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Analysis of Femoral Shaft Fractures in the Pediatric Population at a Tertiary Care Center: A Longitudinal Study

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Abstract: Background: Femoral shaft fractures are very common in the pediatric population; however, information is scarce. Methods: A total of 189 pediatric patient records were reviewed to identify the characteristics of diaphyseal fractures, including origin, type, pattern, surgical technique, and complications. Descriptive statistics were used to calculate frequencies and percentages. Meanwhile, continuous and categorical variables were analyzed using logistic regression to compare the different types of fractures in the population. Results: The proportion of males was higher compared to females (2:1). The highest prevalence was observed in the 10–14-year-old age group (n = 71; 37.5%). The primary mechanism of injury was traffic accidents (n = 93; 49.2%). Left femoral shaft fractures (n = 101; 53.4%) were the most prevalent. Transverse patterns predominated among the identified fractures (n = 105; 55.6%), most of which were closed fractures. Among the complications, non-union was the most frequent (n = 13; 6.9%), followed by wound infections (n = 3; 1.5%). Obesity ($p < 0.001$) and overweight ($p < 0.001$) were statistically significant in the left-sided femoral shaft fracture group. Conclusions: Non-union was the main complication identified in our study population. Obesity and overweight were identified as predictive variables for left-sided femoral shaft fractures. Meanwhile, none of the injury mechanisms showed statistical significance. Diaphyseal fractures in the pediatric population are underestimated, as well as the predictors causing them. Therefore, it is necessary to establish better management strategies for this type of fracture in pediatric patients.

Keywords: surveillance; shaft fracture; pediatric; non-union; longitudinal

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1. Introduction

Femoral shaft fractures are a common traumatic injury in pediatric patients requiring hospitalization, accounting for approximately 20% of pediatric admissions due to orthopedic injuries [1]. The incidence of these fractures is estimated at 15–25 cases per 100,000 patients under the age of 16. Common causes include falls, sports injuries, and traffic accidents [2,3].

According to current management guidelines, treatment strategies vary by age group [4]. Conservative treatment is often preferred in younger children, but its use has declined in patients over five years old due to the extended hospitalization required

and its impact on quality of life. Among the surgical options, flexible intramedullary nails, plate fixation, external fixators, and rigid intramedullary nails are commonly utilized [5,6]. However, preventing non-union remains one of the most significant challenges, as shaft fractures have a non-union risk of up to 20%, particularly in complex cases such as high-energy trauma or open fractures [3].

The pediatric classification system of the Association of Orthopedic Surgeons (AO) is a widely used tool for categorizing shaft fractures. This validated system is based on anatomical and morphological criteria and is considered highly reliable among orthopedic surgeons. It describes fracture patterns (e.g., oblique, transverse, spiral) and determines fracture stability [7]. According to the guidelines of the American Academy of Orthopedic Surgeons (AAOS), the typical clinical presentation of a femoral shaft fracture includes significant swelling in the mid-thigh and severe localized pain [7].

The literature indicates that postoperative complications largely depend on the type of osteosynthesis used [8]. Factors such as the extent of soft tissue damage, the presence of undiagnosed infections, and the prior use of medications like Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) can negatively impact bone healing, increasing the risk of complications such as non-union [3]. However, there is limited research on complications specific to the management and treatment of pediatric femoral fractures [8].

This study aims to present the management strategies, complications, and outcomes of a pediatric cohort with femoral shaft fractures at a tertiary care center.

2. Materials and Methods

2.1. Patients

A total of 189 pediatric patients treated by the Traumatology and Orthopedics Service at the "General Ignacio Zaragoza" Regional Hospital (HRGIZ) of Instituto de Seguridad y Servicios Sociales de los trabajadores del Estado (ISSSTE) during the period from January 2018 to January 2023 were included in this study (097/D/619/2024), based on the following selection criteria:

2.2. Inclusion Criteria

- Patients under 18 years of age.
- Patients with a clinical and/or radiological diagnosis of left or right femoral shaft fracture.
- Patients who underwent surgical treatment for the management of a diaphyseal femur fracture.

2.3. Exclusion Criteria

- Patients with incomplete medical records.
- Patients without follow-up for at least six months post-surgery.

2.4. Fractures

A pediatric patient was diagnosed with a femoral shaft fracture if they met the clinical and/or radiological criteria defined by the AO classification system [7]. This system enabled the classification of fractures based on their stability and provided essential guidance for determining appropriate therapeutic strategies. Furthermore, the mechanism of injury was identified and categorized as traffic accidents, falls from a height, or injuries resulting from specific activities (physically risky games such as accidents in inflatables). The diagnosis specified whether the femoral shaft fracture occurred on the left or right side, its exposure status (open or closed), and the fracture pattern (transverse, oblique, wedge, or

comminuted). Lastly, complications, including non-union and surgical wound infections were thoroughly documented.

Non-union, defined as the absence of clinical and radiographic signs of bone consolidation after six postoperative months. All cases of non-union were confirmed intraoperatively during revision surgery, which included surgical debridement of the fracture site, reshaping of the edges, and replacement of the osteosynthesis material.

All diagnosed cases of surgical wound infections were defined as occurring within 30 days after surgery, involving only the skin and subcutaneous soft tissues at the incision site. A surgical wound infection was considered present if at least one of the following conditions was met:

- Purulent drainage from the superficial incision, with or without microbiological confirmation.
- Isolation of a microorganism from a fluid or tissue sample.
- At least one of the following signs or symptoms of infection: pain, swelling, erythema, or warmth.

All cases occurred within the first four postoperative weeks and were successfully managed with oral antibiotics and wound care.

All patients were followed for a minimum of 18 months, allowing for the identification of late complications such as non-union.

2.5. Surgical Approach

Following the diagnosis of left or right femoral shaft fractures, the surgical approach was determined. Treatment options included open reduction and internal fixation (ORIF) with a dynamic compression plate (DCP), as well as open vs. closed reduction with intramedullary nail fixation.

2.6. Statistical Analysis

A comprehensive database was developed to include all pediatric patients who met the study's selection criteria. The recorded variables encompassed sex, age, BMI (body mass index), history of smoking, type of surgery, fracture pattern, fracture exposure, mechanism of injury, and complications. The variables of interest were analyzed and expressed as frequencies and percentages.

Meanwhile, continuous and categorical variables were analyzed using logistic regression to compare fracture types within the study population. Statistical analysis was performed using the Jamovi software program (Version 2.6.6), with a significance threshold set at $p < 0.005$ to determine statistical significance.

3. Results

3.1. Patients

A total of 189 patients were included in this study. The male-to-female ratio was 2:1, indicating a higher prevalence among males (Table 1). The most frequently represented age group was 10–14 years, followed by 15–17, 5–9, and <5 years old. Regarding BMI, 72.4% of the patients had a normal weight, while 25.3% were classified as overweight or obese according to WHO criteria. Smoking was reported in 5.3% (n = 10) of the patients, while the majority (n = 179; 94.7%) had no history of smoking (Table 1).

Table 1. Clinical and demographic characteristics of the patients included in the study.

Variable	Frequency (n)	Percentage
Sex		
Female	73	38.6
Male	116	61.3
Age group		
<5 years old	17	8.9
5–9 years old	47	24.8
10–14 years old	71	37.5
15–17 years old	54	28.5
Nutritional status (kg/m^2)		
BMI (<18.5)	4	2.1%
BMI (18.5–24.9)	137	72.4%
BMI (>25)	48	25.3%

BMI: body mass index.

3.2. Fractures

In our study population, the primary mechanisms of injury were traffic accidents (n = 93; 49.2%), falls from a height (n = 63; 33.3%), and sports-related injuries (n = 19; 10%). Upon diagnosis, femoral shaft fractures were identified more frequently on the left side (n = 101; 53.4%) than on the right side (n = 88; 46.6%).

Among the fracture patterns, transverse fractures were the most prevalent (n = 105; 55.6%), followed by oblique fractures (n = 43; 22.8%). Meanwhile, wedge fractures accounted for 11.1% (n = 21), and comminuted fractures were the least common, representing 10.6% (n = 20) of cases. The vast majority of fractures were closed (n = 186; 98.4%), with only a small percentage classified as open fractures (n = 3; 1.6%).

Regarding surgical intervention, the most commonly employed technique was open reduction and internal fixation with dynamic compression plate (DCP) plating (n = 140; 74%), followed by ORIF with flexible nails (n = 49; 25.9%). These approaches were chosen based on the fracture type and clinical presentation.

Non-union was the most common complication, occurring in 6.9% of cases (n = 13), particularly associated with implant failure. Among these 13 cases, 10 (76.9%) exhibited fatigue of the osteosynthesis material, specifically the dynamic compression plate (DCP), with plate rupture occurring between 7 and 14 months after the initial surgery. The remaining three cases (23.1%) showed no signs of implant failure but met the clinical and radiographic criteria for non-union. All non-union cases were diagnosed between 7 and 14 postoperative months, with an average diagnosis time of 10.2 months. Additionally, all cases were resolved with revision surgery, and no third intervention was necessary.

Surgical wound infections were reported in 1.6% of cases (n = 3) and were treated with Cephalexin 50 mg/kg/day, divided into 3–4 doses for one week. The remainder of the study population (n = 173; 91.5%) did not present any complications.

When comparing fracture types (right femoral shaft fractures vs. left femoral shaft fractures) and body mass index (BMI), a statistically significant association was identified with obesity ($p < 0.001$) and overweight ($p < 0.001$), particularly in the group with left-sided femoral shaft fractures (Table 2). The fracture pattern was not statistically significant for any specific type of fracture. However, logistic analysis of the mechanism of injury in right- and left-sided femoral shaft fractures revealed that falls from standing height, traffic accidents, sports injuries, and other causes were statistically significant predictors ($p < 0.001$).

Table 2. Logistic regression analysis of continuous and categorical variables with respect to fracture types.

	Right Femur Diaphyseal Fracture (n = 88)	Left Femur Diaphyseal Fracture (n = 101)
BMI	0.99	0.99
Normal	0.39	0.02
Obesity	0.002	<0.001
Overweight	0.01	<0.001
Fracture trace		
Oblique	0.76	0.08
Wedge	0.03	0.69
Multifragmented	0.80	0.64
Open fracture	0.88	0.85
Fracture mechanism		
Fall from height	<0.001	<0.001
Traffic accident	<0.001	<0.001
Sports injury	<0.001	<0.001
Other	<0.001	<0.001

BMI: body mass index.

4. Discussion

In the present study, the characteristics of diaphyseal fractures were analyzed, including origin, type, pattern, surgical approach, and complications in a pediatric population over a five-year period. A high prevalence of femoral shaft fractures was observed in the 10–14-year-old age group, particularly among males. Traffic accidents were the primary mechanism of injury, leading to a high incidence of left femoral shaft fractures, with transverse patterns being the most predominant. Most of these fractures were closed fractures. Non-union was the most frequent complication. Additionally, obesity ($p < 0.001$) and overweight ($p < 0.001$) were found to be statistically significant factors in the group with left-sided femoral shaft fractures.

In our cohort, the proportion of male patients was significantly higher (2:1), a finding consistent with international studies that highlight a male predominance in pediatric fractures. This pattern is attributed to greater male participation in high-risk activities, such as contact sports and motorcycle use, particularly in regions with inadequate safety measures [9,10]. Studies, including the Swedish Fracture Register, emphasize that traffic accidents are the leading cause of femoral shaft fractures in adolescents, while falls from lower heights are more common in children under 10 years old [10].

Femur fractures are among the most frequent and severe injuries in motorcycle accidents, highlighting their significance as a public health issue. In our cohort, traffic-related injuries accounted for 49.2% of all femur fractures, with motorcycle crashes being the leading cause. These findings are consistent with studies conducted in urban and developing regions, where motorcycles serve as a primary mode of transportation, often without adequate protective measures. Previous research has highlighted that the absence of helmet use, lack of lower limb protection, and high-speed collisions significantly contribute to the severity of femoral fractures in these settings [10,11].

Transverse fractures were the most common pattern in our cohort (55.6%), followed by oblique fractures (22.8%). Wedge and comminuted patterns were less frequent, accounting for 11.1% (n = 21) and 10.6% (n = 20) of cases, respectively. These results align with the Swedish Fracture Register, where transverse fractures predominate in shaft fractures [10,11]. The distribution of fracture patterns depends on factors such as age and mechanism of injury. Transverse fractures are typically associated with high-energy direct trauma, whereas complex patterns, such as comminuted fractures, are often seen in severe vehicular accidents [9].

Femoral shaft fractures account for approximately 1.6% of all pediatric fractures and are a leading reason for hospitalization in children due to severe trauma. The incidence of these fractures varies depending on the age of the patient and the mechanism of injury [12].

In patients aged six months to five years, the standard treatment is conservative management with a spica cast. However, flexible intramedullary nailing may serve as an alternative therapeutic option in select cases, as it allows for faster recovery and early mobilization. In our study group, patients under 5 years old (4 years; n = 17) underwent closed reduction and fixation with elastic intramedullary nails in specific cases where conservative treatment was not optimal. This included patients with unstable fractures, polytrauma, or those in whom prolonged immobilization with a spica cast was contraindicated.

The only complication identified in this group was a surgical wound infection, which was successfully treated with Cephalexin at a dose of 50 mg/kg/day for 7 days.

On the other hand, femoral fractures in children aged five to eleven years are primarily caused by high-energy trauma, with motorcycle accidents being the most frequent cause in our study population. In this context, the use of elastic intramedullary nails is recommended, considering the patient's weight. However, in our population, no patient underwent this surgical intervention due to the lack of necessary supplies at our institution. Nonetheless, the main complication observed was non-union, which is the most frequently reported complication in patients treated with flexible intramedullary nails. Finally, in patients older than 11 years, rigid intramedullary nails or submuscular plates are considered the preferred treatment, particularly in those weighing more than 50 kg [12].

Of the total population, only five patients were lost to follow-up, so other complications could be identified. However, all the complications identified were resolved favorably.

In our cohort, surgical intervention was the standard approach, with ORIF using a dynamic compression plate being the most employed technique (74.07%). This method is particularly effective for complex femoral shaft fractures, such as comminuted or unstable patterns, as it provides robust fixation and promotes bone healing [3]. Brousil and Hunter [11] highlight that ORIF remains the technique of choice for older children and adolescents due to its ability to maintain precise anatomical alignment and reduce the risk of postoperative complications [11]. However, this approach is inherently more invasive, involving longer surgical times and increased infection risks.

Flexible intramedullary nails represent a surgical option for patients weighing <50 kg. This makes it a less invasive procedure, with shorter surgical time, less intraoperative bleeding, and shorter hospital stays compared to open reduction and plating, as well as a lower complication rate [13].

The high rate of non-union (6.9%) in our cohort, particularly associated with implant failure, underscores the challenges in managing diaphyseal femoral fractures in adolescents. The fatigue failure of DCPs observed in 76.9% of non-union cases suggests that this fixation method may be less suitable for older pediatric patients with higher mechanical demands. This finding aligns with the study by Nicholson et al. [3], who reported that implant failure is a significant risk factor for non-union in high-energy fractures. Our results suggest that alternative fixation methods, such as intramedullary nailing, may be more appropriate for adolescents with diaphyseal femoral fractures, especially in cases with high axial instability. Additionally, close follow-up beyond 6 months is crucial to detect late complications such as implant failure and non-union.

In our study cohort, obesity and overweight showed statistical significance in the group of patients with left-sided femoral shaft fractures. This may be attributed to altered biomechanical loading and weight distribution, which could predispose heavier children to asymmetrical stress on the femur, leading to a higher likelihood of fractures on the left side [14,15].

Obesity and smoking are modifiable risk factors that may impair bone healing and increase the risk of non-union in pediatric fractures. Obesity is linked to altered biomechanics, chronic inflammation, and higher rates of surgical complications, leading to delayed fracture healing [16,17]. Similarly, pediatric smoking and tobacco exposure negatively affect microvascularization, osteoblast function, and collagen synthesis, further slowing bone repair and increasing non-union risk [18,19]. When both risk factors coexist, their combined effects may further complicate fracture recovery, requiring closer monitoring and preventive strategies [20]. More research is needed to fully understand the long-term impact of obesity and smoking on pediatric bone healing. Additionally, the energy level of trauma plays a critical role in fracture healing outcomes. Fractures caused by high-energy trauma, such as severe vehicular accidents, have been identified as a leading cause of non-union in pediatric patients [21]. The extensive soft tissue damage, periosteal stripping, and vascular disruption associated with high-impact trauma significantly impair the bone healing process, increasing the likelihood of non-union [22,23]. Studies indicate that open and comminuted fractures, which are more common in high-energy injuries, exhibit higher rates of delayed healing and non-union compared to low-energy fractures [24].

Given these risks, early identification of high-risk fractures and the implementation of aggressive management strategies, such as rigid fixation and biological enhancement of healing, are essential to reducing non-union rates in pediatric trauma cases [20].

The development of less invasive techniques for managing pediatric fractures has revolutionized surgical approaches, particularly by minimizing damage to surrounding tissues [25]. These advances have been facilitated using fluoroscopy and intraoperative imaging equipment, enabling precise placement of intramedullary devices with millimeter-level accuracy. This technological support reduces the need for extensive incisions and facilitates precise surgical maneuvers, resulting in less surgical trauma and faster recovery. Elastic stable intramedullary nailing (ESIN) has been shown to be an efficient and minimally invasive technique, offering excellent outcomes in pediatric patients [25].

Preserving endosteal and periosteal vascularization by avoiding periosteal stripping during fixation plays a crucial role in enhancing bone healing. This approach also minimizes damage to adjacent soft tissues, promoting faster functional recovery and reducing postoperative pain. Studies indicate that periosteal preservation is particularly important in pediatric fractures, as the periosteum contributes significantly to fracture consolidation and the formation of high-quality bone callus [26]. Reducing surgical trauma is especially critical in pediatric patients, as it directly influences healing time and overall bone remodeling. The implementation of advanced intramedullary devices, combined with real-time imaging techniques, has significantly advanced safer and less invasive pediatric fracture surgeries, reducing complication rates and improving functional outcomes [26].

Despite the prevalence of diaphyseal femoral fractures in the pediatric population, there are limited data on specific complications associated with surgical management, particularly in low- and middle-income countries. Prospective studies with long-term follow-up are essential to evaluate not only biomechanical outcomes but also the psychological impact and quality of life of patients. Direct comparisons of less invasive techniques, such as fluoroscopy-guided intramedullary devices, with more invasive methods like ORIF in specific pediatric populations would provide clearer guidelines for treatment selection.

This study has limitations inherent to its retrospective design, which restricts the ability to establish causal relationships. On the other hand, the sample size is relatively small, and being from a single center limits the generalizability of the findings to other populations. Furthermore, since our institution is a referral center located on a major avenue connecting two states in our country, there is a higher prevalence of diaphyseal fractures, with traffic accidents being the primary mechanism of injury. Additionally, regarding the surgical

technique, the type of material used for fixation is largely dependent on the availability of resources at our institution.

5. Conclusions

Non-union was the main complication identified in our study population. Obesity and overweight were identified as predictive variables for left-sided femoral shaft fractures. However, none of the injury mechanisms showed statistical significance in relation to fracture occurrence.

Femoral shaft fractures in adolescents represent a significant clinical challenge. While important advancements have been made in surgical management and diagnosis, there are still opportunities for innovation and research, particularly in refining less invasive techniques supported by advanced imaging technology. A multidisciplinary approach, combined with effective prevention strategies, is essential to improving long-term outcomes in this population.

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Abbreviations

The following abbreviations are used in this manuscript:AO Association of Orthopedic Surgeons; AAOS American Academy of orthopedic Surgeons; NSAIDs Non-Steroidal Anti-Inflammatory Drugs; ISSSTE Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado; ORIF Open Reduction and Internal Fixation; DCP Dynamic Compression Plate.

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