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# Complications in operatively managed pediatric femoral shaft fractures

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## ABSTRACT

**Objectives:** Despite being the strongest long bone in the body, femur shaft fractures (FSFs) remain steadily prevalent in Saudi Arabia and globally. The goal of treatment is to achieve fracture healing with the least complications. Therefore, this study intended to determine the complications in pediatric FSFs, which were operatively managed.

**Methods:** This study is a retrospective analysis of 76 pediatric FSFs. The inclusion criteria included age ≤14 years, FSFs operatively treated in the study center, at least one-year follow-up, and admission between January 1, 2012, and January 1, 2020. Pathological fractures and patients with neuromuscular or syndromic conditions were excluded from the study.

**Results:** Seventy-two patients (81.9% boys, mean age 8.1 years) with 76 FSFs were analyzed. Most injuries were from motor vehicle accidents (41.6%), falls (29.1%), and pedestrian trauma (15.2%). Titanium was used in 47 (61.8%). Plating was used in 16 (21%), rigid nails in eight (10.5%), and hip spica under general anesthesia in five (6.5%). Out of those 76 fractures, 17 had developed complications. These complications varied in their significance, including limb length discrepancy (LLD) (five), non-union (three), 15° angulation (three), skin irritation due to cast soiling (two), skin swelling due to prominent flexible nail (one), surgical site infection (one), osteomyelitis (one). LLD was significantly associated with increased weight, fracture pattern, non-union, and definitive fixation time.

**Conclusion:** Overall complications in operatively treated pediatric FSFs were low and not disabling. LLD was the most common with a significant association with increased weight, unstable fracture pattern, non-union, and definitive fixation time.

**Keywords:** Complications, Femoral fractures, Management, Outcome, Pediatric

## INTRODUCTION

Among all fractures in children, femoral shaft fractures (FSFs) are the most common orthopedic injuries requiring hospitalization, with a six-day average length of stay.[1] They account for 62% of entire femur fractures, commonly after a high-energy trauma such as a motor vehicle accident.[2] Locally, in Saudi Arabia, the incidence and distribution of pediatric FSFs have not been published; therefore, it is hard to estimate the burden of such cases in the country. However, the overall

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incidence of pediatric fractures has grown over the past decade and increased the burden on the healthcare system.[3]

The management of pediatric FSFs has evolved dramatically over the past century. In the past, most FSFs were treated with a traditional cast and observation. However, recent advances in surgical techniques and implants, such as titanium elastic intramedullary nail, have made it possible for children to undergo surgery and be mobilized early at home and school, becoming the standard of care for children aged 5 to 12 years. As a result of this evolution, treatment modalities currently vary depending on many variables, such as the child's age and weight. Each treatment approach has its complications, which differ in rate and type.

Since orthopedists are interested in providing the best outcome for their patients, it is critical to define the factors that might lead to complications. The complications vary depending on the treatment approach, and it can be challenging to identify which patients are most likely to develop a complication since it is rare in the pediatric population.[4,5] To the best of our knowledge, no data has been published explaining the associated complications and their factors in pediatric FSFs managed operatively in our region. Therefore, our study aimed to determine the associated complications and their factors in operatively managed pediatric FSFs.

## MATERIALS AND METHODS

The study was conducted at a level-one trauma center in Riyadh, Saudi Arabia. The review involved pediatric patients with managed operatively FSFs. We defined operative fracture management as closed or open reduction and stabilization under general anesthesia. Pre-operative and post-operative anteroposterior and lateral femur radiographs were studied for fracture characteristics and healing, while scanogram radiographs were reviewed to assess limb alignment and limb length discrepancy (LLD). The fractures were classified into stable and unstable based on the fracture pattern. The stable fracture was defined as a transverse and short oblique fracture, whereas the unstable fracture was defined as a long oblique (>30° relative to the femur axis) and comminuted fracture.[6] The studied complications were acute respiratory distress syndrome, pulmonary embolism, femoral head osteonecrosis, neurovascular injury, hardware failure, non-union, angulation, LLD, and cast-related complications.

As a standard of care, the fractures were managed based on age, weight, and stability.[7] Spica casting was typically used for fractures in children between eight months and five years of age. Titanium elastic intramedullary nail (TEN) was used for children aged 5–11 years with weight <49 kg and a stable fracture. Antegrade rigid intramedullary (IM) nail fixation was used for those older than 11 years of age weighing >49 kg with stable fracture. A submuscular plating (SMP) was used for unstable fracture patterns. A temporary external fixator was applied for unstable patients.

Microsoft Excel software version 2021 was used for data entry, while SPSS software version 25 was used for data analysis. Categorical variables such as sex were presented as frequencies (*n*), while numerical variables such as age were presented as mean and standard deviation. A Student's *t*-test was used to compare the means of numerical variables. A Fisher's exact test was used to compare the differences between categorical variables. Binary logistic regression was used to assess the effect of variables on outcomes and complications. A test was considered statistically significant if the $P < 0.05$.

## RESULTS

Table 1 shows the baseline characteristics of study population. Of 76 FSFs, 37, 31, and 4 were right-side, left-side, and bilateral, respectively. The majority (73/76) were closed. The mid-third femur fracture, which counted the most, was presented in 33, followed by the proximal third, 28, and the distal third, 15. Twelve fractures were medially angulated with a mean of 39°, and 41 fractures were shortened with a mean of 35 mm.

Closed reduction was used in 59 fractures, and open reduction in 17 fractures. Provisional external fixation was used in eight fractures. TEN was the most frequent type of definitive fixation, used in 47 fractures. Plating was used in 16 fractures, rigid nails in eight, and hip spica under general anesthesia in five fractures.

Complications were observed in 17 cases. The most common complication was LLD, seen in five patients, three cases due to overgrowth of the injured leg. Four out of five patients with LLD had undergone surgical correction. Three children had non-union, one having an open fracture resulting in osteomyelitis and another having a surgical wound infection. After a two-year follow-up, three patients had angulation with a mean of 15°. Two had skin irritation due to spica cast soiling. One child had bluish swelling around the TEN entry and underwent nail trimming [Table 2].

Among all variables included in this study, only fracture stability, weight, definitive fixation time, and non-union were significantly associated with LLD ($P = 0.020$, $P = 0.032$, $P < 0.001$, and $P = 0.011$, respectively). However, in univariate regression analysis, only the definitive fixation time was statistically significant (odds ratio [OR]:1.063, 95% confidence interval [CI]: 1.021–1.107, $P = 0.003$). After the result was adjusted to injury mechanism, isolated or non-isolated injury, fracture severity, and external fixation application, the odds of having LLD increased by 1.1 - folds for every hour delay in definitive fixation time (OR: 1.105, 95% CI: 1.002–1.219, $P = 0.045$) [Tables 3].

**Table 1:** Descriptive analysis of demographic and clinical characteristics.

| Variables | Mean±SD/*n* |
|---|---|
| Sex | |
| Male | 59 |
| Female | 13 |
| Age (years) | 8.1±3.5 |
| Height for age percentile | 70±29 |
| Weight for age percentile | 69±24 |
| Mechanism of injury | |
| Motor vehicle accident | 30 |
| Fall | 21 |
| Pedestrian | 11 |
| Falling heavy object | 2 |
| All-terrain vehicle | 2 |
| Motorbike | 2 |
| Hit by a Camel | 2 |
| Isolated femur fracture | 42 |
| Glasgow coma scale | 13.6±3.3 |
| Time to definitive fixation (h) | 23.7±17.8 |
| Follow-up (month) | 28.7±21.4 |

SD: Standard deviation

**Table 2:** Types and frequency of complications observed in the study.

| Variables | *n*/Mean±SD | |
|---|---|---|
| Limb length discrepancy | 5 | 2.3 cm±1.2 cm |
| Angulation | 3 | 15°±1° |
| Non-union | | 3 |
| Surgical wound infection | | 2 |
| Cast-related | | 2 |
| Osteomyelitis | | 1 |
| Prominent nail requiring trimming | | 1 |
| Total | | 17 |

SD: Standard deviation.

## DISCUSSION

The reported complication rate for TEN fixations varied widely in the literature. Ho *et al.* found a 17% rate of complications, while Flynn *et al.* observed complications in 31.5% of cases.[8,9] In contrast, Sebaei *et al.* reported a much higher rate of complications (65.1%).[10] This study's complication rate was lower than those reported in previous studies. Out of 48 patients between the ages of 4 and 11 with a weight <49 kg treated with TEN, four patients (8.3%) only developed complications. These were prominent nail-causing irritation and swelling ($n$ = 1), a surgical site infection ($n$ = 1), an LLD of 2.5 cm that required surgical correction ($n$ = 1), and 15° varus angulation ($n$ = 1). This variation in complication rate is attributed to several factors, including but not limited to the type of complication being reported, the characteristics of the patients being studied, the methodology of research, and the center's experience.

**Table 3:** Factor associated with limb length discrepancy.

| Variables | Limp length discrepancy Mean±SD/*n* | | *P*-value |
|---|---|---|---|
| | Yes | No | |
| Age (years) | 10.2±3.8 | 8±3.3 | 0.18 |
| Fracture pattern | | | |
| Stable | 1 | 53 | 0.02 |
| Unstable | 4 | 17 | |
| Open fracture | 1 | 2 | 0.189 |
| Non-union | 2 | 3 | 0.01 |
| Weight (kg) | 48.2±21.8 | 31±15.9 | 0.032 |
| Time to definitive fixation (h) | 57.2±23.3 | 21.81±17.5 | <0.001 |

SD: Standard deviation.

Therefore, it is difficult to directly compare the complication rates of different studies.

A short length of the rod is typically left protruding from the bone after TEN fixations to facilitate retrieval. This may cause significant skin irritation if the rod protrudes excessively or is misaligned. Consequently, some patients may require revision surgery to re-advance, trim, or remove the nail early. In fact, this was the most reported complication following TEN fixations.[6,11] In the original study by Ligier *et al.*, who pioneered this technique, 10.5% (13/123) experienced skin ulceration or tissue swelling caused by a prominent nail.[12] All these patients required further surgery; three required the nail to be reintroduced, while the remaining 10 required the nail to be trimmed. However, later studies had shown a decrease in this complication's prevalence.[13,14] Flynn *et al.* reported that only 7% (4/58) of their patients had soft tissue irritation caused by prominent nails, which necessitated nail removal in one case.[9] Similarly, in this study, only one out of 48 patients experienced skin swelling at the entry site, which required nail trimming. This decrease in prevalence may be attributed to the learning curve effect and the introduction of new instrumentation that allows for nail removal when only a few millimeters are left extra-osseous. Moreover, the use of end caps has reduced the risk of soft tissue irritation and nail back-out.

Angular malunions are more common than rotational malunions after TEN fixations.[6,8,11] However, the rate of clinically important malunion requiring intervention had been low. A retrospective analysis of 70 femur fractures by Sagan *et al.* found that angular malunion occurred in 16 (22.8%) cases without rotational malalignment.[15] Of the 16 fractures, 11 had an anterior bow >15°, five had a varus deformity >10°, and two had a valgus deformity >10°. Similarly, Ho *et al.* showed that out of 94, 16 (17%) had angular malunion.[8] Of these, 14 had a sagittal malalignment >15°, and one had a coronal malalignment >10°. At nine months post-operative, these malalignments had been remodeled. However,

this study reported low malunions, with only one of 48 fractures having 15° varus angulations that remodeled at the final follow-up at 30 months. This study did not investigate the factors associated with these malunions, as only one fracture had this complication. Luhmann *et al.*, Sagan *et al.*, and Moroz *et al.* analyzed these factors and concluded that increased weight may contribute.[6,13,15] Ho *et al.* reported that the prevalence of angular malunion increased with age, but this was not statistically significant.[8]

Lower limb inequality is relatively common following TEN fixation, usually due to overgrowth, but can be due to shortening, especially in comminuted fractures. Several authors have documented that LLD can reach ≥10 mm following IM nailing.[8,11,16] Nevertheless, it rarely reaches clinical significance due to the remodeling potential in the pediatric age group. Ho *et al.* reported that 12% of patients (11/91) had an increased limb length of more than 1 cm.[8] However, after 24 months, only two had an LLD >2 cm, one due to overgrowth and the other due to shortening. Both patients were treated with distal femoral epiphysiodesis. Similarly, in this study, with an average follow-up of 29 months, only one child out of 48 had an LLD of 2.5 cm due to overgrowth requiring epiphysiodesis [Figure 1].

Since plating is typically used for more complicated fractures, the rates of non-union, LLD, and infection are expected to be relatively higher. In this study, of 16 patients treated with SMP for unstable fractures, nine developed complications: four had LLD ranging from 1 cm to 4.5 cm, three had non-union, one had osteomyelitis, and one had surgical site infection. Among the four cases of LLD, two were associated with non-union, and one was also associated with osteomyelitis due to an open fracture (Gustilo IIIB). The complication rate in this study is higher than in other studies, possibly due to the small sample size and the interrelated nature of the complications.[17,18]

The risk of LLD is not solely related to treatment modalities. The fracture itself may have an inherent risk of LLD. A multicenter study by Kim *et al.* reviewed 72 patients under 13 years old and found that length-stable fractures were associated with LLD.[19] Of nine patients with LLD >2 cm, eight had length-stable fractures. In contrast, Ho *et al.* and Park *et al.* compared stable and unstable fractures and found that LLD tended to be greater in the latter.[8,20] Likewise, this study found that unstable fractures were statistically significantly associated with LLD. Of five patients with LLD, four had unstable fractures and were treated with SMP. Another factor that may influence LLD risk is the patient's weight. Moroz *et al.* and Ulici *et al.* found that the weight of the child was a strong predictor of LLD in fractures treated with TEN.[4,13] Similarly, this study found that weight was associated with LLD, although the treatment differed. However, this significance was lost after adjusting the weight to the age.

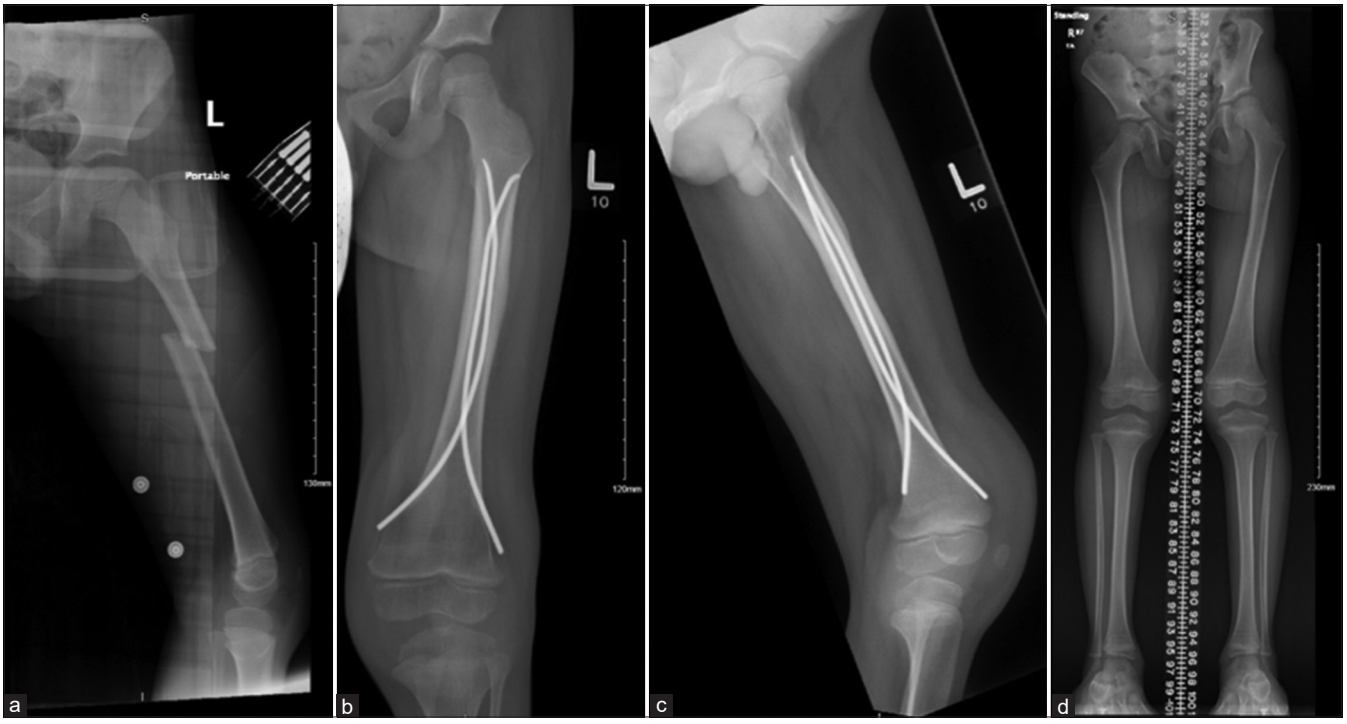


**Figure 1:** A 4-year-old child weighing 18 kg sustained a femoral shaft fracture following a motor vehicle accident. (a) Anterior-posterior radiograph made on the day of injury. (b and c) made at 12 months post-fixation with titanium elastic intramedullary nail. (d) scanogram made 12 months post the nail removal and 48 months after the injury showing 2.5 cm limb length discrepancy.

In pediatric patients, IM rigid nail fixation may result in avascular necrosis (AVN) of the femoral head, which although rare, can be a devastating complication of rigid IM nailing. A systematic review by Plost *et al.* reported five cases of AVN with piriformis entry, two cases with tip of greater trochanter entry, and no cases with lateral greater trochanter entry among 458 patients aged 6–18.[21] In this study, eight patients were treated with rigid nails using lateral greater trochanter entry, and none had developed AVN or proximal femur deformity.

The optimal timing of definitive fixation in time in pediatrics remains controversial.[22-25] Mendelson *et al.* reported that early fracture stabilization within 48 h is associated with fewer days in the hospital and intensive-care unit.[23] However, they have found no difference in LLD between the two groups. Their study's small number of LLD patients ($n = 1$) may have rendered an insignificant association. Our study found that a delay in definitive fixation time was associated with increased odds of having LLD by 1.1-fold ($P = 0.045$).

Since a lesser portion of femur shaft fractures in children are treated operatively, a small sample size is one of the limitations of this study. Furthermore, a retrospective rather than a prospective data collection may possess some confines. Therefore, larger multicenter prospective cohort studies are recommended to assess the associated complications, including the relation between fracture stabilization time and LLD. Although this study suggests that delay in fracture stabilization is a risk factor for LLD, the study design cannot confirm this hypothesis.

## CONCLUSION

Femur shaft fractures in children have excellent outcomes due to remolding potential in this age group. Few complications were observed in this study. Of these complications, only LLD was significantly associated with weight, fracture pattern, non-union, and definitive fixation time. A delay in definitive fixation time was associated with increased odds of having LLD.

### Recommendation

The treatment should be tailored to the patient's condition. The optimal timing of fixation for fractures is still being debated. Early fixation is generally recommended, but further research is needed.

## AUTHOR'S CONTRIBUTIONS

YIA, AMA, and SAA conceived and designed the study, conducted research, provided research materials and collected and organized data. SAA and LMA analyzed and interpreted data. All authors wrote the initial draft of the article and provided logistic support. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

## ETHICAL APPROVAL

The Institutional Review Board (IRB) at King Abdullah International Medical Research, Riyadh, Saudi Arabia, approved this retrospective study on April 19, 2022, with the IRB approval number IRB/0813/22.

## DECLARATION OF PATIENTS CONSENT

The authors certify that they have obtained all appropriate patients consent forms for this study. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

## USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY FOR MANUSCRIPT PREPARATION

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

## CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

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