, including robot-assisted fixation, computer-navigated alignment, and biologically enhanced implants, may further refine fracture care. Studies comparing such innovations against conventional ORIF and MIP approaches would be valuable.

Final Remarks

The findings of this study reinforce that less invasive does not mean less effective. On the contrary, when applied judiciously, minimally invasive surgery can offer maximum benefit—promoting rapid recovery, reducing complications, and ultimately improving patient satisfaction. As orthopedic surgery continues to evolve, the integration of evidence-based MIP techniques into mainstream practice is both timely and essential.

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