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Functional Outcomes of Femoral Shaft Fractures in Children Treated with Titanium Elastic Nailing

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Abstract **Original Research Article**

***Background*:** Pediatric femoral shaft fractures are common injuries with significant implications, requiring careful management to stabilize the fracture, maintain alignment, and reduce complications for the child and their family. This study aims to evaluate the functional outcomes of femoral shaft fractures in children treated with Titanium Elastic Nailing (TEN), focusing on its effectiveness as a minimally invasive treatment modality. ***Aim of the Study*:** The aim of the study was to evaluate the functional outcomes of femoral shaft fractures in children treated with titanium elastic nailing. ***Methods*:** This prospective observational study was conducted at the Department of Orthopedics and Traumatology, Dhaka Medical College Hospital, Dhaka from July 2017 to June 2019, involving 30 children aged 6-14 years with mid-diaphyseal femoral fractures. Preoperative evaluations and postoperative management, including limb rest, exercises, antibiotics, and pain management, were conducted. Data were analyzed with SPSS version 17, and ethical approval was obtained. ***Results*:** Among 30 patients, 66.7% achieved union within 7-10 weeks and 90.0% full weight bearing within 8-12 weeks. Only 6.7% had minor complications, and 76.7% showed no leg length discrepancies or malalignments. Most patients (70.0%) had knee motion >130°, with 73.3% returning to pre-injury activities. Flynn's TEN Scoring Criteria indicated predominantly excellent outcomes with minimal complications or pain. ***Conclusion*:** Titanium elastic nailing effectively treats pediatric femoral shaft fractures, promoting timely recovery and excellent functional outcomes with minimal complications.

Keywords: Femoral Shaft Fractures, Pediatric Orthopedics, Titanium Elastic Nailing, Functional Outcomes, Fracture Management.

INTRODUCTION

Femoral shaft fractures are a common injury in the pediatric population, accounting for approximately 1.6% to 2.2% of all bone injuries in children [1]. These fractures display a bimodal distribution: one peak occurs between 1 to 3 years of age, often resulting from low-energy incidents, while the second peak is observed during early adolescence, typically due to high-energy trauma such as motor vehicle accidents [2]. The male-to-female ratio for these fractures is 2.6:1, with boys being 2.6 times more likely to experience these fractures than girls [3, 4]. In children who are not yet walking, up to 80% of femoral fractures may be attributed to abuse, while high-energy injuries are the leading cause in older children [5-7]. Pediatric femoral shaft fractures are among the most common major injuries treated by orthopedic surgeons, with an incidence of 20-25 cases per lakh children annually [7].

The treatment of femoral shaft fractures in children depends on factors such as the child's age, the fracture's location, and whether it is open or closed. Traditionally, conservative methods like traction followed by plaster cast immobilization have been used,

particularly in younger children [8]. However, these approaches have drawbacks, including extended bed rest that isolates the child from their usual environment and the high costs associated with prolonged hospitalization [9]. For older children, non-operative treatments may result in complications such as malunion and loss of reduction, particularly as skeletal maturity nears [10]. Consequently, surgical options, including intramedullary nailing, external fixation, and internal fixation with plates and screws, have been explored. Among these, Titanium Elastic Nailing (TEN), also known as elastic stable intramedullary nailing, has gained popularity due to its minimally invasive technique, which facilitates quicker recovery and better functional outcomes for pediatric femoral fractures.

In pediatric femoral shaft fractures, the primary treatment goals are to stabilize the fracture, maintain appropriate length and alignment, promote bone healing, and reduce morbidity and complications for the child and their family [11]. Ideal fixation methods function as an "internal splint," sharing mechanical loads and maintaining fracture reduction until hard callus formation occurs, without disrupting the growth potential or blood supply of the femoral head [12]. Minimally invasive techniques offer several advantages, including reduced soft tissue trauma, quicker recovery, shorter hospital stays, earlier mobilization, and reduced psychosocial complications [13]. These benefits have contributed to the growing preference for flexible intramedullary nail fixation, which provides elastic stability to maintain alignment, enables rapid mobilization, supports early weight bearing, and ensures high patient satisfaction.

However, there is ongoing debate about the optimal treatment for children aged 6 to 16 years, as conservative approaches often lead to suboptimal outcomes, including angulation, shortening, and malrotation. Titanium Elastic Nailing (TEN) has emerged as the preferred stabilization method for this age group, promoting early fracture union through controlled micromotion at the fracture site, facilitating easy implant removal, and preserving the growth plate (physis) [14]. Despite its advantages, the adoption and availability of TEN remain limited in some regions, such as Bangladesh, where data on its effectiveness is sparse [15]. While several studies underscore its potential to meet the criteria of an ideal treatment modality, further research is essential to establish TEN as the definitive standard of care for this demographic. The purpose of the study was to assess the functional outcomes of femoral shaft fractures in children treated with titanium elastic nailing.

Objective

- The aim of the study was to evaluate the functional outcomes of femoral shaft fractures in children treated with titanium elastic nailing.

METHODOLOGY & MATERIALS

This prospective observational study was conducted at the Department of Orthopedics and Traumatology, Dhaka Medical College Hospital (DMCH), Dhaka, from July 2017 to June 2019 (24 months). The study population included all patients with mid-diaphyseal transverse, short oblique, or short spiral fractures of the femur with minimal comminution, in children aged 6 to 14 years admitted to the hospital for surgery during the study period. A total of 30 children were selected for this study.

Inclusion Criteria:

- Femoral mid-diaphyseal transverse, short oblique, or short spiral fractures with minimal comminution.
- Closed fractures of the shaft of the femur.
- All patients aged between 6 to 14 years.
- Fractures within 2 weeks of occurrence.
- Cases purposively selected irrespective of sex, occupation, mechanism of injury, and associated other injuries.

Exclusion Criteria:

- Open fractures of the shaft of the femur.
- Undisplaced fractures treated by non-operative method.
- Age below 6 years or above 14 years.
- Infected cases.
- Pathological fractures.

Informed consent was obtained from all participants, ensuring confidentiality, voluntary participation, and the right to withdraw at any time. A complete history regarding the cause and mechanism of injury, including duration, was taken. Initial resuscitation with intravenous fluids, blood, nonsteroidal analgesics, and antibiotics was performed. Routine investigations for anesthesia (blood counts, urea, serum creatinine, blood glucose, blood grouping, chest X-ray (Posterior-Anterior view), and ECG) were completed. Thorough preoperative evaluation and informed consent were taken, with all necessary implants and instruments prepared in advance. Pre-anesthetic check-ups were conducted, and preoperative antibiotics were administered intravenously just prior to the incision. Postoperative management included resting the limb on a pillow, initiating isometric quadriceps exercise the day after surgery, and continuing injectable antibiotics for 3 days followed by oral antibiotics for 7 days. Analgesics were administered initially intravenously and per rectum, then orally, with stitches removed on the 12th to 14th postoperative day. Plain X-rays of the thigh including hip and knee (AP and LV views) were taken post-surgery to assess stabilization, and patients were allowed to walk using crutches without weight bearing on the operated limb as long as pain was tolerable. Data were collected using a pre-tested structured questionnaire and analyzed with SPSS version 17 for descriptive and inferential

statistics. Ethical approval was obtained from the IRB of DMCH, with strict confidentiality maintained through special ID numbers and proper privacy during data collection and examinations.

RESULTS

Table 1: Duration of Union Time and Full Weight Bearing (n=30)

Variable		Number of patients	Percentage (%)
Union time (weeks)	7-10 weeks	20	66.7
	10-13 weeks	10	33.3
	Total	30	100.0
Weight bearing time (weeks)	8-12 weeks	27	90.0
	12-16 weeks	3	10.0
	Total	30	100.0

Among the 30 patients, radiological evaluation of the fracture site revealed that 20 (66.7%) cases achieved union within 7–10 weeks, while 10 (33.3%) cases united within 10–13 weeks, with a mean union time of 9.6 ± 1.9 weeks. Following union, full weight bearing was achieved in 27 (90.0%) patients within 8–12 weeks and in the remaining 3 (10.0%) cases within 12–16 weeks, with a mean full weight-bearing time of 10.6 ± 1.67 weeks.

Table 2: Distribution of Complications, Leg Length Discrepancy, and Malalignment (n=30)

Variable		Number of patients	Percentage (%)
Complications	Minor complication (Nail-tip irritation)	2	6.7
	No complications	28	96.3
	Total	30	100.0
Leg length inequality	0.5 cm	2	6.7
	1 cm	3	10.0
	1.5 cm	2	6.7
	No inequality	23	76.7
	Total	30	100.0
Malalignment	5-6^0 varus	3	10.0
	6-8^0 vulgus	4	13.3
	No malalignment	23	76.7
	Total	30	100.0

Among the 30 cases, only 2 (6.7%) patients experienced nail-tip irritation, while the majority, 28 (96.3%), developed no complications. Objective evaluation during follow-up revealed limb length discrepancies in a small number of patients, with 2 (6.7%) exhibiting a 0.5 cm discrepancy, 3 (10.0%) a 1 cm discrepancy, and 2 (6.7%) a 1.5 cm discrepancy, whereas the majority showed no discrepancy. In terms of malalignment, 3 (10.0%) patients exhibited anterior-posterior angulation or varus deformity of 5–6°, 4 (13.3%) had valgus deformities of 6–8°, while the majority, 23 (76.7%), showed no malalignment.

Table 3: Outcome of Patients Based on Range of Knee Motion and Activity Level (n=30)

Variable		Number of patients	Percentage (%)
Rang of knee motion (Degree)	100-120	2	6.7
	120-130	7	23.7
	> 130	21	70.0
	Total	30	100.0
Activity level	Preinjury activities with mild limitation	8	26.7
	Return to preinjury activities	22	73.3
	Total	30	100.0

Objective evaluation of the outcome revealed that 21 (70.0%) patients exhibited a wide range of knee motion, with flexion greater than 130°, while 7 (23.3%) had a restricted knee motion range of 120-130°, and 2 (6.7%) had a limited range of 100-120°. In terms of activity level, 22 (73.3%) patients were able to return to their pre-injury activities, while 8 (26.7%) experienced mild limitations.

Table 4: Final Outcome According to Flynn's *et al*., TEN Scoring Criteria (n=30)

Final outcome		Excellent	Satisfactory	P value
Leg length inequality (n=7)	< 1.0 cm	5	0	0.017*
	< 2.0 cm	0	2	
	No leg length inequality	18	5	
Mal alignment (varus/valgus) (n=7)	5 degree	2	0	<0.001*
	10 degree	0	5	
	No mal alignment	21	2	
Pain	Present	0	0	
	Absent	30	30	
Complications	Mild	0	5	<0.001*
	Absent	23	2	

Table 4 presents the final outcomes according to Flynn's *et al*., TEN scoring criteria. Among 30 patients, leg length inequality was observed in 7 cases, with 5 patients showing a discrepancy of less than 1.0 cm ($p = 0.017$). No patient had a leg length inequality of more than 2.0 cm. Malalignment, specifically in varus/valgus, was recorded in 7 cases, with 2 patients showing a 5° deviation and 5 patients with a 10° deviation ($p < 0.001$). No malalignment was observed in 21 patients. Regarding pain, none of the patients experienced pain, with all having an absence of pain. The complications were mild in 5 patients, while 23 patients had no complications ($p < 0.001$).

DISCUSSION

Femoral shaft fractures account for less than 2% of all pediatric fractures, with conservative treatment traditionally preferred, particularly for younger children. However, prolonged immobilization and associated rehabilitation challenges have led to increased interest in surgical options, including Titanium Elastic Nailing (TEN). TEN provides an effective solution by offering load-sharing stabilization, preserving growth plates, and allowing early mobilization, promoting quicker recovery with minimal disruption to the child's life [16, 17]. Unlike other surgical methods like plating or external fixation, TEN minimizes complications such as implant failure or need for second surgeries, making it a favored option for treating femoral shaft fractures in children. This study aims to evaluate the functional outcomes of TEN in pediatric femoral shaft fractures, contributing to the growing evidence supporting its effectiveness.

In the current study, radiological evaluation of fracture site union showed that 20 (66.7%) cases united within 7-10 weeks, and 10 (33.3%) cases united within 10-13 weeks. The mean union time was 9.6±1.9 weeks. Our findings correlate with the study of Mishra *et al*., [18], which reported radiological union in all cases was achieved in a mean time of 9.5 weeks.

In the present study, after assessing the radiological status of union, full weight bearing was possible in 27 (90.0%) patients within 8-12 weeks, and the remaining 3 (10.0%) cases were able to bear weight within 12-16 weeks. The mean full weight bearing time was 10.6±1.67 weeks. Our results correlate with the study of Kumar *et al*., [19], who reported a mean time of 10 weeks for full weight bearing.

In the present study, evaluation during follow-up of limb length discrepancy revealed that 2 (6.7%) patients exhibited a 0.5 cm discrepancy, 3 (10.0%) patients exhibited a 1 cm discrepancy, 2 (6.7%) patients exhibited a 1.5 cm discrepancy, and the majority of the patients showed no discrepancy. Moroz *et al*., [20], reported a leg-length discrepancy exceeding guidelines in 5 (2.1%) cases.

In this study, in terms of deformity in the sagittal plane, such as anterior-posterior angulation, and in the coronal plane, such as varus deformity, 5-60° occurred in 3 (10.0%) patients, 6-80° valgus deformity occurred in 4 (13.3%) patients, and the majority of the patients (23, 76.7%) had no malalignment. Rajak *et al*., [16], noted that out of 20 patients, 2 had varus angulation (10° and 7° each), while 1 had valgus angulation (90°), which correlates with our study.

In the current study, 21 (70.0%) patients exhibited a wide range of knee fixation greater than 130°, 2 (6.7%) patients had a restricted knee motion range of 120-130°, and 7 (23.3%) patients had a restricted knee motion range of 100-120°. Rajak *et al*., [16], noted that the mean range of knee flexion at the end of the follow-up was 0-120°, which correlates with our findings.

In the final outcome of the study, the TEN outcomes scoring by Flynn *et al*., demonstrated satisfactory results in 7 (23.3%) cases, and excellent results were found in 23 (76.7%) patients. Mishra *et al*., [18], noted similar results, with excellent outcomes in 80% of cases and satisfactory outcomes in 20%.

Limitations of the Study

This study had some limitations:

- The sample size was small (n=30), representing only 7.8% of the required sample size.
- The study duration was only two years.
- Some patients did not follow up consistently, either arriving late or too early for their follow-ups.

- The cost of the instruments was a constraint.
- The small sample size limits the generalizability of the findings to the reference population.
- Larger studies are recommended to definitively prove the outcomes.

CONCLUSION

The aim of this study was to evaluate the functional outcomes of femoral shaft fractures in children treated with titanium elastic nailing. The results demonstrated that 66.7% of patients achieved union within 7-10 weeks, and 90.0% achieved full weight bearing within 8-12 weeks. Most patients (70.0%) exhibited excellent knee motion (>130°), and 73.3% returned to pre-injury activities. Complications were minimal, with only 6.7% experiencing minor issues, and 76.7% showing no leg length discrepancies or malalignments. According to Flynn's TEN Scoring Criteria, the outcomes were predominantly excellent, with no significant pain and minimal complications. These findings suggest that titanium elastic nailing is an effective treatment for pediatric femoral shaft fractures, promoting timely recovery and excellent functional outcomes.

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