

UNSTABLE FEMORAL FRACTURES TREATED WITH TITANIUM ELASTIC INTRAMEDULLARY NAILS, IN CHILDREN

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ABSTRACT

Objective: To evaluate the indications, epidemiology, associated lesions, complications and prognosis among children with unstable femoral diaphysis fractures who were treated with titanium elastic intramedullary nails. **Method:** This was a retrospective analysis on 24 patients aged 5-12 years with unstable femoral diaphysis fractures who underwent surgical treatment with elastic titanium intramedullary nails at the Cajuru University Hospital, Curitiba-PR, between April 2002 and March 2008, with a minimum follow-up of 36 months. The epidemiological data, angular deviations, leg shortening and bone consolidation were evaluated. **Results:** The medical files of 113 cases operated between April 2002 and March 2008 were reassessed. From these, 24 cases of unstable femoral

diaphysis fractures treated with elastic titanium intramedullary nails with retrograde insertion were included in the study. There were two bilateral fractures and two exposed fractures. Seven patients were female and 17 were male, and the mean age was 8.3 years. The following were presented at the end of the study: shortening, varus or valgus displacement, final retrocurvatum or antecurvatum of zero, and absence of delayed consolidation or pseudarthrosis. **Conclusions:** The elastic titanium intramedullary nails were easily placed and removed. We believe that using elastic titanium intramedullary nails is a good option for fixation of unstable femoral fractures in children.

Keywords – Fracture Fixation; Femoral Fractures/complications; Intramedullary; Internal Fixators; Orthopedic Fixation Devices; Titanium; Child

INTRODUCTION

Femoral diaphysis fractures are caused by high-energy trauma and are among the commonest pediatric traumatic lesions treated by orthopedic surgeons⁽¹⁻³⁾. In children and adolescents, these fractures present bimodal distribution, with peaks at between two and three years of age (5.9/10,000/year) and at 17-18 years (4.2/10,000/year)⁽⁴⁾. The commonest causes are falls, bicycle and motorcycle accidents, and road accidents⁽⁵⁾.

The treatment for these fractures ranges from immediate closed reduction using a plaster cast, traction and a plaster cast later on, to surgical stabilization with intramedullary devices, plates and screws and

external fixators⁽⁶⁻⁸⁾. However, there is still much debate regarding the best treatment for children between the ages of six and 16 years.

Use of plaster after a period of traction is a secure method with few complications. However, it is associated with psychological, social, educational and economic difficulties. Certain complications that are present in surgical methods like external fixation, plates and solid intramedullary nails have led to a search for “ideal” fixation devices for the pediatric population. In this manner, flexible intramedullary nails made of titanium have emerged⁽³⁾.

Surgical treatment of pediatric femoral fractures was avoided for many years, partly because of its

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complications (such as renewed fracturing, scarring and infection) and also because of the belief that overgrowth of the femur would occur and therefore that anatomical reduction might not be favorable⁽⁹⁾.

Reynolds demonstrated that fractures of the femur and tibia resulted in accelerated growth of these bones for up to two years, reaching a maximum after three months, with a growth rate up to 38% greater than in the contralateral limb⁽³⁾. Several studies have shown accelerated overgrowth may occur following a femoral fracture during childhood^(10,11) and that this creates deformity in the limb, which persists until adolescence and the start of adulthood⁽¹²⁾.

The complications that have been described in relation to the use of titanium elastic nails in cases of femoral fracture are knee pain at the insertion, protruding nail, nail migration or exit, shortening of the fracture, pseudarthrosis and delayed consolidation⁽¹³⁻¹⁵⁾. The complications are classified as major or minor. Major complications are those that require surgical treatment, such as skewed consolidation, delayed consolidation or pseudarthrosis^(3,13,16).

Intramedullary titanium elastic nails used to treat femoral diaphysis fractures in children present good results, but the same fractures in older children present greater incidence of complications⁽¹⁷⁾.

The conclusion from many studies is that there are greater numbers of complications among patients over the age of 11 years, obese patients or patients with unstable fracture patterns^(13,14,16,17). Fractures are considered to be unstable if they are comminuted or long and oblique, i.e. the length of the fracture is greater than the diameter of the femur at the level of the fracture^(15,18).

The aim of the present study was to assess the indications, epidemiology, associated lesions, complications and prognosis in treatments for unstable femoral diaphysis fractures in children, using elastic intramedullary nails made of titanium.

MATERIALS AND METHODS

Retrospective assessments were made on 113 cases of femoral fractures in children that had been treated surgically using titanium elastic intramedullary nails at Cajuru University Hospital, in Curitiba, PR, between April 2002 and March 2008. This study was approved by the Ethics Committee for Research on Human Beings of the Pontifical Catholic University of Paraná, under report no. 0005267/11.

The inclusion criteria were as follows:

- unstable diaphyseal femoral fractures (comminuted or long and oblique, i.e. the length of the fracture was greater than the diameter of the femur at the level of the fracture)^(15,18);
- treated using elastic intramedullary nails made of titanium, with retrograde insertion; and
- minimum follow-up of 36 months.

The exclusion criteria were as follows:

- stable femoral fractures;
- fractures in bones presenting pathological conditions;
- fractures in the metaphyseal region; and
- cases in which the approach chosen was antero-grade insertion of the flexible intramedullary nails made of titanium.

In total, 24 fractures in 24 patients were studied. Two patients presented bilateral fractures, but only one of the fractures was unstable in each patient (cases 14 and 24).

Chart 1 presents the population analyzed.

This was a retrospective observational study, in which the medical files were evaluated and the following data were gathered: age, sex, mechanism of the trauma, presence of exposure and side affected.

Chart 1 – Data on the patients.

Case	Sex	Side	Age	Exposure	Trauma mechanism
1	M	R	12	Closed	Run over
2	M	R	6	Closed	Run over
3	M	L	8	Closed	Fall from bike
4	M	L	9	Closed	Fall from height
5	F	L	11	Closed	Car crash
6	M	R	12	Closed	Car crash
7	M	R	9	Exposed	Car crash
8	M	R	5	Closed	Run over
9	M	R	9	Closed	Run over
10	M	R	7	Closed	Run over
11	F	R	8	Closed	Run over
12	M	R	6	Closed	Run over
13	M	R	5	Closed	Car crash
14	F	R unstable + L stable	9	Exposed	Car crash
15	M	R	9	Closed	Fall from motorcycle
16	F	R	7	Closed	Tripped over
17	M	R	12	Closed	Tripped over
18	M	R	8	Closed	Fall from bike
19	F	R	6	Closed	Run over
20	M	R	6	Closed	Run over
21	F	L	9	Closed	Car crash
22	M	R	10	Closed	Tripped over
23	F	L	10	Closed	Car crash
24	M	R unstable + L stable	7	Closed	Car crash

Legend: M = male, F = female, R = right, L = left.
Source: SAME HUC PUC-PR.

The angular deviations were assessed on anteroposterior and lateral radiographs produced before the operation, immediately after the operation, later on after the operation and after removal of the synthesis material (Figure 1). The angular deviations evaluated were valgus, varus, antecurvatum and retrocurvatum.

Shortening or overgrowth was assessed using sca-nometry or panoramic radiographs of the lower limbs at the end of the treatment.

The criteria of Flynn *et al*⁽¹⁾ were developed in order to assess the results relating to use of flexible intrame-dullary nails and consisted of four criteria: discrepancy between the limbs, deviations, pain and complications. The criteria for determining that the prognosis was poor were discrepancies greater than 2 cm, more than 10 degrees of deviation, pain and major complications and/or elevated morbidity. If a patient presented any of these criteria, the prognosis was considered to be poor⁽¹⁸⁾. Consolidation was evaluated using the abo-vementioned criteria of Flynn *et al*⁽¹⁾ with regard to angular deviation, shortening and bone consolidation.

STATISTICAL METHODOLOGY

For the statistical analysis, descriptive statistical measurements were calculated with the objective of summarizing the set of data analyzed. Thus, the quan-titative variables of the study were characterized by calculating means, standard deviations, minimums and maximums. The categorical variables were sum-marized by means of frequency tables.

To compare the evaluation times regarding the pro-portion of cases with null deviation, Fisher's exact test was applied. To compare the assessment times regarding the mean angular deviation, Wilcoxon's test was applied. To investigate the association between age and deviations, Spearman's coefficient was cal-culated. The association between sex and deviation was investigated by applying the Mann-Whitney test.

RESULTS

We observed that 70.83% (17 patients) were male. The maximum age was 12 years and the minimum age was five years (mean of 8.33 years) (Table 1).

Regarding the side affected, 79.17% of the patients presented a fracture in the right femur and there were two cases of bilateral fracture. In 91.67% of the pa-tients, the fractures did not present exposure. The trauma mechanisms were high energy, among which 37.5% consisted of being run over, 29.17% were falls (from a height, tripping over or from bicycles) and 33.33% were collisions (Table 2).

Regarding shortening, the proportion with zero an-gular deviation increased significantly from before the operation to the final evaluation ($p = 0.0151$). The mean shortening reduced from 1.61 degrees to 0.39 degrees, which was a significant difference ($p = 0.016$) (Chart 2).

The proportion for which the varus or valgus de-viation in the frontal plane was considered to be zero increased significantly from before the operation to the final evaluation ($p = 0.0002$). The mean reduced from 1 to 0 degrees, which was a non-significant di-fference ($p = 0.50$) (Chart 3).

The proportion for which the antecurvatum or re-trocurvatum deviation in the sagittal plane was con-sidered to be zero increased significantly from before the operation to the final evaluation ($p = 0.0001$). The mean reduced from -0.38 degrees to 0 degrees, which was a non-significant difference ($p = 0.94$) (Chart 4).

There was a significant association between the deviations and age, with shortening in the immediate postoperative period ($p = 0.03$) (Table 3).

There was no significant association between the deviations and sex (Table 4).

The deviations and shortening did not show any significant association with age or sex (Table 5).

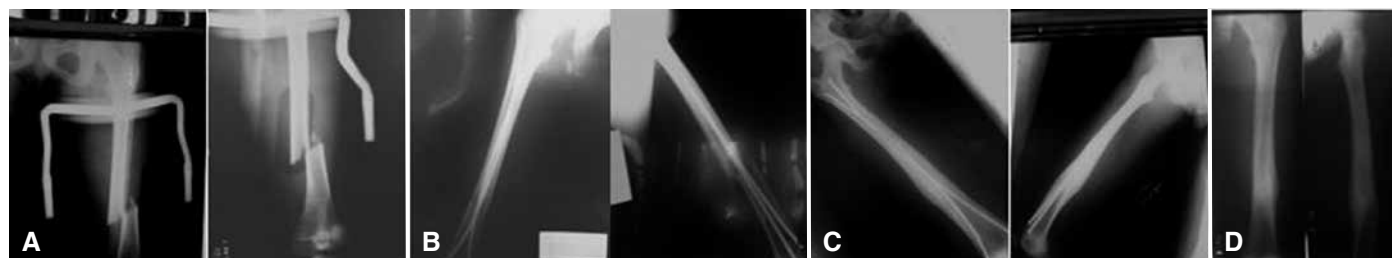


Figure 1 – Series of anteroposterior and lateral radiographs on the femur of a 10-year-old female patient who was a victim in a car crash: before the operation (A), early postoperative period (B), late postoperative period (C) and final postoperative evaluation (D) after removal of the elastic intramedullary nails.

Source: SAME HUC PUC-PR.

Table 1 – Patient distribution according to sex and age.

Sex		Frequency		Percentage	
Male		17		70.83%	
Female		7		29.17%	
Total		24		100.00%	
	Sample	Mean	Minimum	Maximum	Standard deviation
Age	24	8.33	5	12	2.14

Source: SAME HUC PUC-PR.

Table 2 – Patient distribution according to side affected, fracture mechanism and exposure of the fracture.

Side		Frequency		Percentage	
Right		19		79.17%	
Left		5		20.83%	
Total		24		100.00%	
Trauma mechanism		Frequency		Percentage	
Run over		9		37.50%	
Fall		7		29.17%	
Collision		8		33.33%	
Total		24		100%	
Exposure		Frequency		Percentage	
Closed		22		91.67%	
Exposed		2		8.33%	
Total		24		100%	

Fonte: SAME HUC PUC-PR.

Chart 2 – Evaluation of shortening before the operation and in the early postoperative period, late postoperative period and final postoperative evaluation.

Shortening	Before operation		Early postop		Late postop		Final	
	F	%	F	%	F	%	F	%
Same	4	25.00%	8	33.33%	20	83.33%	15	65.22%
> 0	12	75.00%	16	66.67%	4	16.67%	8	34.78%
< 0	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Sample	16	100.00%	24	100.00%	24	100.00%	23	100.00%
Shortening	Before operation		Early postop		Late postop		Final	
	Mean		Mean		Mean		Mean	
Mean	1.61		1.04		0.4		0.39	
Minimum	0		0		0		0	
Maximum	4.2		5		5		2.7	
SD	1.32		1.18		1.11		0.72	

Legend: F = frequency, % = percentage, postop = postoperative period, Final = final postoperative evaluation, sd = standard deviation.

Source: SAME HUC PUC-PR.

Chart 3 – Evaluation of the varus and valgus deviations before the operation and in the early postoperative period, late postoperative period and final postoperative evaluation.

Varus / valgus	Before operation		Early postop		Late postop		Final	
	F	%	F	%	F	%	F	%
Same	8	50.00%	15	62.50%	22	91.67%	23	100.00%
> 0	5	31.25%	5	20.83%	1	4.17%	0	0.00%
< 0	3	18.75%	4	16.67%	1	4.17%	0	0.00%
Sample	16	100.00%	24	100.00%	24	100.00%	23	100.00%
Varus / valgus	Before operation		Early postop		Late postop		Final	
	Mean		Mean		Mean		Mean	
Mean	1		-0.21		-0.29		0	
Minimum	-21		-10		-10		0	
Maximum	20		12		3		0	
SD	9.3		4.71		2.16		0	

Legend: F = frequency, % = percentage, postop = postoperative period, Final = final postoperative evaluation, sd = standard deviation.

Source: SAME HUC PUC-PR.

Chart 4 – Evaluation of antecurvatum and retrocurvatum deviations before the operation and in the early postoperative period, late postoperative period and final postoperative evaluation.

Ante / retro	Before operation		Early postop		Late postop		Final	
	F	%	F	%	F	%	F	%
Same	7	43.75%	18	75.00%	21	87.50%	23	100.00%
> 0	3	18.75%	4	16.67%	2	8.33%	0	0.00%
< 0	6	37.50%	2	8.33%	1	4.17%	0	0.00%
Sample	16	100.00%	24	100.00%	24	100.00%	23	100.00%
Ante / retro	Before operation		Early postop		Late postop		Final	
	Mean		Mean		Mean		Mean	
Mean	-0.38		1.96		0.92		0	
Minimum	-20		-4		-4		0	
Maximum	20		18		16		0	
SD	9.07		5.68		3.91		0	

Legend: F = frequency, % = percentage, Ante = antecurvatum, retro = retrocurvatum, postop = postoperative period, Final = final postoperative evaluation, sd = standard deviation.

Source: SAME HUC PUC-PR.

Table 3 – Correlations between age and deviations.

	Sample	Ratio	p-value
Pre-short	16	-0.21694	0.42
Pre-VV	16	-0.19511	0.47
Pre-AR	16	0.05553	0.84
EPO-short	24	-0.43923	0.03
EPO-VV	24	0.02206	0.92
EPO-AR	24	-0.37332	0.07
PO-short	24	-0.17974	0.4
PO-VV	24	0.07393	0.73
PO-AR	24	-0.39462	0.06
F-short	23	-0.33096	0.12
F-VV	23	2.18E-10	1
F-AR	23	2.18E-10	1

Legend: Pre-short = preoperative shortening, Pre-VV = preoperative varus/valgus, Pre-AR = preoperative antecurvatum/retrocurvatum, EPO-short = early postoperative shortening, EPO-VV = early postoperative varus/valgus, EPO-AR = early postoperative antecurvatum/retrocurvatum, PO-short = postoperative shortening, PO-VV = postoperative varus/valgus, PO-AR = postoperative antecurvatum/retrocurvatum, F-short = final postoperative shortening, F-VV = final postoperative varus/valgus, F-AR = final postoperative antecurvatum/retrocurvatum.

Source: SAME HUC PUC-PR.

Table 4 – Results from correlations between sex and deviations.

	p-value
Pre-short	0.43
Pre-VV	0.54
Pre-AR	1
EPO-short	0.59
EPO-VV	0.59
EPO-AR	0.28
PO-short	0.57
PO-VV	1
PO-AR	0.82
F-short	0.84
F-VV	1
F-AR	1

Legend: Pre-short = preoperative shortening, Pre-VV = preoperative varus/valgus, Pre-AR = preoperative antecurvatum/retrocurvatum, EPO-short = early postoperative shortening, EPO-VV = early postoperative varus/valgus, EPO-AR = early postoperative antecurvatum/retrocurvatum, PO-short = postoperative shortening, PO-VV = postoperative varus/valgus, PO-AR = postoperative antecurvatum/retrocurvatum, F-short = final postoperative shortening, F-VV = final postoperative varus/valgus, F-AR = final postoperative antecurvatum/retrocurvatum.

Source: SAME HUC PUC-PR.

Table 5 – Differences in deviations and shortening between before the operation and at the final evaluation, in relation to sex and age.

Age	p-value
Shortening	0.36
Varus/valgus	0.43
Ante/retro	0.79
Sex	p-value
Shortening	0.75
Varus/valgus	0.28
Ante/retro	0.91

Legend: ANTE = antecurvatum, RETRO = retrocurvatum.
Source: SAME HUC PUC-PR.

DISCUSSION

Femoral diaphysis fractures occur frequently in children, but dilemmas still exist regarding the treatment in some cases, depending on the patient's age, fracture pattern, soft-tissue conditions, type of trauma and comorbidities. Surgical treatment enables early mobilization and has become an alternative of interest, especially for children presenting multiple trauma, cranial-encephalic trauma, floating knee, multiple fractures and vascular injuries^(3,5,15,19,20), which occur mainly in cases of high-energy trauma.

These fractures in children generally result from high-energy trauma, as observed in the present sample⁽⁵⁾. Flexible intramedullary nails are considered to be a safe and minimally invasive method with relatively low complication rates⁽²¹⁾. Studies have demonstrated that surgical treatment with flexible intramedullary nails successfully achieves the objective of treating pediatric femoral diaphysis fractures and also enables early mobilization and weight-bearing^(5,17).

Flexible intramedullary nails made of titanium provide relative stability, with less injury at the focus, thus favoring bone consolidation. They present an excellent consolidation rate, as demonstrated in our study, and rates of 97 to 100% can be found in the literature^(14,20). The length of hospital stay is short. Few problems are found in removing the synthesis material, and the patients' satisfaction rate is high⁽⁵⁾.

Studies have demonstrated complication rates of 33 to 62%, and most of these are soft-tissue alterations at the site of the nail implantation. Thus, these are minor complications that do not require surgical intervention and do not leave sequelae. The commonest of these are pain at the nail insertion

site, nail protrusion and nail migration or exit. Most of these complications are due to technical failures: for example, the technical guidelines state that the nail should be a maximum of 1 cm outside of the bone and should not be angled, so as to avoid protrusion and consequent local irritation^(13,14,15,20). Many complications are difficult to assess because of retrospective study designs and incomplete data in the medical files. Anterograde insertion presents a low risk of osteonecrosis of the femoral head or injury to the proximal growth plate of the femur, while retrograde insertion avoids these two sequelae. Therefore, in our clinic, we firstly indicate retrograde insertion and then, exceptionally, antero-grade insertion⁽²⁰⁾.

Several studies have shown that overgrowth may occur after a femoral diaphysis fracture during childhood, and that this may create a discrepancy in the lower limbs that persists until adolescence and young adulthood^(5,12). Reynolds suggested that overgrowth occurred because of the increased vascularization needed for consolidation, and not through a compensatory mechanism⁽²²⁾. It has been suggested that cerebral dominance may have a role in this: one study did not present significant shortening and most of the patients were affected on the right side⁽⁵⁾. It is unnecessary for the lower limbs to be of precisely equal size, given that at the time of skeletal maturity 40-70% of the population presents discrepancies. This is greater than 2 cm in 0.1% of the population⁽⁵⁾.

With regard to assessment of the results from using flexible intramedullary nails, the criteria of Flynn *et al*⁽¹⁾ are widely used. However, even though these are considered to be a good system for evaluating surgical treatments on pediatric femoral fractures, they do not take into consideration rotational deviations, which are an important factor in fracture reduction⁽³⁾.

Sink *et al*⁽¹⁵⁾ found that the risk of shortening and angular deviation in the early postoperative period following unplanned surgery was significantly greater with the use of elastic intramedullary nails in cases of femoral fracture that were considered to be unstable. Narayanan *et al*⁽²³⁾ observed that comminuted fractures that compromised more than 25% of the femoral diaphysis presented higher rates of pseudarthrosis or delayed union, thus suggesting that the stability should be increased using external fixation⁽¹⁸⁾, thereby protecting the reduction, especially in the sagittal plane, as

reported by Mani *et al*⁽²⁴⁾. Luhmann *et al*⁽¹³⁾ concluded that fixation of femoral fractures in overweight patients and use of flexible intramedullary nails of smaller diameter were associated with greater sagittal angles, and that the coronal angle was correlated with the size of the nail, with technical failure also involved.

Rathjen *et al*⁽²⁵⁾ reported that the complications in cases of unstable fractures of the femoral diaphysis in children treated using flexible femoral nails in their study were similar to the complications in cases of stable fractures.

CONCLUSION

Most cases of femoral diaphysis fracture occur through high-energy trauma.

We conclude that elastic intramedullary nails made of titanium can be indicated for cases of unstable pediatric femoral diaphysis fracture, with good long-term results presented.

We consider that use of elastic intramedullary nails is a good option for fixation of unstable femoral fractures in children.

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