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The Incidence of Malrotation after Closed Reduction and Antegrade Intramedullary Nailing of Femoral Shaft Fractures

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ABSTRACT

Background: Femoral shaft fractures are very common injuries, often secondary to high-energy trauma, occurring at age-specific peaks in young children, young adult men, and older women, and commonly with other injuries. Intramedullary nailing is the preferred treatment due to its minimally invasive method and predictable healing, though malrotation is a common complication.

Aim: The aim of this prospective study was to evaluate incidence of malrotation of the femur after closed reduction and internal fixation of femoral shaft fracture by antegrade intramedullary nail.

Patients and Methods: This was a prospective study that included 50 adult patients with isolated, closed femoral shaft fractures treated by antegrade intramedullary nailing at Menoufia University between April 2024 and February 2025.

Results: This study found that 74% were males and 60% sustained their injuries in motor vehicle accidents. The comorbidities included diabetes (18%), hypertension (12%), and smoking (8%). Early operation (<6 hours) was experienced by half of them, and fracture patterns were more likely to be left-sided (58%), short spiral (46%), and transverse (44%). Most patients (86%) had neutral rotation. Group B (malrotation) had a significantly higher mean age and different fracture types but showed no significant differences in gender, side, BMI, or injury mechanism. Malrotation occurred more frequently in the lateral position but did not have a significant effect on functional outcomes.

Conclusion: Closed reduction and antegrade intramedullary nailing is an effective treatment for femoral shaft fractures, with a low incidence of clinically significant malrotation. Most patients (86%) maintained neutral rotation, and mild malrotation did not significantly affect functional outcomes. External rotation is more prevalent than internal, and using the supine position may help reduce malrotation risk.

Keywords: Femoral Fractures, Intramedullary nailing, Malrotation, Functional outcome.

INTRODUCTION

Femoral shaft fractures occur 10–21 times per 100,000 annually, making them one of the most frequent injuries orthopedic surgeons treat. High-energy trauma usually causes these fractures, which are frequently linked to severe bone comminution [(1)]. Femoral shaft fractures are more common in children aged one to four, men patients aged 15 to 30, and female patients aged 75 and beyond. These age-related peaks occur in these populations. In 30% of instances, femoral shaft fractures coexist with other injuries [(2)].

There are many different categories of fracture type in the literature, depending on factors including fracture location and geometry, comminution, the severity of soft tissue injuries, and the lack of related injuries. None of these categories are widely used in reality, though. Therapy and prognosis are unaffected by the AO classification, which classifies diaphyseal femoral fracture patterns according to the fracture's location (proximal, mid-shaft, or distal), anatomy (oblique or transverse), and degree of comminution. Nonetheless, there are therapeutic implications to the **Winquist *et al.*** categorization, which is based on the degree of comminution [(3)].

The most effective treatment for an adult femoral shaft fracture is intramedullary nailing. Antegrade or retrograde entry locations are frequently used for intramedullary nailing, and both are appropriate and safe [(4)]. Plate osteosynthesis is also used, depending on the soft tissue injuries, age of the patient, and kind of fracture. Small incisions, dependable fracture healing, preservation of the periosteum and fracture hematoma, and quick patient mobilization are all benefits of intramedullary nailing. Malrotation is the most common complication in the treatment of femoral shaft fractures treated with closed intramedullary nailing, despite the excellent union rate [(5)]. A discrepancy in femoral anteversion between the damaged and unaffected lower limb indicates rotational malalignment or torsional deformity of the femur [(6)]. The angle created by the femoral condyles plane (bicondylar plane) and a plane that runs through the middle of the neck and femoral head is known as the anteversion angle (declination) of the femur neck [(7)]. It is difficult to diagnose torsion using clinical and radiological anatomic markers during surgery, and only postoperative computed tomography can provide an accurate assessment [(8)]. The average intraindividual variation in femoral rotation was between 2° and 5°. The intraindividual rotational difference of both lower limbs was less than 11° in 95% of the adults and less than 15° in 99% of them [(9)].

When malrotation exceeds 15 degrees, it might cause functional problems including anterior knee pain during intense activities like sports, running,

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and climbing stairs. It is easier to withstand external rotation than internal rotation [10].

Assessing the incidence of femur malrotation following closed reduction and internal fixation of femoral shaft fracture by antegrade intramedullary nail was the aim of this prospective investigation.

PATIENTS AND METHODS

This prospective study consisted of 50 patients with femoral shaft fractures and was conducted at the Department of Orthopedic Surgery, Menoufia University Hospitals. Participants in the study were chosen in a systematic way following definite inclusion and exclusion criteria from April 2024 to February 2025. Femoral malrotation after closed reduction and internal fixation of femoral shaft fracture by antegrade intramedullary nailing was to be determined.

Ethical approval: Ethical clearance was obtained from Menoufia University local Ethics Committee (IRB 3/2024 ORTH21), and informed written consent was obtained from all the patients after explaining the purpose, procedures, and risks of the study. The study adhered to the Helsinki Declaration throughout its execution.

Inclusion criteria: Included adult patients aged 18 to 65 years presenting with closed femoral shaft fractures. Patients with no history of previous surgical procedures on the fractured femur, who were operated on within 48 hours of trauma, had an isolated shaft fracture of the femur without any other fracture of bones, and had a minimum follow-up of six months were enrolled.

Exclusion criteria: Involved patients with polytrauma requiring multidisciplinary management, pre-existing femoral deformity (congenital or acquired), femoral fracture in conjunction with neurological or vascular injury, or those unable or not willing to attend postoperative rehabilitation and follow-up regimens.

On hospital admission, a detailed clinical examination was performed in all patients starting with detailed history-taking on mode and timing of trauma, associated injuries, and past and present medical history, including comorbid illnesses such as diabetes and hypertension. Clinical examination assessed the skin status over the fracture site for edema, bruising, or wound and deformity of the limb such as shortening or malrotation.

Radiological assessment was made up of standard anteroposterior (AP) and lateral X-rays of the injured hip, pelvis, and whole femur to determine fracture patterns and exclude other types of injury. Laboratory tests preoperatively involved complete blood count, renal function tests, liver function tests, random blood sugar, and coagulation profile.

Preoperative management involved alleviation of pain with systemic analgesics, temporary stabilization of the limb with a Thomas splint as needed, and optimization of comorbid conditions. Prophylactic antibiotics (first-generation cephalosporins) were administered one hour before surgery. Imaging of the unaffected limb was also performed to establish a reference for measurement of femoral anteversion intraoperatively.

Surgical stabilization was done under spinal anesthesia with the patients positioned either laterally on a radiolucent table or supine on a traction table at the discretion of the surgeon. A comparison radiograph of the normal femoral anteversion was obtained from the unaffected limb before fixation **(Figure 1)**. Closed reduction was achieved using fluoroscopy with caution in restoring coronal and sagittal plane alignment. Intramedullary nail insertion followed reaming of the medullary canal, and the nail size was chosen 1 mm smaller than the final reamer. Proximal and distal locking screws secured the implant and gave stability. Malrotation was prevented through precise intraoperative evaluation of limb rotation through imaging of the patella and lesser trochanter, comparing the injured limb with the opposite limb.

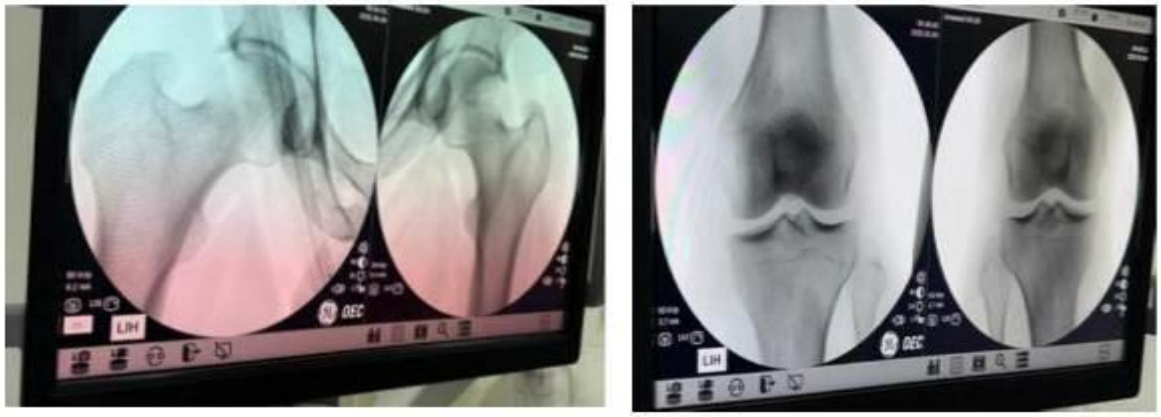

Fig. (1): Intraoperative evaluation of limb rotation through imaging of the patella and lesser trochanter, comparing the injured limb with the opposite limb.

Following surgery, patients received intravenous broad-spectrum antibiotics for 48 hours and low-molecular-weight heparin for 7–10 days to prevent deep vein thrombosis. A stepwise weight-bearing regimen was started with non-weight-bearing crutch ambulation for two weeks, followed by partial weight-bearing for four weeks, and full weight-bearing at six weeks, contingent on healing, as part of an early physical therapy program that focused on hip and knee range-of-motion exercises. Regular wound care was performed, along with follow-up for any complications like infection or hardware failure.

Six weeks, 12 weeks, and 6 months postoperatively, patients were clinically and radiographically followed up. Clinical evaluation quantified gait impairment, rotational deformities (hip and knee flexed 90° prone and supine position), and pain on weight-bearing. Radiologic evaluation included acute postoperative X-rays and computerized tomograms (CT scans) to determine femoral torsion angles and malrotation by comparing injured with uninjured femurs. Functional status was evaluated with Harris Hip Score (HHS), Lower Extremity Functional Scale (LEFS), and pain Visual Analog Scale (VAS).

The Harris Hip Score measured pain, function, deformity, and range of motion with ratings categorized as excellent (90–100), good (80–89), fair (70–79), or poor (<70). The LEFS questionnaire assessed the ability to perform 20 activities of daily living with scores ranging from 0 (extreme limitation) to 80 (normal). The VAS provided a patient self-report measure of pain from 0 (none) to 10 (pain worst possible).

The primary outcome was the development of clinically significant femoral malrotation following fixation. Secondary outcomes included functional status measured by HHS, LEFS, and VAS scores, and radiographic time to fracture union by bridging callus formation.

Statistical analysis

SPSS version 25 was used for data analysis. Quantitative data were presented as mean, standard deviation (SD), median, and interquartile range (IQR). Qualitative data were presented as frequency and percentage. When the data satisfied the requirements of normality and homogeneity of variance, the independent t-test was employed to compare the means of continuous variables between two groups. The non-parametric Mann-Whitney U test was used for continuous variables that did not fit these presumptions. Categorical variables were analyzed using Fisher's Exact Test (FET), as the anticipated cell counts were low. Statistical significance was defined as a significance level of $p < 0.05$.

RESULTS

The study population was predominantly males (74%) with most of the patients (62%) having no comorbid illnesses, though some were diabetic, hypertensive, or smokers. Motor vehicle accidents resulted in the highest number of injuries (60%), followed by other causes and sport injuries.

Timing of surgical intervention was equally divided between early (within 6 hours) and delayed (6–48 hours) interventions. Left-sided femur fractures were more common (58%) than right-sided fractures. The most frequent fracture patterns were transverse (44%) and short spiral (46%), with less typical long spiral fractures. These findings reflect average patterns of trauma and patient population for femoral shaft fractures **(Table 1).**

Table (1): Demographic data and fracture characteristics

Variable		Number	Percentage (%)
Sex	Male	37	74%
	Female	13	26%
Comorbidities	No comorbidity	31	62%
	Diabetes mellitus (DM)	9	18%
	Hypertension (HTN)	6	12%
	Smoking	4	8%
Type of Accident	Motor vehicle accident	30	60%
	Sports injury	4	8%
	Other	16	32%
Timing of Surgical Treatment	First 6 hours	25	50%
	6-48 hours	25	50%
Side	Right	21	42%
	Left	29	58%
Fracture Shape	Short spiral	23	46%
	Long spiral	5	10%
	Transverse	22	44%

The distribution of rotation types shows that the majority of patients (86%) exhibited a neutral rotation outcome, while external and internal rotations were observed in 14% of cases.

This indicates that rotational malalignment was relatively uncommon in the studied population, with external rotation being more prevalent than internal rotation **(Table 2).**

Table (2): Distribution of rotation types among the study population

Type of Rotation	Prevalence	Percentage
Internal Rotation	2	4%
External Rotation	5	10%
Neutral	43	86%

Table (3) presents a comparison of baseline characteristics and injury mechanisms between Groups A and B. A significant difference was found in age, with Group B patients being considerably older than Group A patients. However, no between-group differences were observed in the distribution of gender, injured side, BMI, mechanism of injury, or type of fracture. This indicates that other than age, both groups were comparable in terms of other baseline characteristics as well as injury-related variables.

Table (3): Comparison of patient characteristics and injury mechanisms between Group A (accepted rotation), Group B (true malrotation)

Variable	Group A (n = 43)	Group B (n = 7)	p-value
Age (years) (mean ± SD) Median (IQR)	25.75± 5.21 26.6 (23.4 – 28.4)	41.61±10.49 41.8 (32.6 – 47.9)	<0.001
Gender			0.384
• Male	32 (74.4%)	4 (57.1%)	
• Female	11 (25.6%)	3 (42.9%)	
Side			1.00
• Right	29 (67.4%)	5 (71.4%)	
• Left	14 (32.6%)	2 (28.6%)	
BMI (kg/m²) (mean ± SD) Median (IQR)	25.56± 3.80 25.3 (22.9 – 28.4)	24.18±1.3 23.7 (23.4 – 25.1)	0.246
Mechanism of Injury			0.573
• Motor	19	4	
• Sports	8	2	
• Others	16	1	
Type of Fracture			0.235
• Type A	29	3	
• Type B	13	3	
• Type C	1	1	

SD = Standard deviation, IQR: Interquartile range

Table 4 shows no differences in functional outcomes between patients with accepted rotation (Group A) and those with true malrotation (Group B). Group A had slightly higher mean Harris Hip Scores and LEFS, but without statistical significance. Pain and functional class were similar, although Group B showed a trend for more fair or poor results. The small number of patients in Group B could restrict the power to find differences. In general, malrotation did not have a significant influence on functional results in this study.

Table (4): Differences between functional scores classes as Group A (accepted rotation), Group B (true malrotation)

Measure	Group A (n = 43)	Group B (n = 7)	p-value
Harris Hip Score Mean ± SD	88.03 ± 6.89	83.47 ± 8.74	0.124
Class			0.801
─ Excellent	23 (53.5%)	3 (42.9%)	
─ Good	18 (41.9%)	3 (42.9%)	
─ Fair	2 (4.7%)	1 (14.3%)	
─ Poor	0	0	
Lower Extremity Functional Score Mean ± SD	68.95 ±60.86	61.69 ±60.62	0.673
Class			0.992
─ Excellent	13 (30.2%)	2 (28.6%)	
─ Good	23 (53.5%)	2 (28.6%)	
─ Fair	7 (16.3%)	2 (28.6%)	
─ Poor	0	1 (14.3%)	
VAS (Pain Level)			0.231
─ No pain	20 (46.5%)	3 (42.9%)	
─ Mild pain	18 (41.9%)	2 (28.6%)	
─ Moderate pain	5 (11.6%)	1 (14.3%)	
─ Severe pain	0	1 (14.3%)	

SD = Standard deviation, IQR: Interquartile range,

Table (5) shows that the lateral position had a higher rate of malrotation compared to the supine position, however the difference was not statistically significant.

Table (5): The correlation between incidence of malrotation and patient position (lateral and supine)

Patient Position	Malrotation Present	Malrotation Absent	Total	P value
Lateral	5	20	25	0.417
Supine	2	23	25	
Total	7	43	50	

CASES

Case 1 (Figure 2):

A 25-year-old diabetic male presented with a transverse mid-shaft femoral fracture with external rotation deformity and limb shortening after a twisting football injury. Stabilization was initially with a Thomas splint, and 12 hours later, surgical fixation was performed by closed reduction and antegrade intramedullary nailing using interlocking screws. The 45-minute bloodless procedure was followed by early mobilization and supervised rehabilitation regimen. Union of the fracture was complete at 8 weeks with nearly normal rotational alignment and without gait disturbance. CT scan showed femoral anteversion angles approximating the uninjured side. Functional outcomes were excellent with HHS 89, LEFS 76, and VAS pain score 2.

Fig. (2 A): Case 1: preoperative X-ray shows left short oblique fracture mid shaft femur.

Fig. (2 B): Case 1: Immediate postoperative X-ray shows anatomical reduction of the fracture

Fig. (2C): Case 1: Immediate postoperative clinical assessment of external-internal ROM of the injured side (wrapped with creep bandage) and the sound side.

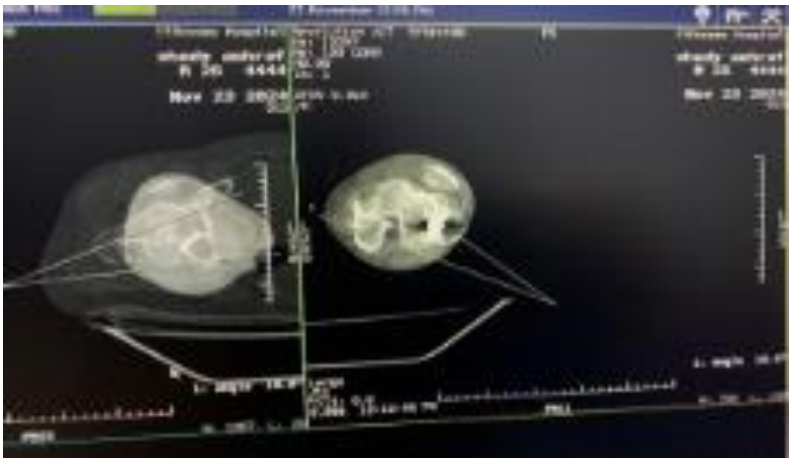

Fig. (2D): Case 1: CT axial cuts of the femoral version of the sound (18.6 degrees and injured side 15.4 degrees).

Case 2 (Figure 3):

A 25-year-old female sustained a right mid-shaft femoral fracture with a small butterfly fragment, external rotation deformity, and limb shortening following a road traffic accident. She underwent initial stabilization with a Thomas splint and surgical fixation 6 hours later using closed reduction and antegrade intramedullary nailing with interlocking screws. The 45-minute procedure, performed supine on a traction table, had no blood loss, and she was discharged after one day. Postoperative care included progressive mobilization, with full weight bearing by 6 weeks and fracture union achieved at 8 weeks. Clinical rotation was near normal with no gait disturbance, and CT showed femoral anteversion of 10.5° on the injured side versus 20° on the sound side. Functional outcomes were excellent, with HHS of 86, LEFS of 73, and VAS pain score of 3.

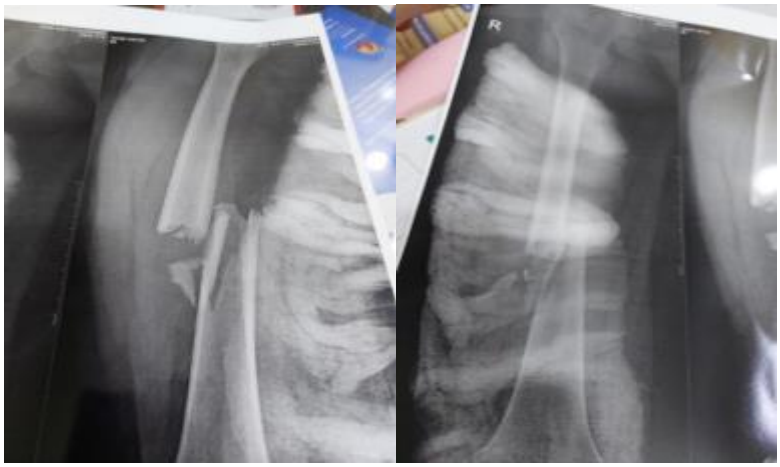

Fig. (3 A): Case 2: preoperative X-ray shows left short oblique fracture mid shaft femur.

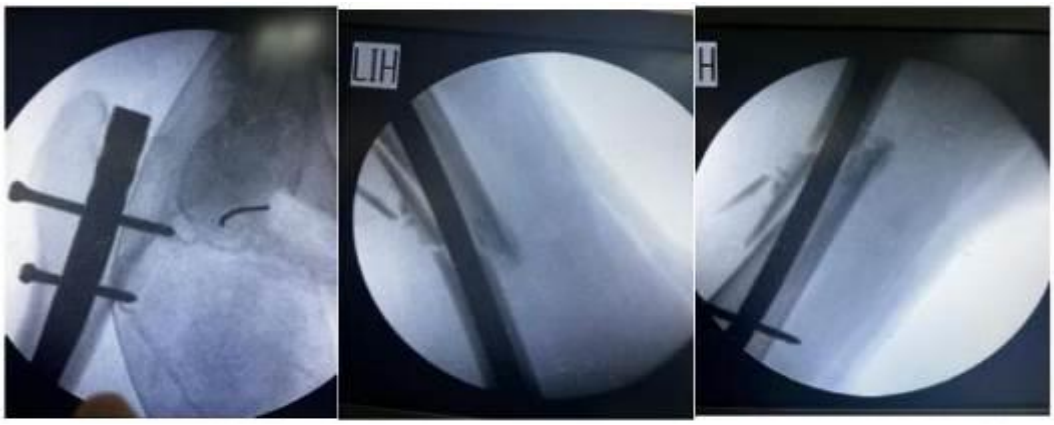

Fig. (3B): Case 2: Immediate postoperative X-ray shows anatomical reduction of the fracture.

Fig. (3 C): Case 2: Immediate postoperative clinical assessment of external-internal ROM of the injured side (wrapped with creep bandage) and the sound side.

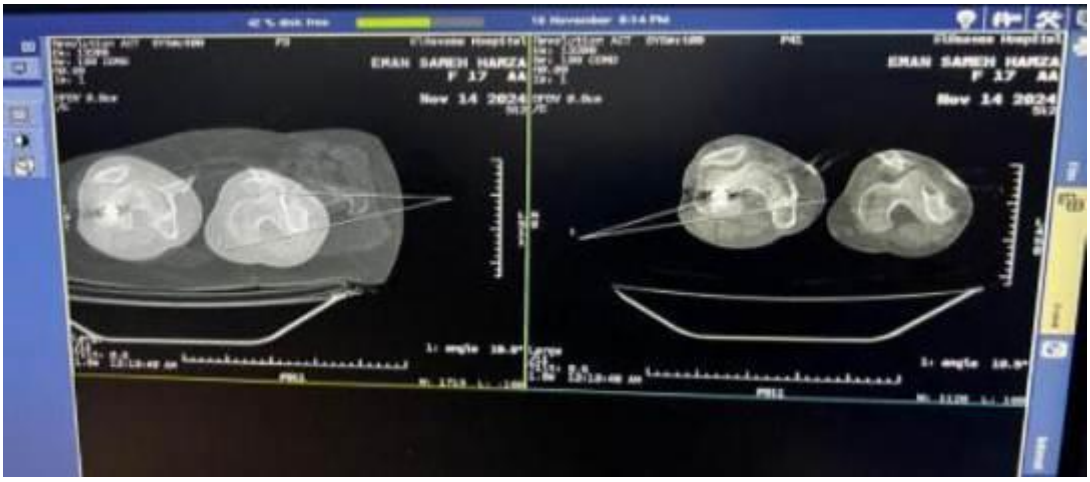

Fig. (3 D): Case 2: CT axial cuts of the femoral version of the sound (20 degrees and injured side 10.5 degrees).

DISCUSSION

Femoral shaft fractures are common, often secondary to high-energy trauma, occurring at age-specific peaks in young children, young adult men, and older women, and commonly with other injuries. Intramedullary nailing is the preferred treatment due to its minimally invasive method and predictable healing, though malrotation is a common complication [(3)].

The aim of this prospective study was to evaluate incidence of malrotation of femur after closed reduction and internal fixation of femoral shaft fracture by antegrade intramedullary nail.

In our study, the majority of the patients with femoral shaft fractures were males (74%), a finding that was concordant with previous studies. **Ibrahim *et al.*** [(11)] also noted a male predominance (64%) in 402 patients treated for femur fractures, while **Khan *et al.*** [(12)] saw bimodal distribution with younger male patients (median age 65.6) and older women patients (median age 71). This gender predominance is often accounted for by differences in the mechanism of injury between age groups and sex groups.

The main cause of trauma in our cohort was motor vehicle collision (60%), then other etiologies and sport injury. Our findings concur with those of **Khan *et al.*** [(12)], which described high-energy injury being highly prevalent among men (70.5%), while women tended to develop fracture more commonly from low-energy etiologies (82.7%, $p<0.0001$). **Enninghorst *et al.*** [(13)] also stated that almost half of all femoral shaft fractures (48.4%) were caused by high-energy trauma, of whom 31.1% of patients were ranked as polytrauma cases (ISS 28 [±12]). Globally, **Agarwal-Harding *et al.*** [(14)] approximated that the annual incidence of femoral shaft fracture due to road traffic crashes varied between 1.0 and 2.9 million.

The most frequent pattern of fracture in our study was AO/OTA 33-A (52%), with short spiral (46%) and transverse (44%) being the most frequent patterns of fracture. Long spiral fractures were uncommon. These figures are reflective of the typical biomechanical patterns of femoral shaft injury.

Notably, the majority of patients (62%) did not have significant comorbidities, consistent with the

general demographics of young adults that sustain such injuries. A small number of patients, however, did have diabetes, hypertension, or a history of smoking.

Regarding laterality of fracture, left femur fractures predominated over right femur fractures (58%). Early (≤6 hours) compared with delayed (6–48 hours) surgery was allocated equally. There are evidence-based indications for an early fixation in the context of a traumatic femoral fracture. **Byrne *et al.*** [15] demonstrated it was feasible to carry out early definitive intramedullary nailing (<24 hours) in the majority of cases and that fewer complications followed. Similarly**, Alobaidi *et al.*** [16] found that early intramedullary nailing was correlated with reduced hospital stay (median 3.2 hours for early vs. 68 hours for delayed), and there was no difference in outcome after confounders adjustment.

A study by **Jaarsma *et al.*** [17] highlighted the difficulty in determining anatomic rotation following IM nailing of the femur. The study emphasized the challenges in accurately assessing rotational alignment, which may contribute to the observed incidence of malrotation. This study intended to determine the prevalence of rotational malalignment occurring after intramedullary nailing of femoral shaft fractures using CT scans

The distribution of rotation types in our study was the majority of patients (86%) exhibited a neutral rotation outcome, while external rotation was observed in 10% and internal rotation in only 4% of cases. This indicates that rotational malalignment was relatively uncommon in the studied population, with external rotation being more prevalent than internal rotation

When we compared the baseline characteristics and injury mechanisms between Groups A and B, a statistically significant difference was observed in age, with Group B being significantly older than Group A. No significant differences were noted between the groups in terms of gender**,** injured side**,** BMI**,** or mechanism of injury, as all corresponding p-values were > 0.05. Notably, a significant difference was detected in the type of fracture between the two groups ($p = 0.048$), suggesting a potential association between fracture pattern and group allocation. Fisher's Exact Test (FET) was appropriately used for categorical variables due to the small sample size, especially in Group B.

This finding is consistent with a number of previous studies that were not able to identify clinically important differences when rotational deformities were mild to moderate. Prospective and retrospective series that restricted malrotation to 10–15° had similar patient-reported outcome measures (PROMs). **Abbas *et al.*** [18]**,** for example, with a mean malrotation of approximately 10°, reported no difference in HHS or Lysholm scores between groups. **Jaarsma *et al.*'s**[17] gait compensation study demonstrated normal gait velocity despite a mean malrotation of 16°, and **Hüfner *et al.*'s**[19] early CT audit demonstrated that malrotation less than 15° was not associated with increased pain or activity limitation. These results suggest that the majority of patients, particularly young patients, may be able to physiologically compensate for small amounts of axial malalignment.

However, multiple studies have revealed a functional threshold beyond which malrotation begins to have a measurable impact on results. Large or angle-stratified series have revealed poorer outcomes with increasing deformities if the rotation deformities are over the mid-teen degrees. In a study of 96 EOS patients, there was found a 10-point loss of HHS in deformities ≥14°, and **Karaman *et al.***[20] found more hip and knee pain if malrotation was >10°. **Jaarsma *et al.*** [17] similarly described difficulty in higher-demand activities such as running and climbing stairs in 28% of the patients with ≥15° torsional deformity. Similarly, **Gugenheim *et al.*** [21] long-term follow-up documented abnormal foot progression angles and subjective dysfunction in those with mean external rotation deformity of 18°. **Sharma *et al.*** [22] also found this threshold effect, showing that patients with actual rotational malalignment ≥15° after femoral shaft fracture fixation had significantly worse LEFS ($P=0.009$) and WOMAC scores ($P=0.033$), indicating impaired lower limb and knee function. Notably, HHS did not significantly vary between groups, and patients with both internal and external rotation deformities had equal outcomes, favoring the hypothesis that standard hip function scores may not truly reflect the impact of rotational errors.

The distribution of malrotation incidence across two patient positions: lateral and supine. Malrotation was observed in 5 out of 25 patients (20%) in the lateral position and in 2 out of 25 patients (8%) in the supine position. Although the lateral position showed a higher rate of malrotation compared to the supine position, the difference was not statistically significant

A few studies have addressed the relation of patient position during intramedullary nailing with postoperative femoral malrotation incidence. Surprisingly, in one study by **Rashid *et al.*** [23]**,** malrotation was detected in 19% of laterally positioned patients and 16% of supine patients, without a statistically significant difference ($p = 0.76$). Similarly, **Güler *et al.*** [24] had rates of malrotation of 50% in the lateral decubitus position versus 35.7% in the supine position, once more with no statistical difference. These findings demonstrate a trend towards higher rates of malrotation in the lateral position but differences that are not yet statistically significant in these studies.

However, other studies have found no statistically significant difference between the two positions in rates of malrotation. **Sholla *et al.*** [25] conducted a randomized controlled trial and found no clinically significant malrotation in either supine or lateral position. This suggests that factors other than

patient positioning, such as surgical technique and intraoperative assessment techniques, may be more critical to avoiding malrotation.

Interlocking nails are prone to rotational, sagittal, and coronal malalignment when used to fix femur fractures. Moderate to severe malrotation can result in pain and impairment, whereas mild malrotation is well tolerated by the patient. According to the current study, the incidence rate of malalignment with IM nail for femoral shaft fractures is similar to that found in literature published worldwide. The existence of more than 15° of rotation, either internally or externally, is referred to as rotational malalignment. To avoid malrotation during surgery, we employ foot position and C-arm intraoperatively. The gold standard for detecting malrotation is still computed tomography scanning, which also makes it possible to see concealed rotational variations.

CONCLUSION

Closed reduction and antegrade intramedullary nailing is an effective treatment for femoral shaft fractures, with a low incidence of clinically significant malrotation. Most patients (86%) maintained neutral rotation, and mild malrotation did not significantly affect functional outcomes. External rotation is more prevalent than internal, and using the supine position may help reduce malrotation risk.

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