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Bone Overgrowth after Femoral Shaft Fracture in Children Managed by Operative Versus Non-Operative Techniques in Sulaimani City

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Abstract

Background and objectives: Femoral overgrowth is not related to age, fracture level, or fracture anatomical location. This study measures the amount of bone overgrowth in operative and non-operative ways to manage femoral shaft fractures in children.

Methods: In this prospective cohort study, 50 participants with femoral shaft fractures were recruited at Shar/Shorsh teaching hospitals from June 2022 to June 2023. We collected patients' socio-demographics and clinical data (fracture side, site, and the mode of the treatment they received). The participants were treated with various methods. Later, we assessed the mean shortening at the time of bone union and overgrowth after one year of follow-up by x-ray and clinical exam.

Results: Most shaft fractures were at the dominant side (74%), mid-femur (64%), and (52%) had undergone hip Spica. No-operatively managed cases comprised (52%). There was a significant difference in the femoral shortening before and after one year using the X-ray parameter (p=0.000). Moreover, a statistically significant difference (p=0.038) was seen in femoral overgrowth after one year of follow-up by x-ray assessment only. Additionally, non-significant differences were noted between all treatment types (hip Spica, plate and screw, elastic nail, and closed reduction + external fix) in femoral shortening at the time of union/femoral overgrowth using both x-ray and clinical assessment following a year.

Conclusion: No significant difference was noticeable in the amount of bone overgrowth between operative and non-operative managements that caused no laming or restriction of daily activities.

Keywords: Bone overgrowth, Bone shortening, Clinical assessment, Comparative study, Fracture management, X-ray.

Introduction: Children frequently suffer femoral shaft fractures, which account for around 1.6% of total pediatric fractures. Boys experience femoral shaft fractures at a higher rate than girls do at all ages.[1] Management modalities for pediatric femoral shaft fractures encompass immediate or late hip spica casting, fixating externally, flexible or complex intramedullary nailing, and plate fixation. Treatment planning considers several factors, such as the patient's age, weight, fracture pattern, and the choice of the clinician.[2] The most common consequence after pediatric femoral shaft fractures is a leg-length discrepancy LLD because of the extra growth of the injured femur.[3] Evidence from the literature suggests that pains from the lower back and hip and stress fractures can be related to LLD.[4] There are five categories for classifying developmental markers in lower limb length disparities. Type 1: upward slope pattern; the lower limb length discrepancy develops and escalates with age, with an identical proportional pace. Type 2: upward slope-deceleration pattern; the lower limb length discrepancy increases at a stable pace but at different times and then demonstrates a decrease in acceleration, which is unrelated to skeleton growth. Type 3: upward slope-plateau pattern; this divergence increases over some time in the beginning, but it will stay constant for the rest of the growth period. This class is subdivided into A & B subtypes. Type 4: upward slope-plateau-upward slope pattern; this discrepancy first accelerates, then remains constant for a specific time, and then accelerates one more time until growth completion. Type 5: upward slope-plateau-downward slope pattern; this unmatching accelerates with time, becomes stable, but later declines without operation.[5] Most of the excessive growth proved to happen in one year and a half after the fracture. The reason behind that is a physiological process related to posttraumatic activation of the growth plate. Since the overgrowth rate is almost 10 mm.[6] Juniors who sustain fractures to the femur's shaft do not experience difficulties with the union. Still, these fractures have frequently been studied for angulation, rotation, and overgrowth of the broken femur.[7] The eventual difference in length between the femur shafts depends on the degree of overgrowth, which Truesdell initially documented in 1921.[8] Understanding the causes of overgrowth is crucial for adjusting the overriding of the fracture fragments to minimize any length disparity that could occur in the final stage of healing.[9] There is disagreement on the quantity, temporal evolution, and other elements that affect overgrowth. The growth plate's stimulation causes the overgrowth, which is thought to be a physiological reaction to the growth plate's posttraumatic hyperemia.[10] Measurements are done clinically from anterior-superior iliac spine to medial knee joint line by tape measure and comparing it to the uninjured side.[1] Femoral length measurements were performed using the Synapse PACS software by measuring the distance from the center of the femoral head to the distal-most point along the articular surface of the lateral femoral condyle on full length anteroposterior femur radiographs.[11] The measurements applied for detecting the overgrowth after one year of follow up are outlined in the figures 1 and 2 below.

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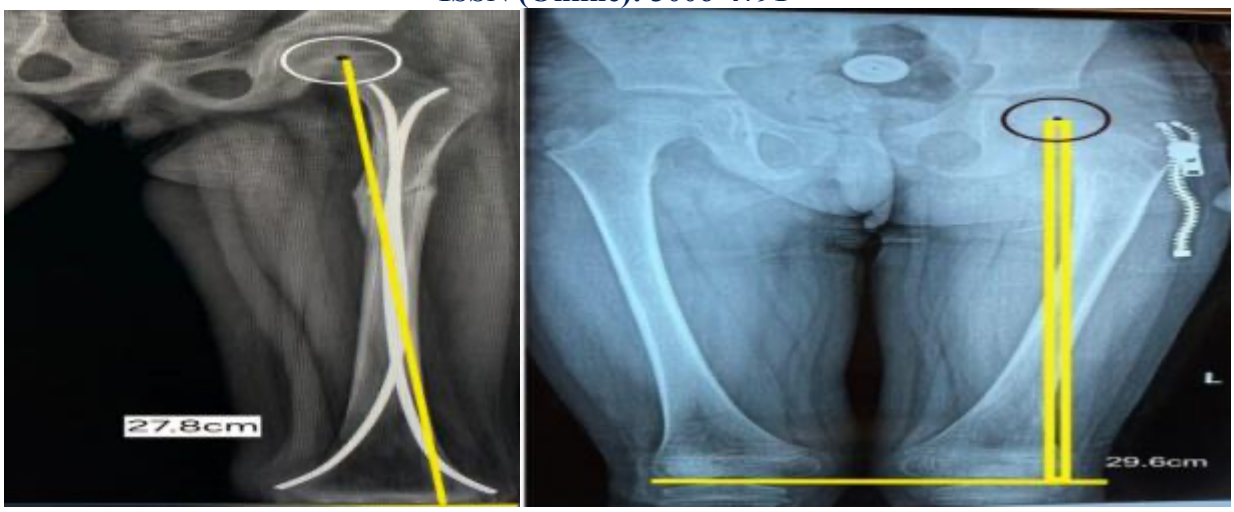

Figure (1). 7 years old girl with mid-shaft femoral fracture (RTA) managed by titanium elastic nails, clinical measure is 0.4 cm overgrowth.

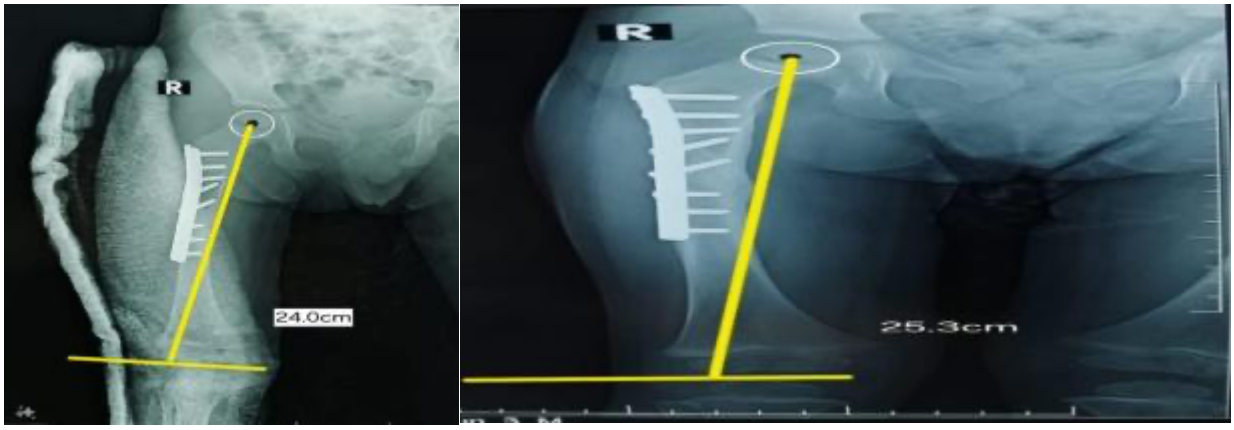

Figure (2). Shows 2 years old boy with proximal one-third femoral shaft fracture after road traffic accident managed by open reduction and internal fixation by plate-screws, clinical measure is 0.3 cm overgrowth.

We intend to identify potential factors that may expedite this event by evaluating the disparity in femoral length and the rate of femoral overgrowth one year after union following femoral diaphyseal fracture in children in Sulaimani city of Iraq.

Patients and methods: In this prospective cohort investigation, 50 pediatric participants with femoral shaft fractures were recruited at Shar/Shorsh Teaching Hospitals from June 2022 to June 2023. The age group of the participants was 1-13 years with femoral shaft fractures, regardless of gender. Patients with pathological fractures, metabolic bone diseases, congenital

anomalies, cerebral palsy, and open fractures were excluded from the study. Then, the participants were divided into two groups who were either managed by operative or non-operative methods. Then, the mean shortening at the time of union and bone overgrowth after one year of treatment was evaluated by x-ray and clinical examination using a tape measure. Then, we collected patients' Socio-demographic characteristics (age and gender) and clinical data, including fracture side, fracture site, and the type/mode of treatments they received. Children with femoral shaft fractures were managed by an Orthopedics expert team using either:
Closed reduction and holding by hip Spica.
Closed reduction and internal fixation (elastic nail),
Sub-muscular plating by minimally-invasive plate osteosynthesis or open reduction internal fixation (plate and screw),
Closed reduction + external fixation.
The Scientific and Ethical Committee of the Kurdistan Higher Council of Medical Specializations (KHCMS) revised and accepted the study protocol. Patients and their parents provided written informed consent. Before starting the study, they were given the right to leave the study at any time they desired without giving a reasonable excuse.
Statistical Package for the Social Sciences SPSS from IBM V.24 was used for data analysis. Data tabulation was expressed as numbers and percentages for categorical data and mean ± standard deviation (SD) for numerical data. The T-test was used for categorical variables, while the analysis of variance (ANOVA) test was used to measure the differences in numerical variables. P-value considered as highly significant ($p<0.001$), significant ($p<0.05$), non-significant ($p>0.05$), and very highly significant ($p<0.000$).

Results: Participants were 6 ± 2.92 years, with a median of 6.07 years. The majority of the patients were males (64 %) and aged <5 years (50 %), while the minority were between 10-13 years (8.0 %). The treatment modality was routed as 26 patients (52%) for non-operative and 24 for operative management, as is figured out in table (1). Thirty-seven patients had fractures on the dominant leg (74%) and 13 on the non-dominant leg (26%). Seven patients had fractures in the distal femur (14%), 32 in the middle (64%), and 11 in the proximal (22%). Those who were managed by hip spica were (52%), three patients received plate and screw (6%), 19 received elastic nails (38%), and only 2 participants (4%) underwent closed reduction and external fixation.

Table (1). Shows the sociodemographic and clinical data of studied patients.

Variable		Frequency	%
Sex	Male	32	64
	Female	18	36
Age (Years)	<5	25	50
	5-10	21	42
	10-13	4.0	8.0
Fracture Side	Dominant	37	74
	Non-Dominant	13	26
Fracture Site	Distal	7.0	14
	Middle	32	64
	Proximal	11	22
Treatment Type	Closed Reduction And Hip Spica	26	52
	Open Reduction And Internal Fixation /Plate And Screw	3.0	6.0
	Closed Reduction And Elastic Nail	19	38
	Closed Reduction + External Fixation	2.0	4.0
Treatment Modality	Non-Operative	26	52
	Operative	24	48
Total		50	100

Consequently, the mean femoral reduced at the time of union measured by accurate size x-ray was 1.4680 ± 0.358 cm, while clinically, it was 0.82 ± 0.261 cm. Femoral overgrowth after one year measured by x-ray was 1.112±0.479 cm, and by clinical examination was 0.520±0.325 cm. Both techniques showed a significant difference (p=0.000) in the femoral shortening before and after 1-year follow-up, table (2) has outlined it.

Table (2). Shows the patient's femoral shortening during union and femoral overgrowth after one year of follow-up.

Variable	Mean ±SD (Cm)	T-Test	P-Value
Femoral Shortening At The Time Of Union By X-Ray	1.468±0.358	5.22	0.000**
Femoral Overgrowth After One Year By X-Ray	1.112±0.479		
Femoral Shortening At The Time Of Union By Clinical Examination	0.820±0.261	5.32	0.000**
Femoral Overgrowth After One Year By Clinical Examination	0.520±0.325		

**: Highly significant difference using parried samples t-test

Furthermore, femoral shortening at the time of union by x-ray using non-operative modality was reported to be the highest (1.519±0.332 cm), while femoral overgrowth after one year by clinical examination using operation reported the lowest (0.512±0.305 cm). Thus, using an x-ray after 1-year, a significant difference (p=0.038) was seen in femoral overgrowth between both treatments (operative and non-operative). However, non-significant differences (p>0.05) were found between both treatment modalities (operative and non-operative) for shortening at the time of union using either x-ray or clinical assessment after 1-year, as in table (3).

Table (3). Comparison between treatment modalities of shortening at the time of union by x-ray and clinical assessment after one year.

Variable	Treatment Modality	Mean±SD (Cm)	T-Test	P-Value
Femoral Shortening At The Time Of Union By X-Ray	Non-Operative	1.519±0.332	1.052	0.298
	Operative	1.412±0.384		
Femoral Shortening At The Time Of Union By Clinical Examination	Non-Operative	0.861±0.256	1.172	0.247
	Operative	0.775±0.265		
Femoral Overgrowth After One Year By X-Ray	Non-Operative	1.246±0.517	2.132	0.038*
	Operative	0.966±0.396		
Femoral Overgrowth After One Year By Clinical Examination	Non-Operative	0.526±0.349	0.155	0.878
	Operative	0.512±0.305		

*: Significant difference using independent samples t-test

Moreover, femoral shortening at the time of union using x-ray assessment for various treatment ways (hip Spica, plate and screw, elastic nail, and closed reduction + external fix) was reported at the highest level. On the contrary, femoral overgrowth after 1-year by clinical examination produced the lowest rate. However, non-significant differences were noted among all the treatment modalities (hip Spica, plate and screw, elastic nail, and closed reduction + external fix) in the femoral shortening at the time of union/femoral overgrowth using x-ray and clinical examination scales after one year, as shown in table (4).

Table (4). Comparison between treatments of femoral shortening at the time of union by X-ray and clinical assessment after one year.

Variable	Treatment Type	Mean±SD (Cm)	F-Test	P-Value
Femoral Shortening At The Time Of Union By X-Ray	Hip Spica	1.519±0.332	0.429	0.733
	Plate And Screw	1.40±0.400		
	Elastic Nail	1.426±0.410		
	Closed Reduction + External Fixation	1.30±0.141		
Femoral Shortening At The Time Of Union By Clinical Examination	Hip Spica	0.861±0.256	0.898	0.451
	Plate And Screw	0.933±0.305		
	Elastic Nail	0.757±0.271		
	Closed Reduction + External Fixation	0.70±0.141		
Femoral Overgrowth After One Year By X-Ray	Hip Spica	1.246±0.517	1.728	0.174
	Plate And Screw	0.933±0.404		
	Elastic Nail	1.00±0.415		
	Closed Reduction + External Fixation	0.70±0.141		
Femoral Overgrowth After One Year By Clinical Examination	Hip Spica	0.526±0.349	0.091	0.965
	Plate And Screw	0.533±0.230		
	Elastic Nail	0.521±0.332		
	Closed Reduction + External Fixation	0.40±0.141		

Discussion

Participants were 6 ± 2.92 years; the majority were aged less than five years (50%) and were males (64%). The majority of the children had fractures in the dominant leg (74%) and in the middle of the femur (64%). These outcomes were mainly similar to those found by Engström et al. who mentioned that most pediatric patients were males (64%) who had femoral fractures on the shaft (64%) with a bimodal age distribution peak among 2–3 and 16–19 year.[12] Generally, pediatric fractures occur when the child starts to walk, then during more high-energy activities such as motor crosses and rough plays that happen more commonly among boys than girls.[13] Femoral shaft fractures were the dominant fracture in this study, which aligned with Loder et al. [14] and Engström et al.[12] The percentage of shaft fractures was higher among the younger group than among the adults.[15] Most patients underwent non-operative treatment (52%), and the rest

underwent operation (48%). It has been mentioned that non-operational management is more common in younger age groups, while the prevalence of operational management increases with age. Jain et al. mentioned that surgical management is usually the most chosen option in pediatrics shaft fractures. It decreases hospitalization time and morbidity, which lets the child go back to school earlier.[16] Treatment modalities used were hip Spica (52%), elastic nail (38%), plate, and screw (6%), followed by the least performed procedure; closed reduction and external fixation (4%). Our findings agree with those reported by Heineken et al. showed that the external fixation and traction maneuvers declined in 1987 and were replaced with intramedullary elastic nails.[13] Broadman et al. suggested that stable and non-displaced trans-physeal fractures can be treated with Spica casting in children less than 5.[17] All displaced fractures in children older than five years of age require surgical fixation using elastic nails, screws or plate fixation.[18] Moreover, the operator's approach shows a vital value in selecting the management method.[19] From 5 years onwards, intramedullary nailing was the most common surgical way for managing femoral shaft fractures (external fixation and traction were only used infrequently).[20] Shapiro F. classified patterns of lower limb discrepancies in five types. Type 1: After age two, the pattern will change in many radiographic assessments of length, which will be sufficient to determine the final disparity accurately. Type 2 is the most challenging pattern to show because the discrepancy shows a lowering rate of increase that varies among individuals and conditions. Thus, this group has to be closely watched. Type 3: when a plateau is completed, the lower limb length discrepancy will remain constant for the rest of the growth period. Type 4: discrepancies typically are discovered following hip diseases in juniors that affect the proximal femoral capital epiphysis, like septic arthritis of the hip, leg-Perthes disease, avascular necrosis of the femoral head, early closure of the proximal femoral capital epiphysis can happen after discrepancy has stayed in plateau phase. Type 5: if the discrepancy is starting self-correction, the growth charts are referred to see how much growth is pending.[5] Additionally, the mean femoral shortening at the time of union measured by x-ray was 1.4680±0.358 cm (≈14.7 mm), while it was 0.82±0.261 cm (8 mm) by clinical examination. Consequently, after 1-year follow-up, the femoral overgrowth measured by x-ray was 1.112±0.479 cm (11 mm), and by clinical examination was 0.520±0.325 cm (5 mm). There is a significant difference (p=0.000) between femoral shortening (4.6 mm) and femoral overgrowth (3 mm) before and after 1-year of follow-up in both techniques. However, x-ray yields better investigation results for shortening and overgrowth measurements. These outcomes comply with those found by Al-mukhtar et al. who reported an average of 7 mm and 6 mm femoral bone shortening at the time of union by x-ray and clinical examination, respectively. They also showed an average of 4 mm and 8 mm bone overgrowth after one year of clinical and radiological follow-up.[1] On the other hand, femoral shortening/overgrowth rates at the time of union were almost the same in both non-operative and operative cases using either x-ray or

clinical examination (p≥0.05). On the contrary, an x-ray after 1-year showed a notable difference (p=0.038) in femoral overgrowth. These findings rely on those of Gandhi et al. 2019 who announced that in children receiving conservative treatment, there is a positive link between the initial shortening and future growth of the broken femur.[21] However, these outcomes are contrary to those found by Basener et al., who mentioned a limb length discrepancy (LLD) of >1.5 cm in 22% of pediatric patients and more clinically significant growth stop following conservative management (37%) in contrast to the surgery (27%).[22] Generally, the fractured femur may be short from fragments at the start, revoking at the time of unification; an increased rate of growth occurs to make up the difference, but often, this acceleration goes on, and overgrowth occurs.[1,23] By radiological assessment, overgrowth occurred in 100% of the cases, with an average of 8.4 mm. Average overgrowth in those with shortening of ≥10 mm at the time of union was 12 mm, and for those with shortening of <10 mm, was 8 mm, as in figure (3).[24] However, non-significant differences (p≥0.05) were seen among all the procedures (hip Spica, plate and screw, elastic nail, and closed reduction with external fixation) regarding femoral shortening at the time of union/femoral overgrowth using both x-ray and clinical assessment after 1-year.[25]

Although children below 2 years of age have less potential for overgrowth after femoral fracture, a mean increase in length of 0.85 cm can be expected in the affected femur.[26]

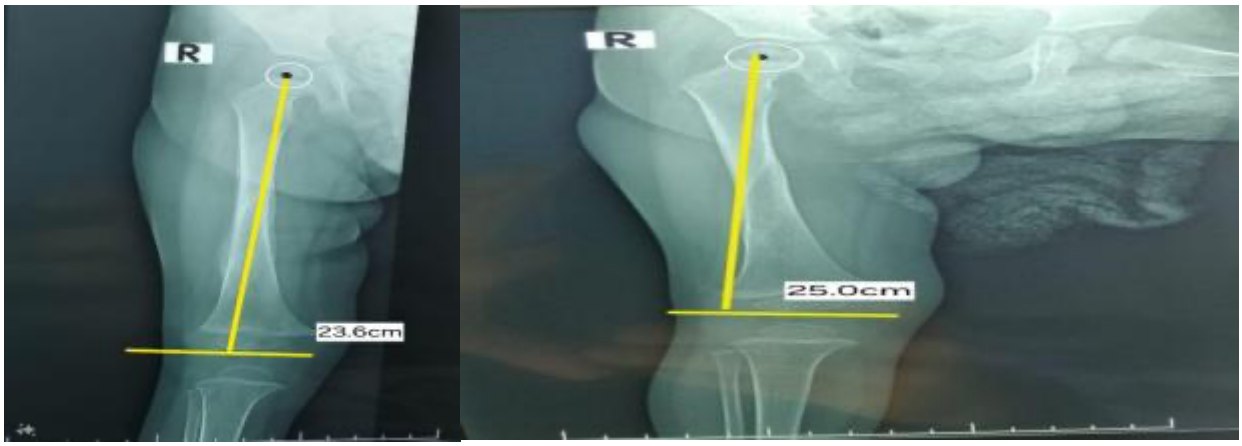

Figure (3). Describes 1.5 years old boy with mid-femoral fracture, fall from mother lab managed by Spica, clinical measure is 0.6 cm overgrowth.

Conclusion: Femoral shaft fracture is more common among pediatric males under five years of age, especially on the dominant side. Bone overgrowth was not affecting daily activities in almost all those who were managed by either operative or non-operative methods as the discrepancy measurement was more noticeable by x-ray than by clinical assessment. X-ray is,

thus, considered a preferable measurement tool to determine the amount of bone overgrowth in operative and non-operatively managed femoral shaft fractures in children.

Recommendations: Greater sample size and long-term follow-up till skeletal maturity are recommended for future work-up to determine the effect of age, gender, fracture type, site location etiology, and its proposed management option on the rate of femoral bone shortening and bone overgrowth at the time of union and after one year of follow-up in pediatric age groups.

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