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Results and prognostic factors for distal femoral physis fractures in children at Bouaké University Hospital centre from 2021 to 2023: A strobe observational study

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Abstract
Introduction: fractures of the distal femoral growth plate are serious because they halt growth. The primary objective was to evaluate the therapeutic outcomes of distal femoral growth plate fractures. The secondary objective was to identify factors influencing functional outcome.
Methods: this was a three-year (2021-2023) observational, cross-sectional, and analytical STROBE study. It involved 33 patients who underwent surgery, with a mean age of 12.1±2.4 years (7-15). Therapeutic and evolutionary variables were studied. N'dour's evaluation criteria were used to assess the functional outcome of the pelvic limb. Univariate (p<0.2) and multivariate (p<0.05) logistic regression was performed to identify predictors of an unsatisfactory functional outcome.
Results: the mean time to surgery was 3.8±4.7 (1-21) days. Osteosynthesis was performed using pins (n=21; 62%) and screws (n=13; 38%). The mean length of hospital stay was 2.8 ± 1.1 (1-7) days. The mean time to union was 3.3±0.8 (2-5) months. The most common complication was knee stiffness (9%). At 13 months, functional outcomes were satisfactory (97%). Salter-Harris type 2 and the presence of a skin opening were independent predictors of an unsatisfactory functional outcome.
Conclusion: functional outcomes were satisfactory (97%). Salter-Harris type 2 and the presence of a skin opening influenced the satisfactory functional outcome. Long-term monitoring of sequelae is required.

Keywords: Child-Epiphyseal separation-Distal femur-Fractures-Growth plate-Treatment

Introduction
Epiphyseal or physeal fractures of the distal femur are relatively common [1, 2]. They account for 1 to 6% of physeal injuries in children and 1 to 15% of fractures in children [2-4]. Most occur during road traffic accidents or sports accidents [4-7]. Their severity is linked to damage to the growth plate, resulting in the cessation of limb growth, which can sometimes lead to disabling sequelae [3-8]. These sequelae depend mainly on the complexity of the growth plate injuries, bone injuries, and sometimes associated knee ligament injuries. Leg length discrepancy, axial deviations and knee stiffness are the most common sequelae [3-7]. However, the major complication remains epiphysiodesis [5-8]. Their management is an emergency [5, 6]. The basis of treatment consists of anatomical reduction that respects the growth plate and fracture immobilisation, which can be either orthopaedic or surgical. The optimal treatment is surgical. New percutaneous surgical techniques have made treatment easier, with early weight-bearing. However, therapeutic difficulties impacting functional outcomes have been reported in the literature [9, 10]. The type of fracture according to skin condition and Salter-Harris classification are factors highlighted in the literature [8-12]. In Ivory Coast, previous studies on the treatment of traumatic injuries to the physis and epiphyseal separation fractures of the limbs in children noted a frequent location (15%) in the distal femur and good functional results [4, 13]. However, to our knowledge, no studies in the local literature have reported specific results for distal femoral physis fractures in children. The principal objective of this study was to evaluate the therapeutic outcomes of distal femoral physis fractures in Bouaké.

The secondary objective was to identify factors influencing functional outcome.

Methods

This was an observational, cross-sectional, analytical study of patient records with distal femoral physis fractures. This study was guided by ethical standards. Anonymity and confidentiality of information were respected. The free and informed consent of the patients' parents was obtained. This article was written in accordance with SRTOBE [14] recommendations. The records covered the period from July 2021 to 31 July 2023. This study was conducted in the Paediatric Surgery Unit of the Bouaké University Hospital Centre (Ivory Coast). Patients were admitted and treated for a fracture of the distal physis of the femur in the department. They were under 15 years of age and were treated and monitored for a recent fracture (< 21 days) of the distal femoral physis. Patients with older fractures (> 21 days) and those with multiple traumas were not included in the study. The diagnosis was made based on medical history, clinical examination and X-rays with orthogonal incidence of the knee. The minimum sample size was calculated using Cochran's formula [15]. This size was calculated based on the study conducted in Mali in 2023, which found a prevalence of distal femoral physis fractures of 0.76%6. The size n= Z(α) 2.p (1-p) /α2 (n: minimum sample size; p: prevalence; α: significance threshold (5%); Z(α): 95% confidence coefficient which is equal to 1.96). This was a simple random sample with consecutive patient recruitment. The information was obtained from patients' hospital records. Epidemiological data (prevalence, age, gender, educational level, aetiology, type of fracture, skin condition and associated injuries) were recorded. The Salter-Harris classification was used for injuries to the distal physis of the femur. The Gustilo-Anderson classification was used for open injuries. The variables studied were the delay and type of treatment, length of hospitalisation, time to consolidation, complications and functional outcome. For open fractures, parenteral antibiotic therapy upon admission combined ceftriaxone (100 mg/kg/day) and metronidazole (35 mg/kg/day). This treatment was continued orally after the patient was discharged from hospital with amoxicillin-clavulanic acid (50 mg/kg/day) for up to 10-15 days. Self-rehabilitation exercises were prescribed to patients to improve functional outcome. These consisted of isometric quadriceps contractions and verticalisation of patients to enable early mobilisation, with active mobilisation of the hip, knee and ankle. N'dour's criteria [17] were used to assess the functional outcome of the pelvic limb (Table I). Reduction was considered anatomical when all four bone cortices were aligned, acceptable if two or three cortices were aligned. It was considered poor when only one cortex was aligned [18]. Postoperative infection was assessed according to the following criteria, at least one of which was required: a wound with signs of infection (pain, swelling, redness, increased local temperature); presence of purulent discharge from the wound; positive microbiological culture of fluid from the wound [18]. Consolidation was defined clinically by the absence of pain when weight-bearing and the absence of mobility of the fracture sites.

Radiologically, consolidation was defined as the formation of callus involving at least three out of four cortices. The statistical analysis followed the SAMPL guidelines for writing and reading statistical methods and analyses.

Data processing was performed using SPSS version 25 software. For quantitative variables, the Wilk-Shapiro normality test was performed beforehand with a margin of error of 5% and a confidence interval of 95% [20]. All quantitative variables followed a normal distribution. The distribution was symmetrical. The calculated central tendency and dispersion parameters were the mean and standard deviation, respectively.

Furthermore, categorical variables were expressed as absolute frequencies and relative frequencies. Descriptive statistics for the population were calculated using epidemiological data. Tables and figures were used to summarise certain results. Next, univariate and multivariate logistic regression analysis was performed to explore the factors associated with an unsatisfactory functional outcome. The initial logistic model was saturated, including relevant variables likely to influence the functional outcome. To arrive at the final model, a stepwise analysis with a top-down strategy was adopted [21-23]. Variables with a p≤ 0.2 in univariate analysis were significantly associated with an unsatisfactory functional outcome. They were included in the multivariate model to control and identify confounding and interaction factors. Finally, in the final model, the aim of which was to select as much information as possible about the dependent variable from the smallest possible number of explanatory variables, the independent variables with a

$p \leq 0.05$ were retained and considered to be the independent predictive factors determining an unsatisfactory functional outcome. In this study, the dependent variable was the functional outcome assessed according to N'dour's criteria[14]. The independent variables were age, skin condition, fracture displacement, Salter-Harris type, treatment delay, type of treatment, and complications. The results of the logistic regression analysis were expressed as crude Odds Ratios (ORc) with 95% confidence intervals (CI) in univariate analysis and adjusted Odds Ratios (Ora) with 95% confidence intervals in multivariate analysis.

Table 1: N'dour's evaluation criteria

Criteria	
Good	
• Walking normally or with slight limping • No pain • Unevenness in lower limb length < 20 mm • Knee flexion greater than 90° (from extension)	• No deviation of the limb axis • No osteitis or epiphysiodesis • No disassembly or expulsion of osteosynthesis material
Fairly Good	
• Moderate pain • Moderate lameness • Lower limb length discrepancy between 20 mm and 30 mm	• Angular malalignment less than 20° • Rotational malalignment less than 15° • Delayed union
Bad	
• Residual pain • Lower limb length discrepancy greater than 30 mm • Knee stiffness in flexion of 45° or misalignment	• Delayed union or pseudarthrosis • Angular malunion greater than 20° • Rotational malunion greater than 15°

Results

General characteristics of the series

The size n= Z(α) 2.p (1-p) /α2 = [(1.96)2x0.0076(1-0.0076)/ (0.05)2] = 25.6951; (n: minimum sample size; p: prevalence; α: significance threshold (5%); Z(α): 95% confidence coefficient equal to 1.96), i.e. a minimum of 12 cases. In total,

this study involved 33 patients (34 fractures) during the study period, representing an exhaustive sample. One case was bilateral. The prevalence was 12.4% of all femur fractures. The characteristics of the study are summarised in Table II.

Table 2: General characteristics of patients with distal femoral physis fractures at Bouaké University Hospital from 2020 to 2023

Variables	Values
Average age (years)	12,1± 2,4 (7-15)
Gender	
Male	(n=27 ; 82%)
Female	(n= 6 ; 18%)
Education	
Yes	(n=26;79%)
No	(n=7;21%)
Circumstances	
Road traffic accident	(n=27 ; 82%)
Sports accident	(n= 5 ; 15%)
Fall from a tree	(n= 1 ; 3%)
Skin condition	
Open	(n=4; 12%)
Closed	(n=30; 88%)
Average consultation time (hours)	19,8± 7,3 (3-49)
< 24 h	(n=24 ; 73%)
> 24 h	(n=9 ; 27%)
Type of fracture (Salter-Harris)	
Type 1	(n=10 ; 29%)
Type 2	(n=20 ; 59%)
Type 3	(n=3 ; 9%)
Type 4	(n=1 ; 3%)
Displaced fracture	
Yes	(n=25; 73%)
No	(n=9 ; 27%)

The age groups were 0-5 years (*n*=5; 15%), 6-11 years (n=7; 21%) and 12-15 years (n=21; 64%). Open fractures were type I (*n*=1; 3%) and type II (n=3; 9%). Associated injuries (4; 12%) were varied. These included chest contusion (*n*=1; 3%), pertrochanteric fracture (*n*=1; 3%) and minor head trauma (n=2; 6%).

Therapeutic Results of the series

The average time to treatment was 3.8 ± 4.7 (1-21) days. Debridement preceded bone fixation in cases of open fractures. Osteosynthesis was performed in closed fractures (*n*=14; 41%) and open fractures (n=20; 59%). Bone fixation by osteosynthesis was supported in all cases by a leg cast for 45 days. The results of the fixation methods are summarised in Table III. Osteosynthesis was performed using pins (*n*=21; 62%) and screws (n=13; 38%). Figure 1 shows pre- and post-operative images of a fracture of the distal physis of the femur.

Table 3: Methods of fixation for fractures of the distal femoral physis at Bouaké University Hospital from 2021 to 2023

Salter-Harris Type	Osteosynthesis
Type 1 (n=10)	Screws (n=4)
	Pins (n=6)
Type 2 (n=20)	Screws (n=8)
	Pins (n=12)
Type 3 (n=3)	Screws (n=1)
	Pins (n=2)
Type 4 (n=1)	Screws (n=0)
	Pins (n=1)

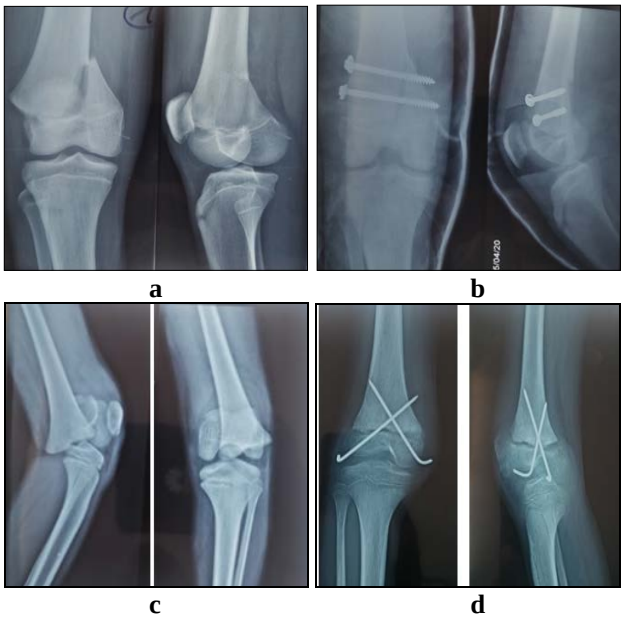

Fig 1: Pre- and post-operative radiographic images of fractures of the distal physis of the femur

A-Initial frontal and lateral radiograph showing a Salter type 2 fracture
B- Follow-up frontal and lateral radiograph showing a Salter type 2 fracture treated percutaneously with screws
C- Initial frontal and lateral radiograph showing a Salter type 1 fracture
D- Follow-up frontal and lateral radiograph showing a Salter type 1 fracture treated percutaneously with broaching

Results of treatment progression in the series

The average length of hospital stay was 2.8±1.1 (1-7) days. Bone reduction and consolidation were complete in all patients. The average time to consolidation was 3.3 ± 0.8 (2-5) months. Healing was normal in all cases after open surgery. Postoperative infection was observed in one patient. The isolated germ was Staphylococcus aureus. Knee stiffness in extension (n = 2; 6%) with a deficit of 10° and in flexion of less than 90° (n = 1; 3%) was noted. Table IV summarises knee joint mobility. At a mean follow-up of 13 months, functional results according to N'dour's criteria were good (n = 25; 74%), fairly good (n = 8; 23%), and bad (*n* = 1; 3%) with resumption of activities. The pins were removed at 60 days. The screws were removed at an average of 15.3 ± 8.9 (9-21) months.

Table 4: Post-treatment knee mobility at last follow-up

Knee mobility	n	%
Knee flexion		
< 90°	1	3
= 90°	7	21
> 90°	26	76
Total		100
Knee extension		
180°	32	94
10° deficit	2	6
Total	34	100

Logistic regression analysis

Table V summarises the univariate (p<0.2) and multivariate (p<0.05) analysis of the predictive factors for an unsatisfactory functional outcome. In the univariate analysis, displaced fracture, presence of an open fracture, Salter-Harris

type 2 fracture, pre-treatment delay > 72 hours and type of osteosynthesis (pin) were the factors associated with an unsatisfactory functional outcome. In the multivariate analysis, Salter-Harris type 2 and the presence of a skin opening were the independent predictive variables for an unsatisfactory functional outcome.

Table 5: Results of logistic regression analysis of predictors of unsatisfactory functional outcome of the knee after distal femoral physis fracture in children at Bouaké University Hospital from 2021 to 2023

Independent variables	Univariate analysis		Multivariate analysis	
	ORc (IC 95%)	p- value	ORa (IC 95%)	p-value
Age (>10 years)	4,32 (1,06- 13,23)	0,76		0,68
Skin condition (open)	2,11 (1,33- 9,77)	0,07	4,38 (2,09-12,98)	0,04
Displaced fracture (yes)	1,63 (0,020- 15,48)	0,02		0,53
Salter-Harris type (type 2)	3,59 (0,97- 89,16)	0,04	7,30 (1,26-25,14)	0,01
Delay of treatment (> 72 h)	2,17 (0,012- 0,45)	0,19		0,08
Osteosynthesis (pin)	2,78 (1,81-14,10)	0,13		0,06
Complications (no)	1,74 (1,55- 12,34)	0,35		0,70

Discussion

The main objective of this study was to evaluate the therapeutic outcomes of distal femoral physis fractures in Bouaké. The secondary objective was to identify the factors influencing the functional outcome. Management was early. Surgical treatment with pinning (62%) was common. Healing was normal. Infection (3%) and stiffness of the knee (9%) were the complications noted. The outcome was satisfactory (97%). Salter-Harris type 2 and the presence of skin opening were the independent predictive variables for an unsatisfactory functional outcome.

This study reports on the experience of a paediatric surgery unit. The epidemiological and clinical results observed in this study are consistent with data in the literature. The average treatment delay (72 hours) was long compared to that reported by Diallo *et al*. [6] (26 hours). The list of factors contributing to the delay is not exhaustive. The unavailability of operating theatres, which are shared by all surgical departments [24, 25]. The treatment charges are covered by the patient, who has no social security cover, or by the parents [24, 25]. Patients sometimes come from remote areas [24, 25]. The impoverishment of the population is real and these factors are specific to the African working context [24, 25]. Physis injuries in children are difficult to treat and their prognosis remains difficult to establish. The femoral growth plates experience the most rapid growth in children [10]. However, the risk of malunion is a major problem for paediatric surgeons treating fractures of the distal femoral growth plate. It is essential to follow the basic principles of treatment. Treatment methods vary. After closed or open reduction, bone immobilisation is achieved either with a plaster cast or by osteosynthesis using a screw, pin, plate, or a combination of pin and screw [4-7]. However, none of these methods is without complications. Surgical management remains the gold standard for early weight-bearing and improved knee function [5-10, 26]. The main challenge is to obtain a solid, anatomical and stable fixation. Osteosynthesis using Kirschner wires was common, as in several other studies [4–10, 26]. In addition, orthopaedic treatment is sometimes used in certain non-displaced fractures treated early in the absence of oedema [4, 5]. Complications were rare, tolerable and compatible with patient rehabilitation. The infection was related to the skin opening. The stiffness could be explained either by the plaster cast support or by the fracture opening. The articular nature of fracture should also be noted [27]. No axial deformities and no limb length discrepancies were observed in this study. The satisfactory functional results obtained are consistent with those reported in African and Western literature [4-10, 13, 26]. The rigor of the intervention planning and the experience of the team could explain these results. The self-rehabilitation recommended to patients after plaster has been removed could also justify this satisfactory overall result. Salter-Harris type 2 and the presence of a skin opening were the independent predictive variables for an unsatisfactory functional outcome.

Each factor so determined multiplied the risk of an unsatisfactory functional outcome by at least 4. This observation was similar to those of other authors [8-12]. Open fractures are associated with knee stiffness due to delayed mobilisation and full weight-bearing [27]. Additionally, Salter type 2 fractures are unstable and may lead to long-term sequelae (epiphysiodesis, angular deformity) [2, 10, 11]. Their complication rate varies between 25 and 60%. Distal femoral physis in children appear to be biomechanically weak, making them vulnerable to injury [11]. This increases the risk of physeal bar formation and permanent physical growth arrest[26]. In adolescents, the potential for remodelling is minor and the risk of deformity is high.

llharreborde *et al* [11] proposed an additional subdivision of distal femoral physeal lesions of type 2 according to Salter-Harris. It is based on the absence (2A) or presence (2B) of metaphyseal comminution [11]. In type 2B, associated displacement (>3 mm) and injury to the growth plate present a higher risk of complications. This concept is sometimes poorly understood by clinicians, who are sometimes surprised to discover late complications in Salter-Harris type 2 fractures. Lesions of the vessels and perichondral ring influence the functional outcome but are often overlooked [11, 28]. The significance of displacement noted in this study is also found to be a predictive factor for poor functional outcome [11, 28].

This study has some limitations. It is monocentric. The sample size remains small compared to previous series in Ivory Coast. This study is homogeneous and may serve as a reference for future studies. It is the first in the local literature to specifically study distal femoral physis fractures in children. It has identified the factors associated with an unsatisfactory functional outcome. The identification of prognostic factors is important because they will help surgeons interpret the prognosis and improve the management of these fractures.

Conclusion

This STROBE observational study evaluated treatment outcomes and identified factors influencing distal femoral physis fractures in children in Africa. Surgical treatment with pinning was associated with satisfactory functional outcomes (97%). Knee stiffness (9%) was the most common complication. However, Salter-Harris type 2 fractures and the

presence of skin opening were independent predictors of unsatisfactory functional outcomes. Evaluation of overall sequelae and patient follow-up should be conducted over the long term until the end of growth.

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Conflict of interest
None.

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