

Modified Dunn Technique for Unstable Slipped Capital Femoral Epiphysis: A Midterm Single Center Experience*

Técnica de Dunn modificada no escorregamento da epífise femoral proximal com instabilidade: Experiência unicêntrica de médio prazo

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Rev Bras Ortop 2023;58(4):e632–e638.

Abstract

Objective To evaluate the safety and reproducibility of the surgery for unstable slipped capital femoral epiphysis (SCFE) through the modified Dunn technique in a single center cohort from Brazil.

Methods We retrospectively analyzed a cohort of patients submitted to this procedure by a single surgeon who was a hip preservation specialist. Demographic data and radiographic angles were evaluated for the relative risk (RR) of avascular necrosis (AVN) using a log-binomial regression model with simple and random effects.

Results Among the 30 patients (30 hips) with a mean age of 11.79 years at the time of the operation, there were 17 boys and 18 left hips, which were operated on in a mean of 11.5 days after the slip. The mean follow-up was of 38 months. The preoperative Southwick angle averaged 60.69° against 4.52° postoperatively ($p < 0.001$). A larger preoperative slip angle was associated with the development of AVN (RR: 1.05; 95% confidence interval [95%CI]: 1.02–1.07; $p < 0.01$). The overall AVN rate was of 26.7%. Function was good or excellent in 86% of uncomplicated hips, and poor in 87.5% of the patients who developed AVN, as graded by the Harris Hip Score. There was no statistical relationship between epiphyseal bleeding and AVN development ($p = 0.82$).

Keywords

- ▶ slipped capital femoral epiphysis
- ▶ femoral head necrosis
- ▶ osteotomy
- ▶ hip

* Study conducted at Hospital Estadual da Criança, Rio de Janeiro, RJ, Brazil.

received
May 10, 2022
accepted
September 12, 2022

DOI <https://doi.org/10.1055/s-0042-1758362>.
ISSN 0102-3616.

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Conclusion The modified Dunn technique is associated with restoration of the femoral alignment and function after unstable SCFE, when uncomplicated. Moreover, it was shown to be reproducible in our population, with a rate of 26% of femoral head necrosis.

Resumo

Objetivo Avaliar a segurança e a reprodutibilidade da cirurgia para escorregamento da epífise femoral proximal (EFPF) com instabilidade por meio da técnica de Dunn modificada em uma coorte unicêntrica no Brasil.

Métodos Analisamos de forma retrospectiva uma coorte de pacientes submetidos a esse procedimento por um único cirurgião especialista em preservação do quadril. Avaliamos os dados demográficos e os ângulos radiográficos quanto ao risco relativo (RR) de necrose avascular (NAV) por meio do modelo de regressão log-binomial com efeitos simples e aleatórios.

Resultados Entre os 30 pacientes (30 quadris) com idade média de 11,79 anos no momento da cirurgia, havia 17 meninos e 18 quadris esquerdos. O procedimento ocorreu em média 11,5 dias após o escorregamento. O tempo médio de acompanhamento foi de 38 meses. O ângulo de Southwick pré-operatório foi, em média, de 60,69° contra 4,52° após o procedimento ($p < 0,001$). O maior ângulo de escorregamento pré-operatório foi associado ao desenvolvimento de NAV (RR: 1,05; intervalo de confiança de 95% [IC95%]: 1,02–1,07; $p < 0,01$). A frequência geral de NAV foi de 26,7%. De acordo com a Escala de Quadril de Harris (Harris Hip Score), a função foi boa ou excelente em 86% dos quadris sem complicações, e ruim em 87,5% dos casos com NAV. Não houve relação estatística entre sangramento epifisário e desenvolvimento de NAV ($p = 0,82$).

Conclusão A técnica de Dunn modificada restaura o alinhamento femoral e a função articular após o EFPF com instabilidade na ausência de complicações. Além disso, mostrou-se passível de reprodução em nossa população, com frequência de necrose da cabeça femoral de 26%.

Palavras-chave

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

Introduction

Slipped capital femoral epiphysis (SCFE) is characterized by an anterior and lateral displacement of the proximal femoral metaphysis in relation to the epiphysis. An important functional impact can derive from the secondary deformity, or from avascular necrosis (AVN) of the femoral head, which is the worst complication related to the slip.^{1–3} According to Loder et al.,⁴ unstable SCFE is one in which the patient is not able to stand up with aid, even without bearing weight on the affected limb. These authors⁴ have also related the instability with a risk of up to 47% of developing AVN. This relationship has been recently reviewed, and the incidence of AVN in unstable slips remained high, ranging from 22% to 50%.^{2,5,6} On the other hand, in cases of stable SCFE there is virtually no risk of developing AVN.^{5,7,8}

Different surgical techniques have been developed to minimize the functional impairments of the slip and its complications. Subcapital realignment osteotomy, known as the modified Dunn technique, has been gaining popularity since its description in 2007 by a group of surgeons from Switzerland.⁹ The possibility of protecting the vascular supply of the femoral head while correcting the deformity to restore the prelesion anatomy has been the main reason for this change in the management of SCFE. Many papers have

been published^{5,10–16} on the experience of specialized centers internationally with AVN incidence varying from lower than 10% to higher than 50%. However, reports of the experience of Brazilian centers are lacking in the literature, and we aim to describe the midterm results of the first 30 cases operated on through this technique in our hip preservation unit.

Material and Methods

After approval by the institutional Ethics Committee (CAAE 80941816.1.0000.5249), we prospectively followed the first 31 patients (31 hips) who were submitted to the modified Dunn technique for unstable SCFE, performed by the same professional, a pediatric orthopedic surgeon specialized in hip preservation. All parents signed the informed consent form for the surgical treatment and participation in the project. The operations were performed from January 2015 to July 2018, in patients with unstable slips according to the classification by Loder et al.⁴ and with moderate or severe slips according to the Southwick angle.¹⁷ The operation followed the technique described by Leunig et al.,⁹ except for the fact that we did not use Doppler flowmetry to assess the vascularity of the femoral head intraoperatively. We also used a different fixation method, consisting of

a 7.0-mm cannulated screw (Synthes, Oberdorf, Solothurn, Switzerland) associated with a 2.0-mm threaded pin in the first 22 cases, and 2 7.0-mm cannulated screws in the next 9 cases.⁹ We determined the vascularity of the femoral head by the presence of bleeding from 1 or 2 holes drilled in the anterior portion of the head with a 1.5-mm smooth Kirschner wire, before retinacular flap dissection and after reduction of the epiphysis.

Mild and stable slips, as well as moderate or severe SCFE with a closed physis, were excluded from the analysis. Patients with a radiographic aspect of AVN before the treatment at our institution and those with endocrine abnormalities or other comorbidities were also excluded from the study group.

The preoperative data included age, gender, laterality, time from symptom onset until operative treatment, stability according to Loder et al.,⁴ and magnitude of the slip according to Southwick.¹⁷ Postoperatively, we recorded the quantitative correction of the Southwick angle, the duration of the follow-up, the incidence of complications, and the functional status through the Harris Hip Score (HHS).¹⁸ The main demographic data are described in ►Table 1. One patient was lost to follow up before 1 postoperative year, and was excluded from the final analysis, comprising 97% of initial sample retention.

The slip angle as described by Southwick¹⁷ was measured in preoperative anteroposterior (AP) and lateral (frog leg or cross table) hip radiographs by the main author (FCMV), and further classified, as per Boyer et al.,¹⁹ as mild for slips below 30°, moderate, between 30° and 50°, and severe for slips above 50° on lateral view. The magnitude of the slip correction was calculated by subtracting the postoperative Southwick angle from its preoperative value. The radiographic diagnosis of AVN was based on the presentation of one or more of the following: subchondral bone sclerosis, subchondral fracture, radiolucency of the subchondral bone, and resorption or collapse of the subchondral bone with flattening of any portion of the femoral head (►Fig. 1). Chondrolysis was determined as a reduction of the joint space to less than

50% of the contralateral hip or 3 mm in bilateral cases, associated with joint stiffness. The postoperative complications were graded according to the modified Clavien-Dindo classification, in which grade I comprises complications that do not require a change in the normal postoperative routine, grade II requires an outpatient-based change in the postoperative care, grade III requires radiological or surgical intervention, grade IV is associated to long-term morbidity or risk of death, and grade V results in the death of the patient.^{20,21}

The postoperative protocol included the absence of weight-bearing for the first six weeks, followed by partial weight-bearing if the initial signs of healing (closure of the proximal femoral physis or callus formation in three out of four corticals bridging the physis in two orthogonal radiographic views) were present at the appointment at six weeks (►Fig. 2). Unrestricted weight-bearing was allowed when full healing occurred, and return to full activities was allowed after six months in uncomplicated cases. Strengthening exercises for the abductor muscles started after healing of the greater trochanteric osteotomy. Cases complicated by AVN were kept without bearing weight and submitted to early femoral head decompression via multiple drilling of the physis with a 4.3-mm cannulated drill and revision of the fixation when needed. Chondrolysis was treated by manipulation under anesthesia associated with intra-articular corticosteroid injection. The functional status was determined by the main author at the one-year follow-up appointment using the HHS.¹⁸

The data were described by absolute frequencies and percentages for qualitative variables, and by means, standard deviations, and minimum, median, and maximum values for quantitative variables. To estimate the relative risk (RR) of complications, we used the log-binomial regression model with simple and multiple random effects. The statistical analysis was performed using the SAS software (SAS Institute, Cary, NC, United States), version 9.2, and the graphics, using the R software (R Foundation for Statistical Computing, Vienna, Austria), version 3.4.1. A significance level of 5% was used for all comparisons ($\alpha = 0.05$).

Table 1 Demographics of the study population

Patients (hips)	30 (30)
Average age (years)	11.79
Gender (male:female)	17:12
Side (right:left)	12:18
Average ΔT (days)	11.53
Avascular necrosis (cases/%)	8/26.67%
Mean follow-up (months)	38.07
Average preoperative Southwick angle (degrees)	60.69
Average postoperative Southwick angle (degrees)	4.52

Notes: Southwick angle – posterior slippage angle of the proximal femoral epiphysis; ΔT , time between the traumatic event and the surgical procedure.

Results

The final sample consisted of 30 patients (30 hips), 56.6% (17) of whom were male, and 60% (18) of left hips. The mean age at operation was of 11.79 (range: 9 to 15) years, and the mean delay from the slip and the surgical procedure was of 11.53 (range: 5 to 45) days (►Table 1). In 9 (56.25%) out of 16 cases in which we evaluated femoral head bleeding before the periosteal flap dissection and after epiphyseal reduction, there was bleeding before the dissection. In 13 (81.25%) of these 16 cases, there was bleeding after the reduction of the epiphysis, which may indicate recovery of the head vascularity in 4 cases with the technique. However, we found no relationship between bleeding and the final outcome of AVN (RR: 0.89; 95% confidence interval [95%CI]: 0.32–2.45; $p = 0.82$).

The mean preoperative slip was of 60.69° degrees (range: 44° to 90°), and the mean postoperative angle was of 4.52°

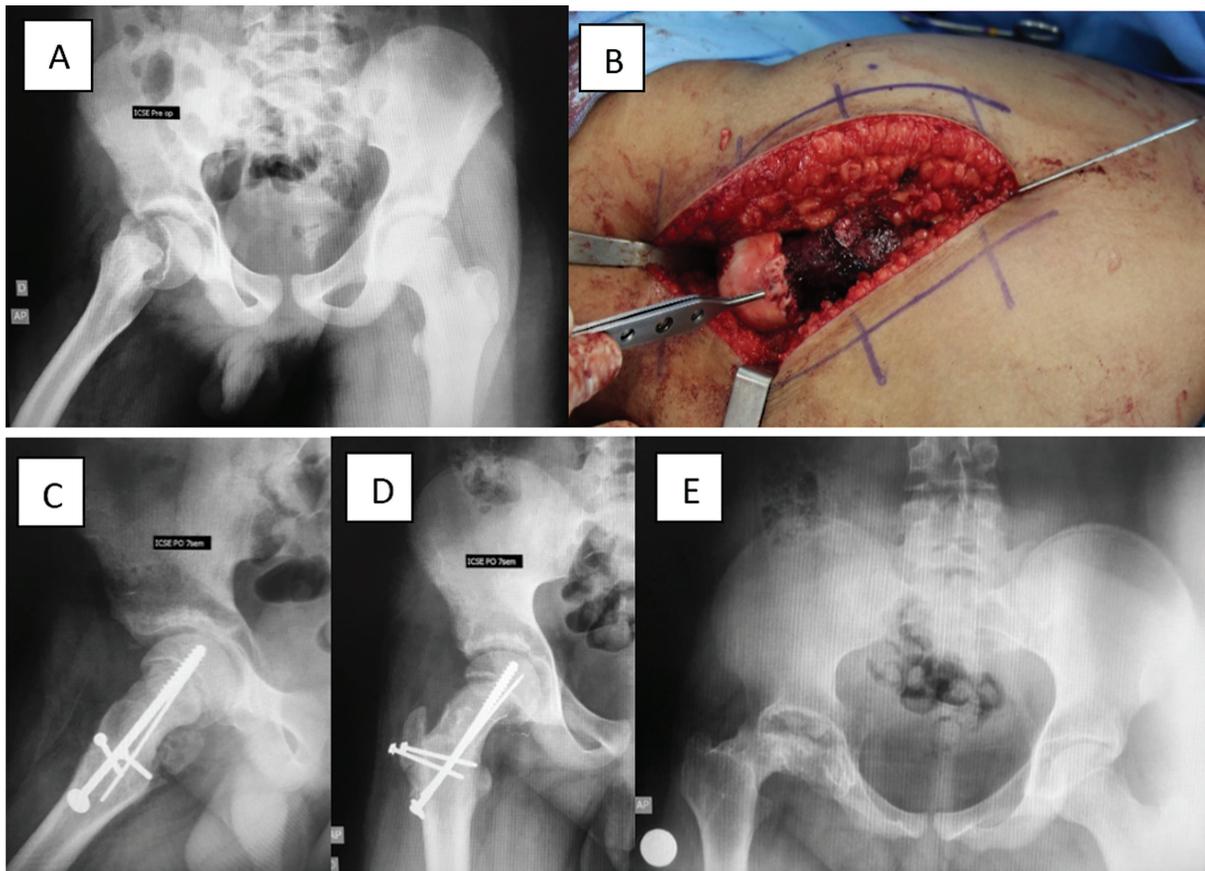


Fig. 1 Preoperative period (A); intraoperative aspect of the footprint of the retinacular vessels in the epiphysis demonstrating its potential avulsion due to the slip (B); immediate postoperative period (C,D); and final (E) radiographic aspect of a severe unstable slip developing avascular necrosis of the femoral head.

(range: -9° to 12°). Therefore, all cases had moderate or severe angulation according to Boyer et al.¹⁹ Among the 30 operated hips, 73.3% (22) had a satisfactory radiographic evolution, with healing within the first 3 months after surgery, and without major complications. The incidence of AVN at the final follow-up was of 26.7% (8 cases). All but one patient developed AVN within the first six postoperative months. The exception was one boy who showed signs of healing at the outpatient appointment at six months, but he returned to the visit at nine months with severe pain after falling during a soccer game and presented with radiographic subchondral fracture and collapse.

Correlating the degree of deformity to the occurrence of AVN, we observed a statistically significant relationship, with a bigger slip being related to a higher risk of AVN (RR: 1.05; 95% CI: 1.02–1.07; $p < 0.01$) (► **Table 2** and ► **Fig. 3**). Moreover, we identified that for every degree of increase in the Southwick angle, the AVN risk had a 4.5% increase. Similarly, a higher degree of the Southwick angle correction was directly proportional to the development of AVN (RR: 1.05; 95% CI: 1.007–1.1; $p = 0.02$). On the other hand, the gender of the patient and the affected hip side had no influence on the development of AVN ($p = 0.17$ and 0.16 respectively), nor had the age at presentation, after adjusting for confounding factors ($p = 0.6$).

The mean HHS score was of 75.7 (range: 35.3 to 96.7) points. After stratification between the cases that developed complications or not, specially AVN, we observed a mean score of 86.6 points (good outcome) in the group without AVN, with 86% (19 hips) having good or excellent function, while the AVN group had a mean HHS score of 48.7 points (poor result), with 87.5% (7 cases) presenting a poor outcome. Two cases of chondrolysis occurred, both Clavien-Dindo III, requiring surgical revision for a steroid injection. They were self-limited, with radiological resolution of the chondral damage after 2 years, one presenting a final HHS score of 86.3 points and the other, 71.8 points. All AVN cases were considered Clavien-Dindo IV, with important functional impairment in the midterm follow up. They were all submitted to femoral head decompression as soon as radiographic signs of AVN were identified. Moreover, two of the AVN cases underwent proximal femoral valgus osteotomy but have remained functionally poor and will be submitted to a total hip arthroplasty (THA). One patient was submitted to arthrodiastasis with an external fixator at the same time of the head decompression, and albeit a bad radiographic outcome, is clinically stable, not yet willing to undergo THA. Three more patients have been submitted to the removal of the fixation devices and will be submitted to THA. The remaining two patients with AVN are functionally satisfied, currently in outpatient follow-up. One Clavien-Dindo II complication

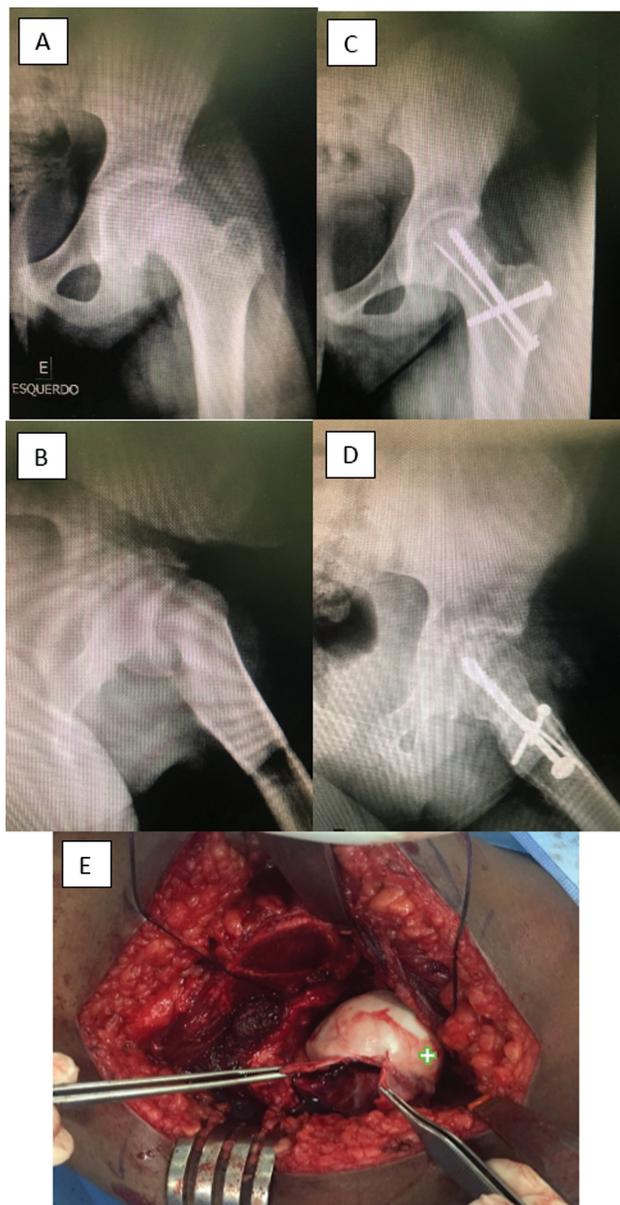


Fig. 2 Radiographic aspect, preoperatively (A,B) and 27 months postoperatively (C,D), of a severe unstable slip with uneventful healing. Note: +Demonstrates the intact softspot, where retinacular vessels penetrating the epiphysis (E).

occurred, consisting of a superficial wound infection, which was successfully treated with oral antibiotics.

Discussion

In its unstable form, SCFE is associated with AVN in up to 47% of the cases.^{2,4,5} Therefore, the acceptance of surgical techniques combining anatomical realignment with little secondary deformity while minimizing the risk of AVN, specially the modified Dunn technique, has increased internationally in the last decade.^{9,14} The international experience with this technique has been published^{5,11,16,22–25} since its description, but limited data are available for the Latin American population. In the present study, the largest

Table 2 Correlation of qualitative variables and avascular necrosis

	no AVN	AVN
ΔT (days)	13.22	9
Average age (years)	11.57	12.38
gender (male:female)	14:07	03:05
Mean preoperative Southwick angle (degrees)*	58.24*	67.13*
Mean Southwick angle correction (degrees)*	54.14*	61.5*
Mean Harris Hip Score (points)*	86.67*	48.75*

Abbreviations: AVN, avascular necrosis; Notes: Southwick angle – posterior slippage angle of the femoral epiphysis; ΔT , time between the traumatic event and the surgical procedure; * $p < 0.05$ by the log-binomial regression model with simple and multiple random effects.

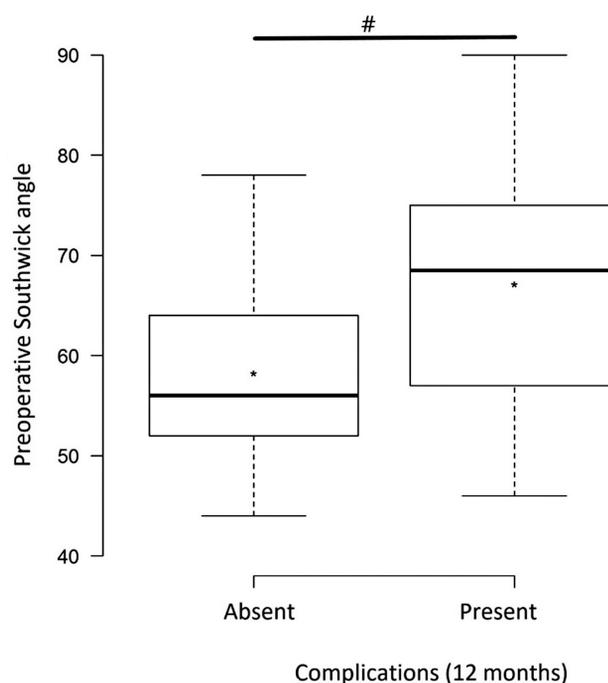


Fig. 3 Relationship between the magnitude of the slip measured by the Southwick angle preoperatively and the occurrence of complications (avascular necrosis). Notes: #RR: 1.05; 95%CI: 1.025–1.076; $p < 0.01$ by the log-binomial regression model with simple and multiple random effects. *Mean value.

Latin-American single center cohort of unstable SCFE treated through the modified Dunn technique to date, we have shown that the technique is reproducible in the Brazilian population, with a risk of AVN of 26% (8 cases).

Our sample presented demographics similar to what has been previously described for age at presentation, higher prevalence in boys, and predominance of left hips.²⁶ The main factors previously related to the development of AVN were the magnitude of the slip and younger age.^{26–28} We have also found a significant relationship between a more severe Southwick angle and a higher risk of AVN. In our

sample, the probability of AVN increased by 4.5% for every degree of increase in the Southwick angle. On the other hand, in our sample, there were more cases of AVN among older patients than younger ones, however, without statistical significance. We believe that this might be related to the thinner periosteum found in older patients, which may be more fragile and susceptible to rupture in an acute unstable SCFE or during the operative procedure (► Fig. 1).

In 16 of our cases, we recorded whether there was bleeding through drilled holes in the femoral head. Among the AVN cases, 5 (62.5%) had this evaluation and 3 (60% of the evaluated) had active bleeding after reduction of the epiphysis. We did not find this test to be accurate in determining the head vascularity, but our sample was underpowered for this variable. Previous studies have used different methods for the identification of epiphyseal viability, with Doppler flowmetry being the most accurate, even though the reading the result may take two minutes.²⁹ Moreover, bleeding through epiphyseal drilled holes has been shown to be as accurate as intracranial pressure catheter monitorization for the purpose of detecting a disruption in the blood flow, and it is still our method of choice for subsequent assessments of larger populations.³⁰ There is still doubt as to whether the femoral head might be avascular before the operation. A French study³¹ using perfusion magnetic resonance imaging (MRI) showed that avascular heads before capital realignment can revascularize after the operation. Superselective angiogram of the medial circumflex artery has also identified the revascularization with surgery; therefore, using a technique that enables the safe reorientation of the femoral epiphysis instead of pinning unstable slips in situ is important.^{32,33}

The prevalence of AVN ranges from 6.5% to 53% in unstable cases in multiple studies found in the literature.^{2,5,6,10,16,23,24,34} Our sample presented a rate of AVN of 26% (8 hips), which is comparable to a previously published multicentric American study published in 2013,¹¹ which only evaluated unstable slips. In a Brazilian SCFE cohort recently published by Valenza et al.,³⁴ an overall AVN rate of 25% was found among stable and unstable slips, which is also compatible with our sample, even though we only studied unstable cases. It is important to mention that different techniques for capital realignment are used internationally to treat SCFE. For instance, a French multicentric study²³ showed that the preferred technique in that country is a cuneiform osteotomy performed through the Hueter approach without periosteal flap dissection, with a rate of AVN of only 13.3% in 45 unstable slips.²³ Treating slips before 24 hours of evolution with gentle reduction and anterior capsulotomy enabled a single German center³⁵ to achieve a rate of AVN of 4.7% in 60 unstable slips during a 19 year period. Unfortunately, the logistics of the Brazilian health system does not enable us to admit patients in such an acute setting, and the results of the latter technique were not reproducible. In unstable cases, in situ fixation presents an AVN rate that ranges from 22% to 47%.^{2,5} Therefore, we believe that a technique that is reproducible and has a rate of AVN of 26% or maybe less, depending on the learning curve, is very useful and must be considered for

the treatment of unstable slips. We also believe that these cases should be referred to a high-volume surgeon, as this has been related to a lower complication rate.³⁶

The present study has some limitations, and the most important is related to the absence of a control group treated through in situ fixation, which would show, in our population, the impact of instability and the modified Dunn technique on the development of AVN. On the other hand, the present study was prospective, with all cases of unstable slips treated by the same surgeon, a specialist in hip preservation, thus avoiding a selection bias and complications related to low-volume surgeons. We aim to publish future results on the subsequent cases, to evaluate the impact of the learning curve on the complications, as well as the expansion of indications for severe stable slips.

Finally, we conclude that the modified Dunn technique is efficient in restoring the anatomy of the proximal femur and justifiable due to its AVN rates in unstable SCFE, and is reproducible in our population when compared with international cohorts.

Financial Support

The authors declare that they have received no financial support to prepare the present manuscript.

Conflict of Interests

The authors have no conflict of interests to declare.

Acknowledgments

The authors would like to thank all patients and families who agreed to share the data, as well as all medical staff and support team at Hospital Estadual da Criança, whose work greatly contributed to the present study.

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