Short-term Results of the Treatment of Hip Fractures in Children

Resultados a corto plazo del tratamiento de fracturas de cadera en población infantil

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Introduction Pediatric hip fractures are infrequent, associated with high-energy trauma, and present devastating complications. Most cases are treated surgically using different types of fixation. The objective of the present study is to report the results of a series of cases of surgical patients in two reference hospitals in Chile. Materials and Methods A case series which included pediatric patients diagnosed with hip fractures and treated surgically between 2004 and 2008. We performed descriptive statistics for the demographic variables, the energy of the accident, the Delbet classification, the type of treatment, the osteosynthesis technique, of complications, and the clinico-radiological evaluation according to evaluation. Results A total of 17 cases were evaluated, 76.5% of which were secondary to highenergy accidents. The median age of the sample was of 7 years, and it was composed of 58.8% of girls. There were 3 cases of Delbet type II, 9 of type III, and 5 of type IV. As fixation method, we used cannulated screws (9 cases), locking compression plates (LCPs; 5 cases), dynamic hip screws (DHSs; 2 cases), and dynamic compression plates (DCPs; 1 case). The median follow-up was of 2.3 years (range: 0.5 to 12.8 years). Complications were observed: coxa vara in one case, and discrepancy in the length of

> the lower extremities in another case, and there were no cases of osteonecrosis. Osteosynthesis removal was performed in seven patients. Good results were obtained

> **Conclusions** Most fractures were associated with high energy trauma, with the most frequent being type III on the Delbet classification. All the patients were treated

Keywords

Abstract

- hip fractures
- osteosynthesis
- ► children

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Level of evidence: 4.

in all patients according to Ratliff criteria.

surgically, with good results, with no cases of osteonecrosis.

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Resumen	Introducción Las fracturas del fémur proximal pediátricas son infrecuentes, se							
	asocian a traumas de alta energía, y presentan complicaciones devastadoras. La							
	mayoría de los casos se tratan en forma quirúrgica utilizando diversos tipos de fijación.							
	El objetivo de este estudio es reportar los resultados de una serie de casos de paciente							
	quirúrgicos en dos hospitales de referencia en Chile.							
	Materiales y métodos Serie de casos tratados entre el 2004y el 2018, en la que se							
	incluyeron pacientes pediátricos con diagnóstico de fractura de fémur proximal que							
	fueron operados. Se realizó estadística descriptiva de las variables demográficas, la							
	energía del accidente, la clasificación según Delbet, el tipo de tratamiento, la técnica de							
	osteosíntesis, la aparición de complicaciones, y la evaluación clínico-radiológica según							

los criterios de Ratliff.

Resultados Se evaluaron 17 casos, de los cuales un 76,5% fueron secundarios a accidentes de alta energía. La mediana de edad de la muestra fue de 7 años, y había un 58,8% de niñas. Hubo 3 casos de tipo II en la clasificación de Delbet, 9 de tipo III, y 5 de tipo IV. Como método de fijación, se utilizaron tornillos canulados (9 casos), placa de compresión de bloqueo (*locking compression plate*, LCP, en inglés; 5 casos), tornillo dinámico de cadera (*dynamic hip screw*, DHS, en inglés; 1 caso). La mediana de seguimiento fue de 2,3 años (rango: 0,5 a 12,8 años). Se presentaron complicaciones: *coxa vara* en un caso, y discrepancia de longitud de extremidades inferiores en otro caso, y no hubo osteonecrosis. Se realizó retiro de osteosíntesis en siete pacientes. Se obtuvieron buenos resultados en todos los pacientes según los criterios de Ratliff. **Conclusiones** La mayoría de las fracturas se asociaron a traumas de alta energía,

Palabras clave

- ► fractura de cadera
- osteosíntesis
- ► niños

Conclusiones La mayoría de las fracturas se asociaron a traumas de alta energía, siendo el tipo más frecuente el III de Delbet. Todos los pacientes fueron tratados en forma quirúrgica, con buenos resultados, sin observar osteonecrosis. Nivel de evidencia: 4.

Introduction

Pediatric proximal femur fractures are rare injuries; however, they can lead to severe complications and potential longterm disability.¹ Due to the features of the immature skeleton, a high-energy mechanism is required in order for the femoral neck to undergo a fracture.² Thus, most of these fractures result from high-energy trauma, especially motor vehicle accidents (53–57%) and falls from height (36–43%).^{3,4} Associated injuries occur in 61% to 86% of the patients, including head, chest, abdomen, pelvic ring lesions, acetabular fractures, hip dislocations, and ipsilateral femur fractures.^{3,4}

Although the incidence of pediatric proximal femur fractures is low, the literature about it consists mainly of case series^{3,4,8–10,13} in which advances have been observed, especially regarding treatment. In the past, conservative treatment involving months of traction and plaster casts, with a high level of complications, was chosen in most cases. The current trend is to try to achieve anatomical reduction and stable fixation; therefore, the rate of surgical indication has increased.⁵

The most frequent complication is avascular necrosis, with an incidence ranging from 0 to 47%, depending on the series. The increased risk compared to that of proximal femur fractures in adults is due to differences in the irrigation of the femoral head. In adults, intraosseous vessels irrigate the femoral head, but, in children, these vessels do not cross the physis, and the contribution from the artery of the ligamentum teres is greater.^{6,7} Other complications include malunion with coxa vara/valga (14–21%), premature physeal closure (7–61%), nonunion (0–8%), septic arthritis (0–8%), and iatrogenic femoral head perforation by screws (0-3%).^{4,8–13}

Although pediatric proximal femur fractures are uncommon, they are relevant because complications can be devastating. Hence, it is critical to understand their diagnosis, proper treatment, and complication management to optimize the outcomes in this population. The present study describes the management of these fractures through a retrospective review of cases from two Chilean reference centers, along with a critical analysis of the treatment and complications.

Materials and Methods

The present is a descriptive series of cases treated from 2004 to 2018 at 2 high-complexity centers. The ethics committee from both participating centers approved the study.

	Good	Regular	Poor
Pain	No pain	Occasional	Debilitating pain
Mobility	Complete	> 50%	< 50%
Activity	Normal mobility	Avoids playing	Restricted mobility
Radiological assessment	Normal	Severe deformity	Avascular necrosis, arthritis, arthrodesis

 Table 1
 Ratliff¹⁵ criteria

A diagnosis database query revealed patients up to 15 years old with proximal femur fracture who underwent surgical treatment at both centers between 2004 and 2018. The excluded subjects presented pathological bone fractures, closed physis at diagnosis, or incomplete records.

The recorded data included the following: age, gender, fracture mechanism, associated injuries, time until surgery, type of reduction (open or closed), osteosynthesis material, the reduction achieved with osteosynthesis, and the duration of the follow-up. Preoperative images were analyzed retrospectively, and the injuries were classified according to the Delbet criteria adapted by Colonna¹⁴ as type I (transepiphyseal), type II (transcervical), type III (basicervical), and type IV (intertrochanteric). To assess the follow-up, we used the Ratliff criteria,¹⁵ shown in **- Table 1**, according to the most recently-available data and images. In addition, complications during the follow-up period were recorded.

Statistical Analysis

The descriptive statistical analysis included demographic variables, fracture mechanism, time until surgery, the Delbet classification, the type of treatment, the osteosynthesis technique, complications, and a clinico-radiological evaluation per the Ratliff criteria. Absolute and relative frequencies were used to describe the categorical variables. For the quantitative variables, the Shapiro-Wilks test determined data normality; given its non-parametric distribution, median values and minimum-maximum ranges were calculated. The Stata (StataCorp LLC, College Station, TX, US) software, version 16, was used for the statistical calculations.

Results

We evaluated 17 patients with proximal femur fractures, and **- Table 2** summarizes the main features of each case. The median age was of 7 years (range: 3 to 14 years), and 58.8% (n = 10) of the patients were female. A total of 76.5% (n = 13) of the cases were secondary to high-energy accidents, and the most common associated injuries were head trauma (n = 3; 17.6%), and long-bone fractures: femur (n = 1; 5,9%) and tibia (n = 1; 5,9%).

As for fracture type, there were 3 (17,6%) cases of type II, 9 (52,9%) of type III, and 5 (29,4%) of type IV. All patients underwent reduction and osteosynthesis, and 12 surgeries (70.6%) occurred within 24 hours. The patients treated after presented injuries classified as type I (n = 1; 5,9%), type III (n = 3; 17,6%), and type IV (n = 1; 5,9%) on the Delbet

classification; the main reason for later treatment was clinical instability.

Table 3 describes the implants used in the present study. All type-II fractures underwent closed reduction and osteosynthesis with screws. Among the type-III fractures, 6 (67%) were treated with closed reduction and cannulated screws, an example is shown in **Figure 1**. The other 3 cases (33%) required open reduction, as the case shown in Figure 2. Closed reduction was not achieved in one patient and not attempted in a second subject with a concomitant pelvic fracture; these two cases underwent fixation with a locking compression plate (LCP). The third case presented a basicervical fracture; fixation was performed using a dynamic hip screw (DHS), with no attempt to perform closed reduction. All Delbet IV fractures underwent open reduction and fixation with LCP (n = 3; 60%), dynamic compression plate (DCP; n = 1; 20%) and DHS (n = 1; 20%). An example of a Delbet IV fracture fixed with an LCP is shown in Figure 3.

The median follow up was 2.3 years (range: 0.5 to 12.8 years). All patients presented good clinical and radiological outcomes according to the Ratliff criteria at the end of the period. Complications ocurred in two (11.8%) cases, including coxa vara (n = 1; 5,9%) and lower limb discrepancy (n = 1; 5,9%). No cases of osteonecrosis were observed in our series. Removal of the osteosynthesis material was performed in 7 (41,2%) cases; all procedures were elective due to implant-related symptoms.

Discussion

The present study described a series of cases of proximal femur fractures in the pediatric population operated in two high-complexity centers in Chile. Our study shows that a high percentage of these cases were due to high-energy trauma; in addition, 70.6% (12 cases) of surgeries were performed within the first 24 hours. Although the complication rate was of 12% (2 cases), no cases of vascular necrosis were observed.

In our study, 76.5% (n = 13) of the fractures were associated with high-energy trauma, which is consistent with the literature.⁵ Although infrequent, these fracture are associated with motor vehicle accidents in 53% to 57% of the cases, depending on the series.^{3,4} In Chile, the number of motor vehicle accidents has increased from 57,087 to 89,311 between 2008 and 2018.¹⁶ Even though there are no chilean data regarding pediatric proximal femur fracture, we can assume that these injuries will remain a concern given their association with traffic accidents.

uration ^c the follow-up ears)	5	6	2.8	6.(8	0	ε	8	-	ε	4	0	7	5	8	8	6
mplications D of (y	xa vara 8.	3.		11	screpancy in 2 length of the ver limbs	4.	1.		3.	2.	- 1-	3.	1.	0.	1.	2.	-
co Co	Ö	No	No	No	Dis Iov	No	No	No	No	No	No	No	No	No	No	No	No
Removal of osteosynthesi material	No	No	No	No	No	Yes	No	No	No	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Anatomical reduction	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Yes
Type of fixation	DHS	DHS	Cannulated screws	Cannulated screws	3.5-mm LCP	Cannulated screws	3.5-mm LCP	Cannulated screws	Cannulated screws	3.5-mm DCP	3.5-mm LCP	Cannulated screws	Cannulated screws	3.5-mm LCP	Cannulated screws	4.5-mm LCP	Cannulated screws
Type of reduction	Open	Closed	Closed	Closed	Open	Closed	Open	Closed	Closed	Open	Open	Closed	Open	Open	Closed	Open	Closed
Delbet classification	Type IV	Type III	Type III	Type II	Type IV	Type III	Type IV	Type II	Type III	Type IV	Type III	Type II	Type III	Type IV	Type III	Type III	Type III
Injury mechanism	Traffic accident	Fall from height	Fall from height	Fall from height	Fall from height	Polytrauma	Gate fell over the patient	Not reported	Fall from height	The patient was run over	Fall from stairs	Fall from same level	Fall from same level	Fall from height	Fall from height	Traffic accident	Traffic accident
Gender	Female	Male	Female	Male	Female	Female	Male	Male	Female	Male	Male	Female	Female	Male	Female	Female	Female
Age (years	11	14	m	7	8	4	4	13	5	9	4	12	12	14	7	14	7
Patient number	-	2	Э	4	5	9	7	8	6	10	11	12	13	14	15	16	17

Abbreviations: DCP, dynamic compression plate; DHS, dynamic hip screw; LCP, locking compression plate.

Table 2 Summary of the patients included in the studysubjects

Table 3 Implants used

Type of osteosynthesis					
Cannulated screws	9				
Locking compression plate (LCP)					
Dynamic hip screw (DHS)					
Dynamic compression plate (DCP)	1				

Avascular necrosis is the most feared complication from these fractures. It relates to the type of fracture, and it is more frequent in type-I and -II fractures due to the disruption of the epiphyseal irrigation.¹⁷ In addition, the risk is greater in patients operated on, after 24 hours.⁵ Regarding other published series, the oldest ones report a higher incidence of necrosis, such as those by Canale and Bourland⁹ (43%) and Davison and Weinstein⁸ (47%), in contrast to more recent series, such as those by Cheng and Tang¹² (0), Song et al.¹¹ (0), Flynn et al.¹⁰ (6%), Shrader et al.¹³ (10%), and Bali et al.⁴ (19%).

It is believed that these differences relate to early treatment and the achievement of an anatomical reduction.^{5,12} In the present series, the rate of complications was of 12% (n = 2), with no cases of osteonecrosis, maybe due to the low incidence of type-I and -II fractures (3 patients - 17.6%) and the fact that most of our patients (12; 70.6%) underwent surgery within the first 24 hours.

Th present study has some limitations. Since it is a retrospective analysis, there may have been biases in recording information; in addition, the period studied to obtain a sufficient number of patients was long, patients treated orthopedically were not considered, and different surgeons performed the procedures. The small number of patients limits the ability to draw conclusions; however, this limitation occurs because these fractures are rare.

It is worth mentioning that the literature on this subject is scarce^{4,5,8-12} and that, to date, there are no chilean case series, so the present is the first publication on the subject. Furthermore, although our series is small, an aggressive surgical management had led to acceptable outcomes in our patients, without increasing the risk of avascular



Fig. 1 A 7-year-old male patient with a Delbet type-II fracture of the proximal femur. The treatment consisted of closed reduction and osteosynthesis with cannulated screws. (**A**,**B**) Preoperative radiographs showing a non-displaced fracture of the femoral neck. (**C**,**D**) Postoperative radiographs showing anatomical reduction and osteosynthesis with cannulated screws.



Fig. 2 A 14-year-old male patient with a Delbet type-III fracture of the proximal femur. The treatment consisted of closed reduction and osteosynthesis with a dynamic hip screw (DHS). (**A**,**B**) Postoperative radiographs showing anatomical reduction and osteosynthesis with a DHS.



Fig. 3 A 4-year-old male patient with a Delbet type-IV fracture of the proximal femur. The treatment consisted of open reduction and osteosynthesis with a 3.5-mm locking compression plate (LCP). (**A**,**B**) Preoperative radiographs showing an intertrochanteric fracture. (**C**,**D**) Postoperative radiographs showing anatomical reduction and osteosynthesis with an LCP.

necrosis. Lack of studies does not enables us to establish the best fixation method and clarify the factors influencing avascular necrosis and other complications.

Conflict of Interests

The authors have no conflict of interests to declare.

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