



Avascular Necrosis After Modified Dunn Surgery for the Treatment of Slipped Capital Femoral Epiphysis*

Necrose avascular pós-cirurgia de Dunn modificada no tratamento do escorregamento da epífise proximal do fêmur

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Abstract

Objective The present study analyzed the incidence of epiphyseal avascular necrosis in patients with slipped capital femoral epiphysis (SCFE) treated using a modified Dunn technique. In addition, this study determined the correlation of other variables with this incidence and described treatment complications.

Methods This is a retrospective study with 20 patients treated by the same surgical team from 2009 to 2019 and followed up for 2 to 12 years. The analysis included general features, time from presentation to surgical procedure, classification, and intraoperative blood perfusion of the epiphysis, as well as complications and their treatment.

Results All cases were severe; 65% were acute on chronic, and 55% of the SCFEs were unstable. Our complication rate was 45%, with 5 cases of avascular necrosis, 2 cases of deep infection, 1 case of material failure, and 1 case of joint instability. The statistical analysis revealed that the risk of necrosis was higher when the surgery occurred after a long hospitalization time and there was no intraoperative epiphyseal perfusion. Four necrosis cases happened within the first 5 years, and 1 case in the last 5 years of the study.

Conclusion Our study showed that necrosis was the most common complication. It also revealed that surgery delay and lack of intraoperative epiphysis perfusion potentially predispose to avascular necrosis. Although with no statistical significance, coxofemoral instability occurred in chronic SCFE, and surgical fixation with threaded wires was less effective than fixation with a cannulated screw.

Keywords

- ▶ slipped capital femoral epiphyses/ complications
- ▶ femur head necrosis
- ▶ osteotomy

* Study developed at the Department of Orthopedics and Traumatology, Hospital do Trabalhador, Curitiba, PR, Brazil.

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The modified Dunn procedure should be reserved for severe cases in which other techniques are not feasible and performed by an experienced, trained, and qualified team.

Resumo

Objetivo Analisar a incidência da necrose avascular da epífise no tratamento do escorregamento da epífise proximal do fêmur pela técnica de Dunn modificada, correlacionando-a com outras variáveis. Como objetivo secundário, descrevemos outras complicações encontradas.

Métodos Estudo retrospectivo com 20 pacientes tratados entre 2009 e 2019, com seguimento de 2 a 12 anos, tratados pela mesma equipe cirúrgica. A análise incluiu características gerais, tempo entre apresentação e procedimento cirúrgico, classificação, presença de perfusão sanguínea intraoperatória da epífise, avaliação das complicações e seus respectivos tratamentos.

Resultados Todos os casos eram graves, 65% crônicos agudizados e 55% dos escorregamentos eram instáveis. Nossa taxa de complicações foi de 45%, sendo 5 casos de necrose avascular, 2 de infecção profunda, uma falha do material e uma instabilidade articular. Pacientes operados com maior tempo após a internação e os sem perfusão intraoperatória da epífise tiveram maior risco de necrose na análise estatística. Considerando o tempo do estudo, tivemos 4 casos de necrose nos primeiros 5 anos e 1 caso nos últimos 5 anos.

Conclusão Nosso estudo demonstrou que a necrose foi a complicação mais comum e que o atraso para a realização da cirurgia e a ausência de perfusão da epífise no intraoperatório podem predispor à necrose avascular. Embora não estatisticamente significativa, a instabilidade coxofemoral foi observada na forma de apresentação crônica e a fixação cirúrgica com fios rosqueados se mostrou menos eficaz que a fixação com parafuso canulado.

Este procedimento deve ser reservado para casos graves nos quais outras técnicas não sejam possíveis e realizado por equipe experiente, treinada e capacitada.

Palavras-chave

- ▶ escorregamento das epífises proximais do fêmur/complicações
- ▶ necrose da cabeça do fêmur
- ▶ osteotomia

Introduction

Slipped capital femoral epiphysis (SCFE) is a relatively common condition affecting the hip in adolescents;¹ its incidence is 11 per 100,000 people.² Its treatment remains controversial. For mild-to-moderate cases, it consists of traditional in situ fixation. The treatment for severe cases includes the base of the cervix, intertrochanteric, or subcapital osteotomy. Epiphyseal avascular necrosis (AVN) is the most common and feared complication of these procedures, and it often results from intracapsular osteotomies. Recently, some authors described other methods for severe cases. Parsch et al.³ proposed a gentle, open reduction under monitoring by palpation with the tip of the index finger through a small anterolateral (Watson Jones) access, followed by articular hematoma drainage and subcapital osteotomy to realign the femoral epiphysis in a controlled hip dislocation (modified Dunn procedure).^{4,5}

In situ fixation stabilizes the capital femoral epiphysis, resulting in physeal closure and preventing disease progression. On the other hand, closed or open epiphyseal reduction corrects the deformity by aligning it, potentially minimizing the progression to coxofemoral arthrosis.

The main benefit of the modified Dunn procedure, described in Bern in 1998,^{6,7} is to surgically restore the proximal femur anatomy with the so-called controlled hip dislocation, often by round ligament resection. This approach uses a neck retinaculum flap to spare the femoral epiphysis vascularization, allowing the safe performance of a femoral neck corrective osteotomy.

Although this surgery provides an excellent SCFE correction, it is a complex procedure requiring experience and adequate training; it also can result in complications.⁸

The most frequent complications include avascular necrosis (AVN) of the femoral epiphysis, hip instability, infection, osteosynthesis material failure (breakage), and greater trochanter pseudarthrosis.^{9,10}

The main objective of our study was to analyze the incidence of epiphyseal AVN in patients with SCFE treated using a modified Dunn technique. A secondary objective was to determine the correlation of other variables with this incidence and describe treatment complications.

Materials and Methods

The research ethics committee approved this study under number CAAE 44899021.6.0000.5225.

This is a retrospective study carried out from 2009 to 2019 in a tertiary hospital and based on the review of medical records from patients with SCFE treated using the modified Dunn technique.

The exclusion criteria were incomplete medical records and a follow-up time lower than 2 years.

Evaluated epidemiological data included gender, age at disease onset, and affected side. Slipped capital femoral epiphysis was classified per severity (mild, moderate, severe) as proposed by Southwick,¹¹ time of presentation (chronic, acute, and acute on chronic) according to Fahey and O'Brien,¹² and stability (stable or unstable) as proposed by Loder et al.¹³ In addition, we assessed the time from diagnosis (admission) to the surgical procedure and the intraoperative perfusion of the femoral epiphysis (determined by the perforation of the femoral epiphysis with a 1.5-mm Kirschner wire).

A comparison between patients with and without AVN tried to identify the factors influencing AVN occurrence. Analyzed data included age of presentation (younger and older than 12 years old), gender, affected side, time until surgery (less or more than 2 days), disease features (severity, time of presentation, and stability), and the presence or absence of intraoperative perfusion.

Other complications included superficial and deep infection, synthesis material failure, instability (hip dislocation), and greater trochanter pseudarthrosis. We also describe any subsequent procedures performed to treat such complications.

The findings were presented as mean, standard deviation, and median values for quantitative or categorical variables. A Student t-test for independent samples compared groups

with and without necrosis per age. A non-parametric Mann-Whitney test analyzed the time from diagnosis to surgery. A Fisher exact test assessed the association between categorical variables and the probability of necrosis. Statistical significance was set at $p < 0.05$. Data analysis used the Stata/SE software v.14.1 (StataCorp LLC, College Station, TX, USA).

Results

Our sample consisted of 20 patients with severe SCFE treated by the same surgical team with the modified Dunn procedure from 2009 to 2019. All patients were followed up after surgery for 2 to 12 years. Eleven patients were male, and the mean age was 12.45 years (8–14 years old). Twelve procedures were performed on the left side, and 12 patients underwent in situ fixation on the contralateral side, either due to bilateral presentation or as a prophylactic procedure. None of the patients had the proposed surgery performed bilaterally. On average, surgery occurred 3 days after disease onset (1–12 days) (► **Table 1** and ► **Figures 1, 2, 3, and 4**).

The Fahey and O'Brien system classified most of the cases (65%; 13/20) as acute on chronic, followed by acute (25%; 5/20), and chronic (10%; 2/20). Per the Loder classification, 55% (11/20) of the cases were unstable, and the remaining 45% (9/20) were stable. All SCFE cases were severe, according to the Southwick classification.

The complication rate was 45% (9/20), including 5 (25%) cases of AVN, 2 (10%) cases of deep infection, 1 (5%) case of hip joint dislocation, and 1 (5%) case of synthesis material failure (► **Table 2**).

Table 1 Study patients

Year	Gender	Age	Side	Days until surgery	Severity	Loder classification	Fahey & O'Brien classification	Complication	AVN	Infection	Material failure	Dislocation
2009	Female	12	Left	2	Severe	Unstable	Acute	No	No	No	No	No
2010	Female	13	Right	2	Severe	Stable	Acute on chronic	Yes	No	Yes	No	No
2010	Male	11	Left	3	Severe	Unstable	Acute	Yes	Yes	No	No	No
2010	Male	14	Left	5	Severe	Stable	Chronic	Yes	No	No	No	Yes
2011	Male	14	Left	12	Severe	Stable	Chronic	Yes	Yes	No	No	No
2012	Female	11	Left	3	Severe	Unstable	Acute	Yes	Yes	No	No	No
2012	Female	11	Left	1	Severe	Unstable	Acute	No	No	No	No	No
2012	Female	11	Right	1	Severe	Stable	Acute on chronic	No	No	No	No	No
2013	Male	14	Left	2	Severe	Stable	Acute on chronic	No	No	No	No	No
2014	Female	12	Right	10	Severe	Unstable	Acute on chronic	Yes	Yes	No	No	No
2015	Male	13	Right	3	Severe	Stable	Acute on chronic	No	No	No	No	No
2015	Male	14	Left	2	Severe	Stable	Acute on chronic	Yes	No	No	Yes	No
2015	Female	11	Right	2	Severe	Unstable	Acute	No	No	No	No	No
2016	Male	14	Right	3	Severe	Stable	Acute on chronic	Yes	Yes	No	No	No
2016	Female	13	Right	2	Severe	Stable	Acute on chronic	No	No	No	No	No
2016	Male	14	Right	4	Severe	Stable	Acute on chronic	No	No	No	No	No
2017	Male	13	Left	3	Severe	Stable	Acute on chronic	No	No	No	No	No
2018	Male	14	Left	1	Severe	Unstable	Acute on chronic	No	No	No	No	No
2018	Male	12	Left	1	Severe	Unstable	Acute on chronic	No	No	No	No	No
2019	Female	8	Left	1	Severe	Unstable	Acute on chronic	Yes	No	Yes	No	No

Abbreviation: AVN, avascular necrosis.



Fig. 1 Anteroposterior radiograph of a patient with acute, chronic, unstable slipped capital femoral epiphysis.



Fig. 2 Immediate postoperative anteroposterior radiograph of a case of acute, chronic, unstable slipped capital femoral epiphysis treated using the modified Dunn technique.



Fig. 3 Anteroposterior radiograph of a patient 8 years after the operation of a slippage of the proximal femoral epiphysis with an acute unstable condition on the left side, treated by the modified Dunn technique and in situ fixation on the contralateral side.



Fig. 4 Radiograph in Lauestein of the patient 8 years after the operation of slippage of the proximal femoral epiphysis with acute instability on the left side, treated by the modified Dunn technique and in situ fixation on the contralateral side.

When evaluating AVN-related factors, there was no difference regarding age, gender, and affected side. In addition, there was no significant difference in presentation time and SCFE stability. Statistically, the risk of necrosis was lower in patients operated on up to the 2nd day of hospitalization ($p < 0.008$) or presenting intraoperative epiphyseal perfusion ($p < 0.032$). Time of presentation (according to the Fahey and O'Brien classification) had no statistically significant influence on the necrosis risk when comparing stable (chronic) versus unstable presentations (acute and acute on chronic) and the 2 unstable presentations.

Subsequent procedures for the five AVN cases included two pelvic support osteotomies, one synthesis material removal with clinical observation, one material removal with neck osteochondroplasty, and one valgus osteotomy with osteochondroplasty (►Table 3 and ►Figures 5, 6, and 7).

Considering the time of the study, from 2009 to 2019, 4 of the 5 AVN cases occurred within the first 5 years; these were also the first 10 patients operated on. Only 1 AVN case happened in the last 5 years, comprising the last 10 operated patients (►Table 4).

Discussion

The treatment of SCFE remains a challenge for orthopedic surgeons. The modified Dunn surgery gained popularity to treat moderate and severe cases. This procedure corrects the deformity in situ, preventing a future hip joint degeneration. However, it is technically complex, with a long learning curve for the surgeon and the team, and complications are relatively common.

In 1964, Dunn¹⁴ described a subcapital osteotomy technique by a posterior surgical approach with an AVN rate of only 4%. Later studies did not reproduce this AVN rate, which

Table 2 Frequency of complications

Complication	N	Presence	Frequency*
AVN	20	No Yes	15 (75%) 5 (25%)
Infection	20	No Yes	18 (90%) 2 (10%)
Material failure	20	No Yes	19 (95%) 1 (5%)
Dislocation	20	No Yes	19 (95%) 1 (5%)

Abbreviation: AVN, avascular necrosis.

*Described as mean ± standard deviation, median (minimum and maximum values), or frequency and percentage.

reached 54%^{15,16} due to posterior retinacular vessels stretching.⁷

Based on the studies of Gautier et al.¹⁷ on femoral vascularization and the description of controlled hip surgical dislocation by Ganz et al.,¹⁸ the Bern group presented the outcomes of a so-called modified Dunn procedure, using this approach to perform a subcapital osteotomy with a surprising AVN rate of 0%.^{6,19} Later, in 2019, Lerch et al.,²⁰ also from the Bern group, analyzed the long-term outcomes of 40 cases of severe SCFE undergoing the modified Dunn procedure, reporting a 2% incidence of osteoarthritis, 5% of AVN, and 7% of material failure.

According to the literature, AVN incidence in patients with chronic SCFE not submitted to reduction is close to zero. In

unstable acute cases, this incidence ranges from 10 to 60% regardless of treatment.^{21,22} Although there were no AVN cases in the initial study by Zierbath et al.,²³ performed in two institutions and referring to the outcomes of the modified Dunn technique, other series reported incidences from 5 to 47%.^{8,9,21,22,24}

In our sample, the incidence of AVN after the modified Dunn procedure was 25%, consistent with the published literature. Here, one patient presented chronic, stable SFCE, one patient had acute on chronic, stable SFCE, one had acute on chronic, unstable SFCE, and two patients presented acute, unstable SFCE. However, due to the small sample size, we could not establish a statistically significant correlation between presentation time, stability (per the Loder classification), and AVN.

From the 5 AVN cases, the time between admission and surgery was 3 days for 3 patients, 10 days for 1 patient, and 13 days for 1 patient. Time from admission to surgery was statistically relevant for necrosis, which did not occur in patients submitted to the procedure on the first day of admission. Therefore, our current conduct is to perform surgery within the first 24 hours if possible. This data is consistent with reports from Persinger et al.²⁵ and Herrera-Soto et al.²⁶

The intraoperative perfusion of the femoral epiphysis was also statistically significant. Of the five patients with AVN, three had no perfusion when tested. This correlation was not observed by Upasani et al.,⁹ but confirmed by Novais et al.²⁷ and Aprato et al.²⁸

Masquijo et al.⁸ and Upasani et al.⁹ correlate complications with the surgeon's learning curve and experience. Our

Table 3 Necrosis-related factors

Variable	Group	N	Necrosis – n (%)	P*
Age group (years-old)	11 or 12	9	3 (33.3%)	0.617
	13 or 14	11	2 (18.2%)	
Gender	Female	9	2 (22.2%)	1
	Male	11	3 (27.3%)	
Admission up to surgery (days)	≤ 2	11	0 (0%)	0.0008
	> 2	9	5 (55.6%)	
Affected side	Left	12	3 (25%)	1
	Right	8	2(25%)	
Loder classification	Unstable	9	3 (33.3%)	0.617
	Stable	11	2 (18.2%)	
Fahey & O'Brien classification	Acute	5	2 (40%)	–
	Acute on chronic	13	2 (15.4%)	
	Chronic	2	1 (50%)	
Time of presentation	Acute/acute on chronic	18	4 (22.2%)	0.447
	Chronic	2	1 (50%)	
Time of presentation	Acute	5	2 (40%)	0.533
	Acute on chronic	13	2 (15.4%)	
Intraoperative epiphyseal perfusion	No	4	3 (75%)	0.032
	Yes	16	2 (12.5%)	

*Student's t-test for independent samples (age); non-parametric Mann-Whitney test (days from diagnosis to surgery); Fisher's exact test (categorical variables); p < 0.05.



Fig. 5 Preoperative radiograph of slippage of the proximal femoral epiphysis acutely unstable on the left.



Fig. 7 Postoperative anteroposterior radiograph of an 8-year-old patient after synthesis material removal and osteochondroplasty using the controlled hip dislocation technique to treat AVN after a modified Dunn surgery.

series had 4 AVN cases among the first 10 patients, operated on within the first 5 years, and a single AVN case during the last 5 years. This data is consistent with previously mentioned studies.

Two patients from our sample developed surgical site infection, successfully treated with surgical debridement and antibiotic agents. None of them had AVN. Elmarhany et al.²⁹ reported a 3% incidence of deep infection, which also did not change the procedural outcome.

One patient (5%) presented failure of the synthesis material (bent threaded wires), which was replaced successfully with two cannulated screws. Since this failure, we prefer to perform epiphyseal fixation with two 7.0-mm cannulated screws. Zierbath et al.³⁰ reported a 7% rate for this complication (3 cases out of 40 patients), whereas Sankar et al.²¹ observed a higher figure of 15%.



Fig. 6 Immediate postoperative radiography of acute unstable proximal femoral epiphysis slippage on the left, treated by the modified Dunn technique and prophylactic fixation on the right.

Table 4 Cases with femoral head avascular necrosis

Year	Days until surgery	Intraoperative perfusion	Proposed treatment
2010	3	None	Pelvic support
2011	12	None	Valgus osteotomy + osteochondroplasty
2012	3	Present	Material removal + osteochondroplasty
2014	10	None	Pelvic support
2016	3	Present	Material removal

In a multicentric review, Upasani and the International SCFE Study Group¹⁰ described a 4% rate of coxofemoral instability after a modified Dunn procedure; all cases were severe, chronic, or acute on chronic SCFE. Among these unstable cases, 47% required further surgery, and 82% evolved with AVN, consistent with Upasani et al.⁹ findings from 2014 reporting an instability rate of 5%. Our series had 1 patient (5%) with hip joint dislocation during the immediate postoperative period (a severe, chronic SCFE case); treatment with reduction and immobilization with a cast from the pelvis to the foot resulted in instability resolution, with no AVN development. Since this intercurrent, in severe chronic SCFE, when the acetabulum is adapted to the femoral epiphysis deformity, we prefer intertrochanteric flexor osteotomy associated with osteochondroplasty through a controlled surgical dislocation of the hip.

Although the modified Dunn procedure is a complex surgery, its great advantage is to restore hip anatomy by providing function preservation and preventing the onset of osteoarthritis. On the other hand, its learning curve is long, requiring adequate training to minimize complications.

Currently, we indicate this procedure only for severe, acute on chronic, or unstable cases not amenable to the Parsch et al.³ technique, that is, more than 48 hours after SCFE onset.

As limitations of our study, we emphasize that this procedure is used in specific situations of severe SCFE, requiring a trained, experienced surgical team. This may partially explain our relatively small sample of 20 cases over 10 years. On the other hand, randomized double-blind studies compared with other surgical options are needed to better assess the incidence of complications correlating with predisposing factors.

Conclusion

Our study showed that necrosis was the most common complication. It also revealed a close relationship with surgery delay and lack of intraoperative epiphysis perfusion, that potentially predispose to avascular necrosis. Although there was no statistically significant outcome, coxofemoral instability occurred in chronic SCFE, and surgical fixation with threaded wires was less effective than fixation with a cannulated screw.

The modified Dunn procedure should be reserved for severe cases in which other techniques are not feasible, and performed by an experienced, trained, qualified team.

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Conflict of Interests

The authors have no conflict of interests to declare.

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