Management of Length Unstable Pediatric Femoral Fracture by Elastic Nails

El Sayed Said[a], Mohammed Fathy Amin[a], Hossam Ahmed Attya[a], Mohamed El-Sayed Anwar Kenawy[a*]

[a]Department of Orthopedic Surgery & Traumatology, Faculty of Medicine, South Valley University, Qena, Egypt

Abstract:

Background: The management of pediatric femoral shaft fractures in skeletally immature, school-aged children have markedly evolved over time to increasingly favor surgical intervention. Historically predominant techniques of nonoperative immobilization have been replaced with operative fixation as the present standard of care for these injuries,

Objectives: To investigate the outcomes of skeletally immature children with length unstable femoral shaft fractures treated with elastic nails.

Patients and methods: This prospective study was conducted at the Orthopedic surgery Department of Qena University Hospital and Horus Hospital in luxor . The study included 100 patients with femoral shaft fractures treated with elastic nails that had a minimum of 6 months follow-up.

Results: The mean follow-up period was 9.5 ± 1.5 months. No statistically significant difference was found between groups regarding major or minor postoperative complications, including loss of reduction, nonunion, refracture, symptomatic hardware, and malunion.

Conclusion: Elastic nails are a safe and effective choice for operative fixation of length unstable femoral shaft fractures in children.

Keywords: Length-unstable; Femoral fracture; Elastic nail; Complication.

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***Correspondence**: ma5450964@gmail.com

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Introduction

Management of pediatric femoral shaft fractures in skeletally immature children has markedly evolved over time and surgical fixation become more popular. **(Li and Hedequist, 2012)**.

Methods for surgical fixation of pediatric femoral shaft fractures include external fixation, rigid antegrade intramedullary nailing, submuscular bridge plating, and elastic stable intramedullary nailing (ESIN) with either stainless steel or titanium elastic nails **(Ellis et al., 2011; Busch et al., 2019)**. Studies have attempted to identify the most effective and safest method of operative fixation for pediatric femoral shaft fractures, but controversy continues regarding optimal treatment for these injuries **(Ramseier et al., 2010)**.

The established advantages of ESIN include early mobilization, shorter hospitalization, and less invasive dissection compared with alternative surgical techniques **(Porter et al., 2012)**. ESIN also avoids major complications inherent to other methods of operative fixation, such as refracture and pin tract infection following external fixation or avascular necrosis after rigid antegrade intramedullary nailing **(Siddiqui et al., 2020)**.

Current indications for flexible intramedullary nailing for pediatric femoral shaft fracture include age between 5 and 11 years, weight less than 50 kg, and length stable fracture pattern. However, the strength of this recommendation has been rated as limited by the American Academy of Orthopedic Surgeons **(Siddiqui et al., 2020)**.

The aim of our study is to investigate the outcomes of fixation of length unstable femoral shaft fractures by elastic nail in pediatric population .

Patients and methods

This was a prospective cohort study carried out at the Department of Orthopaedic surgery and Traumatology at Qena University Hospital and Horus hospital in Luxor between 2019 to 2022 year . The study was approved by the Research Ethics Committee of our institution. Informed consent was obtained from the participants' parents.

Inclusion criteria

- Age 5 to 11 years.
- Weight < 50 Kg.
- Closed femoral shaft fractures

Exclusion criteria

- Age 11 years or above.
- Weight > 50 kg.
- Pathologic fracture.
- Neuromuscular disorders.
- Metabolic bone disease previous femur fracture or instrumentation

All patients underwent initial resuscitation, followed by thorough history taking (age, gender, comorbidities, mode of trauma) general examination (vital signs, associated injuries) and regional examination (skin integrity, local swelling, and gross deformity, neurological and vascular injuries).

AP and lateral plain radiographs were obtained to determine length stability. The femoral fractures were classified into two groups: length unstable (spiral, comminuted, or long oblique) or length stable (transverse and short oblique).

Surgical Technique

1- All procedures were performed under general anesthesia in a supine position on a radiolucent operating table.
2- Closed reduction was achieved in all patients guided by intraoperative fluoroscopy except 2 cases with stable length fracture were reduced by open reduction.
3- The skin was incised at the point of ESIN entry, and an extension was made distally as needed, followed by splitting of fascia and muscle to expose the femoral cortex.
4- At 2 cm above the epiphyseal plate, the femoral canal was opened using an awl under image guidance. Then, the awl was advanced cautiously (to avoid violation of the far cortex) at 45 degrees to create an oblique canal.

5- The ESIN were introduced through lateral and medial entry points in an oscillating manner into the intramedullary canal and processed proximally towards the fracture site. Both nails should accommodate 70 - 80% of the narrowest width of the femoral medullary canal (**Flynn et al., 2001**). The canal fill achieved using ESIN was measured for each patient. Canal fill is defined as the sum of the diameters of the femoral intramedullary nails divided by the width of the femoral intramedullary canal.
6- Lateral and medial ESIN were then advanced proximally towards the greater trochanter and femoral neck, respectively (**Fig.1**).

Postoperative care

All patients were treated with immobilization using a knee immobilizer for approximately 4 weeks**.**

Patients started knee motion exercises after 4 weeks.

Patients started weight bearing after 6weeks of operative fixation.

Patients were followed by X-rays at 6weeks, 3 months, 6 months postoperatively

Radiographic measurements

Femur length was measured from the most superior aspect of the femoral head to the most inferior aspect of the medial femoral condyle.

Angulation was measured as the angle between the anatomic axes of the proximal and distal fracture fragments, and angular deformity is defined as coronal angulation > 10 degrees or sagittal angulation > 15 degrees.

Outcome measures

Complications were categorized as either minor or major complications. Major complications are those, that necessitate revision surgery before fracture union Minor complications are those that did not require revision surgery before fracture union, such as a minor femur length discrepancy or angular deformity which do not limit patient functionality.

Statistical analysis

All data were collected, tabulated and statistically analyzed using SPSS 26.0 for windows (SPSS Inc., Chicago, IL, USA). Qualitative data were described using number and percent. The Shapiro–Wilk test was used to verify the normality of distribution. Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. All statistical comparisons were two tailed with *P* value less than .05 used to declare statistical significance.

Results

The mean follow-up period of the entire study population was 9.5 ± 1.5 months. (**Table.1**) demonstrates the basic demographic data including age, gender, weight, mode of trauma, length stability, and follow-up duration. We had no cases of infection or knee stiffness and we found no significant deference in LLD at final fellow up

Fig.1. Length stable femoral fracture with early fellow up and fellow up after 1 year

Table 1. Patient Demographics

Variables	**Study Population (n = 100)**
Age (years)	
Mean ± SD	7.5 ± 2.7
Range	4 – 10
Weight (kg)	
Mean ± SD	35.2 ± 6.1
Range	22 – 43
Gender	
Male	55 (55%)
Female	45 (45%)
Mode of Trauma	
Road traffic accident	50 (50%)
Falling from height	25 (25%)
Sports injury	25 (25%)
Type of Fracture	
Length stable	45 (45%)
Length unstable	55 (55%)
Follow-up (months)	
Mean ± SD	9.5 ± 1.5
Range	6 – 18

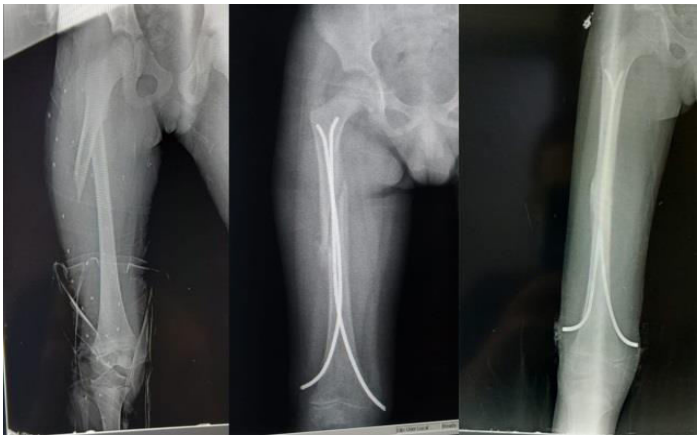

Fig. 2. Length unstable femoral fracture with early fellow up and fellow up after 1 year

Surgical Outcomes

As shown in (**Table.2**), there was no statistically significant difference between length stable and length unstable femoral fractures regarding surgical time, fluoroscopy time, duration of hospital admission, union time, and time to ESIN removal**.** We found no significant deference in LLD at final fellow up

Table 2. Surgical Outcomes (n = 100)

Variables	Length Stable (n = 45)	Length Unstable (n = 55)	*P* value
Surgical Time (min)			.551
Mean ± SD	52.3 ± 4.7	51.1 ± 6.1	
Range	35 – 75	33 – 73	
Fluoroscopy Time (sec)			.332
Mean ± SD	72.5 ± 5.2	70.8 ± 1.2	
Range	42 – 95	41 – 94	
Hospital Stay (days)			.288
Mean ± SD	2.9 ± 0.5	3.0 ± 0.6	
Range	1 – 5	1 – 6	
Union Time (weeks)			.261
Mean ± SD	5.7 ± 1.1	6.1 ± 2.1	
Range	4 – 8	4 – 8	
Time to ESIN Removal (months)			.528
Mean ± SD	8.8 ± 2.4	9.0 ± 1.1	
Range	7 – 12	7 – 13	

Independent sample t test

Complications

In the length stable group, two (4%) patients suffered from major complications, while 19 (42%) complained of symptomatic hardware, and two (4%) developed angular deformities secondary to malunion. In the length unstable group, four (8%) patients developed major complications such as nonunion and loss of reduction, whereas 24 (44%) patients had symptomatic hardware as a minor complication. We had no cases of infection or knee stiffness and No statistically significant difference was found between the two groups regarding postoperative major or minor complications ($P > .05$) (**Tables 3 and 4**).

Table 3. Major Complications (n = 100)

Variables	Length Stable (n = 45)		Length Unstable (n = 55)		*P* value
	No.	%	No.	%	
Loss of Reduction	0	0	2	4	.451
Non-union	0	0	2	4	.560
Refracture	2	4	0	0	.288

Chi-square test.

Table 4. Minor Complications (n = 100)

Variables	Length Stable (n = 45)		Length Unstable (n = 55)		*P* value
	No.	%	No.	%	
Symptomatic Hardware	19	42	24	44	.352
Malunion	2	4	0	0	.420

Chi-square test.

Discussion

The main findings of our study were that ESIN provide a safe and effective method for fixation of pediatric femoral fracture regardless of length stability.

Several techniques have been described in the literature for the management of pediatric femoral fractures, including external fixation, rigid nailing, and submuscular plating. However, significant complications have been repeatedly reported. External fixation may seem as a rapid and less invasive fixation modality **(Andreacchio et al., 2016)**. However, pin tract infections and refracture represent a noticeable drawback **(Guo and Su, 2021) (Ramseier et al., 2010)**. Regarding rigid nailing, there is a high risk of growth disruption and avascular necrosis of the proximal femoral epiphysis.

On the other hand, previous studies have demonstrated the safety and efficacy of ESIN as the treatment of choice in paediatric femoral fractures. **(Chen et al., 2020)** have carried a meta-analysis in which a significantly lower incidence of adverse events such refracture, surgical site infection, limb length discrepancy, and non-union was reported. Similar results were achieved by **(Ramseier et al., 2010)**, who compared ESIN to other fixation methods in more than 180 pediatric patients presented with femoral fractures. They concluded that the lowest incidence of adverse events was associated with ESIN.

Although ESIN has proven both its safety and effectiveness, there has been a controversy on the role of ESIN in length unstable femoral fractures. A study by **(Frei et al., 2019)**, demonstrated two cases of rotational malalignment following fixation of length unstable femoral fractures using ESIN. Consequently, more than 25% of patients had poor functional outcomes. On the contrary, another cohort with length unstable femoral fractures were fixed with ESIN showed favorable functional and radiological results **(Lu et al., 2022)**.

Our findings were comparable to the results of previous studies. We found that the use of ESIN, in the context of length unstable fractures, had the ability to preserve length, with minimal rotational malalignment and early postoperative mobilization and weight bearing. In addition, it does not completely seal the medullary cavity, and endosteal callus formation is not inhibited **(Lascombes et al., 2013)**.

In our study, two (4%) patients suffered from major complications in the length stable fracture such as refracture and managed by sub muscular plating , while 19 (42%) complained of symptomatic hardware, and two (4%) developed angular deformities secondary to malunion. In the length unstable group, only two patients reported nonunion and loss of reduction, whereas 24 (44%) patients reported minor complications. No statistically significant difference was found between the two groups regarding postoperative major or minor complications. No cases of limb length

discrepancy or rotational deformities were reported in either group. Similarly, **(Nixon et al., 2022)** demonstrated that preadolescent children with length unstable femoral fractures are not at increased risk of femoral shortening or leg length discrepancy when treated with ESIN.

In accordance with our results, **(Siddiqui et al., 2020)** reported that mean time to union was 4.6 months, and there was no significant difference in mean time to union between the length stable and length unstable groups (P = .71). There was no significant difference between groups in the incidence of major complications requiring revision surgery (P = .68) and minor complications that did not require revision surgery (P > .99).Another study by **(Li et al., 2020)** compared ESIN versus submuscular plating for unstable femoral fractures. No significant difference was found between groups in terms of functional outcomes or postoperative major complications. Furthermore, ESIN group had less estimated blood loss, operative time and shorter hospital stay.

Conclusion

In children with femoral shaft fractures treated with elastic nails, there was no difference in the incidence of complications or reoperations between those with length unstable fractures and those with length stable fractures. Elastic nails are a safe and effective choice for operative fixation of length unstable femoral shaft fractures in children.

Ethical approval: The study was approved by the Research Ethics Committee of our institution code (332) .

Conflict of interest: The authors of the study have no conflict of interest related to this publication.

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