



The effect of slip grade and chronicity on the development of femur avascular necrosis in surgically treated slipped capital femoral epiphyses

Cerrahi tedavi uygulanmış femur başı epifiz kaymasında kayma derecesi ve kronik veya akut olmasının avasküler nekroz gelişimi üzerine etkisi

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Amaç: Femur başı epifiz kaymasının cerrahi tedavisi sonrasında en sık görülen komplikasyon olan femur başı avasküler nekrozunun (AVN), kaymanın derecesi ve kronik veya akut olmasıyla olan ilişkisi araştırıldı.

Çalışma planı: Femur başı epifiz kayması bulunan ve cerrahi tedavi sonrasında en az bir yıl takip süresi olan 269 hastanın (174 erkek, 95 kız; ort. yaş 12) 424 kalçası, epifiz kaymasının Southwick sınıflamasıyla derecesine ve semptomların akut veya kronik olmasına göre incelendi. Epifiz kaymasının başlangıç derecesi ve kronikliğiyle AVN gelişimi arasındaki ilişki istatistiksel olarak değerlendirildi.

Sonuçlar: Femur başı epifiz kayması 114 hastada tek taraflı, 155 hastada ise iki taraflıydı. Hastaların ortalama takip süresi 32.9 aydı. Epifiz kayması 267 kalçada (%63) I. derece, 120 kalçada (%28.3) II. derece, 37 kalçada (%8.7) III. dereceydi. Yakınmalar 130 kalçada (%30.7) akut, 294 kalçada (%69.3) kronikti. Ameliyat sonrasında 19 kalçada (%4.5) AVN geliştiği gözlemlendi. Bunların 13'ü tek taraflı, altısı iki taraflı epifiz kayması olanlarda görüldü. Lojistik regresyon analizinde epifiz kaymasının derecesiyle AVN gelişimi arasında güçlü bir ilişki olduğu gözlemlendi (odds oranı 10.27; $p < 0.0001$). Kaymanın akut olması da AVN gelişimiyle ilişkili bulundu; ancak bu ilişki daha zayıftı (odds oranı 0.20, $p < 0.01$).

Çıkarımlar: Femur başı epifiz kaymasının başlangıç derecesiyle ameliyat sonrası AVN gelişimi arasında güçlü bir ilişki vardır. Bu nedenle, kayma derecesi yüksek olan hastalar AVN açısından daha yakından izlenmelidir. Kaymanın akut olması da AVN için diğer bir risk faktörüdür.

Anahtar sözcükler: Epifiz kayması/komplikasyon; femur başı/radyografi; femur başı nekrozu/radyografi; risk faktörü.

Objectives: We investigated the relationship between the grade and chronicity (acute-chronic) of the slip and the development of avascular necrosis (AVN) of the femoral head after surgery for slipped capital femoral epiphysis (SCFE).

Methods: The study included 424 hips of 269 patients (174 boys, 95 girls; mean age 12 years) who underwent surgery for SCFE and had a minimum follow-up period of one year. The patients were classified according to the severity and chronicity of the slipping using the Southwick classification. The relationship of the slip severity and chronicity with the development of AVN was statistically evaluated.

Results: Involvement was unilateral in 114 patients, and bilateral in 155 patients. The mean follow-up period was 32.9 months. The hips were classified as grade I to II in 267 hips (63%), 120 hips (28.3%), and 37 hips (8.7%), respectively. The symptoms were acute in 130 hips (30.7%), and chronic in 294 hips (69.3%). The incidence of AVN was 4.5% (19 hips; 13 in unilateral cases, 6 in bilateral cases). In logistic regression analysis, a strong correlation was found between the grade of the slip and the development of AVN (odds ratio 10.27; $p < 0.0001$). The acute nature of the slip was also correlated with the development of AVN, but this relation was weaker (odds ratio 0.20, $p < 0.01$).

Conclusion: A strong correlation is present between the slipping grade and the development of AVN in SCFE, requiring a closer observation of patients having a high grade slipping in terms of AVN risk. The acute nature of the symptoms represents another risk factor for AVN.

Key words: Epiphyses, slipped/complications; femur head/radiography; femur head necrosis/radiography; risk factors.

Slipped capital femoral epiphysis (SCFE) is the most common hip problem encountered during the growth period. It is 2-4 times more common in boys than girls.^[1] There is a displacement of the femoral epiphysis relative to the metaphysis. According to its etiology its divided as idiopathic and atypical. Atypical SCFE is mostly seen with other problems namely endocrinopathies (hypothyroidism, hypogonadism), metabolic problems (renal dystrophies, osteomalasia), radiotherapy and chemotherapy.^[2]

Chronological classification of SCFE is acute if the duration of symptoms is less than 3 weeks and chronic if more than 3 weeks.^[3]

Displacement of the epiphysis relative to metaphysis is measured for radiographic classification. In Southwick classification, which is one of the most commonly used radiological methods, head-shaft angle is measured from the lateral radiographs for classification.^[4]

The main aim of the SCFE treatment is preventing further slip. For this reason, appropriate treatment especially in mild and moderate slips is in situ pinning of the slip with either one or two screws.^[2] The factors that effects the long term clinical results are the degree of initial slip and the post operative complications. Avascular necrosis (AVN) is the most common complication that directly effects the clinical result.^[1,2,5-8] The incidence of AVN is reported ranging between 3-47 % depending on the treatment.^[9]

Although there are studies that support a relation between AVN and the degree and chronicity of the slip,^[10-12] there are others that oppose this relation.^[2,5,6] In the study of Rattey et al. evaluating 208 patients, the incidence of AVN was found higher in patients having acute and high degree of SCFE.^[12] Similarly, Herman et al. reported that the risk of AVN is higher especially in patients having severe slipping.^[10] On the other hand, there are others advocated that there is no relation between the formation of AVN and the degree of the initial slip.^[6,7] Thus, the relation between AVN formation and the

degree and the chronicity of the slip is still debatable.

In this study, whether the slip degree and its chronicity is a factor in the development of AVN was investigated.

Materials and Methods

We performed a retrospective review of the records of all patients with

SCFE treated between 1993 and 2003 in the Children's Hospital of Philadelphia. Inclusion criteria provided that patients had to have a complete set of radiographs made at the time of presentation. Patients who had an endocrine or metabolic disease, or had been treated elsewhere for an initial slip were excluded.

In this study, the surgeons stabilized all SCFE by using either a single or double 7.3 mm cannulated screw. No attempts at closed or open reduction either preoperatively or intraoperatively were made.

There was no documented pin penetrations into the hip joint according to the medical reports. Postoperatively, all patients were instructed to be partial weight bearing on the operated leg for 6 weeks.

The medical records provided information on gender, age, the chronicity and the initial degree of

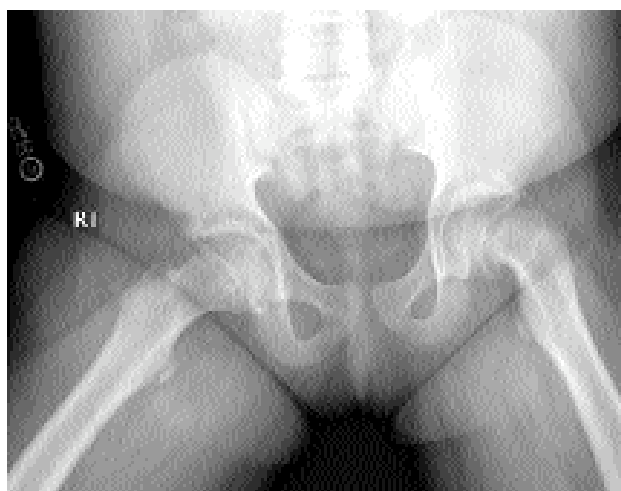


Figure 1. Grade II slipping according to Southwick classification

Table 1. The distribution of slip grading in unilateral and bilateral slips.

	Grade I		Grade II		Grade III		Sum
	Number	Percentage	Number	Percentage	Number	Percentage	
Unilateral SCFE	64	56.1	41	36.0	9	7.9	114
Bilateral SCFE	203	65.5	79	25.5	28	9.0	310
Sum	267	63.0	120	28.3	37	8.7	424

the slip. The grade of the slips were defined as Grade I (<300), Grade II (300to 500), or Grade III (>500) on the basis of the lateral head-shaft angle as described by Southwick.^[4] (Figure 1)

Patients having more than twelve months follow-up were included for detection of AVN. Radiographic evidence of avascular necrosis included partial or total collapse of the femoral head.^[12]

The relation between AVN and the degree and the chronicity of the slip was evaluated in all hips. Than after both in unilateral and bilateral slips separately. The relation was evaluated by using logistic regression analysis test. Chi square test was used to compare the unilateral and bilateral slips.

Results

The database of 520 patients diagnosed with SCFE were initially evaluated. After excluding the

patients who had endocrinologic problems, had been treated elsewhere and having insufficient radiographs, the medical reports of 438 patients were found to be sufficient to be included to the study. SCFE was unilateral in 249 patients and bilateral in 189 patients. Patients having unilateral SCFE, 82 developed a contralateral subsequent slip during the follow-up period. This raised the bilateral SCFE to 271 (61.9 %).

Patients with more than one year follow-up period were evaluated and 269 (174 male, 95 female) were identified. Among them 172 had unilateral and 97 had initial bilateral slips. During the follow-up period, 58 of the patients having unilateral slip developed a contralateral subsequent slip. The slip in the contralateral hip was detected at a mean of 6.5 months (range, one to twenty-five months) from the time of the initial presentation. Including the

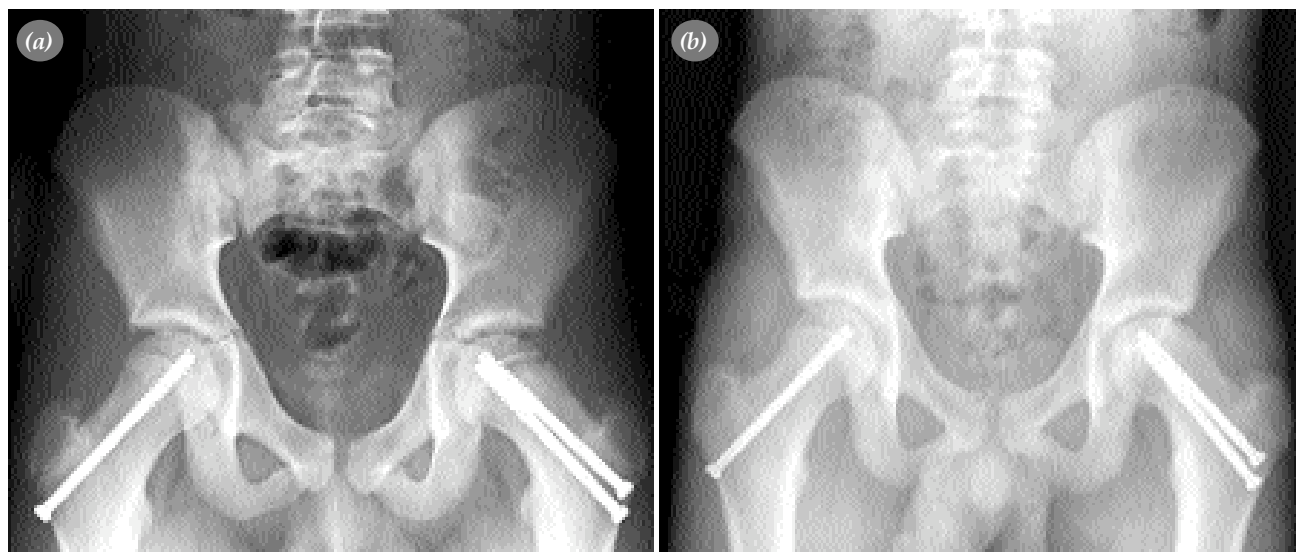


Figure 2. In situ fixation of SCFE (early post-operative radiography) (b) Post operative 3.month radiography of the same patient with early findings AVN

Table 2. The distribution of slip grading according to chronicity.

	Acute		Chronic		Sum
	Number	Percentage	Number	Percentage	
Unilateral SCFE	29	25.4	85	74.6	114
Bilateral SCFE	101	32.6	209	67.4	310
Sum	130	30.7	294	69.3	424

patients having a contralateral subsequent slip, 155 patients (57.6 %) had bilateral SCFE. Thus 144 unilateral and 155 bilateral hips (total 424 hips) were included to the study.

The average follow-up period was 32.9 months. The degree of the slip was Grade I in 267 hips (63%), Grade II in 120 hips (28.3%) and Grade III in 37 hips (8.7%). (TABLE 1) AVN developed in 19 hips (4.5 %). (Figure 2,3) The average interval between the operation and identification of AVN was 170 days (range 15 days to 377 days).

The hips that developed AVN, one had Grade I slip, six had Grade II slip and 12 had Grade III slip. Symptoms were acute in 14 hips and chronic in five hips.

There was no difference between the unilateral and bilateral slips regarding the slip severity.

**Figure 3.** Severe AVN and coxa-vara formation.

(TABLE 1) Similarly, there was no difference between these groups regarding the chronicity of the slips. (TABLE 2)

There was a strong relation between the development of AVN and the degree of the slip (odds ratio 10.27; $p < 0.0001$). A similar relation was also present between the development of AVN and the acute SCFE (odds ratio 0.20; $p < 0.01$). However this relation was weaker.

Development of AVN was evaluated in unilateral and bilateral slips separately. Avascular necrosis of the femoral head was identified only in six hips (1.9%) having bilateral SCFE, whereas it was present in 13 hips (11.4%) having unilateral SCFE. The difference was statistically significant ($p < 0.001$). When the relation between slip severity and development of AVN was evaluated separately in unilateral and bilateral slips, the relation was found to be stronger in hips having bilateral slips (odds ratio was 21.58 and 16.91 in bilateral and unilateral slips respectively; $p < 0.0001$).

Discussion

Avascular necrosis of the femoral head is the most common early complication of slipped capital femoral epiphysis.^[2,5,6,9-14] Since it directly effects the clinical results, the main aim in the treatment of SCFE is prevention of further slip and elimination of the factors that may cause AVN.^[2] The number and position of the fixation screws in the epiphysis, slip degree and attempts for reduction are the proposed factors for development of AVN. Location of the fixation screws on the antero-lateral part of the epiph-

ysis thus damaging the lateral epiphysal arteries was reported to increase AVN formation.^[12,15] Although the relation between AVN formation and the degree and chronicity of the slip was evaluated in the literature, there is no clear consensus on this issue due to the low patient number and non-homogenous distribution of the patients. In the study of Rattey et al, a relation between AVN formation and the acuteness and the high grade of the slip was reported.^[12] In evaluation of 23 patients having Grade III slips, Herman et al. reported a relation between AVN and acute slips, however this relation was not present in chronic Grade III slips.^[10] Loder et al^[5] evaluated 55 acute slip patients and concluded that there was no relation between AVN formation and acuteness of the slipping. The only factor effective on AVN formation was reported to be instability of the slip. In a study on 87 patients, Fallath and Letts^[6] had similar findings as Loder et al and reported that there was no relation between the slip degree and AVN formation.

In the current study, the relation between AVN formation and the degree and the chronicity of the slip was evaluated in a large patient group. Although retrospective nature of the study was the weak part, this study had the strength of having a large patient population and long follow-up periods.

Epiphysis slip was Grade I in 63%, Grade II in 28.3% and Grade III in 8.7 %. This finding was consistent with the meta analysis of Castro et al. (73%, 16% and 11% respectively).^[16] According to the chronicity of the symptoms, slips were acute in 30.7% and chronic in 69.3%. The ratios were found as 25% and 75 % in the meta analysis study of Castro et al. that was done by evaluating 7765 hips.^[16] Our finding about the chronicity of the slip was also consistent with the literature.

Patients having more than 1 year follow-up period was included in the study to determine AVN development. AVN develops within first year in 95 % of the patients after SCFE.^[9,11] According to Loder et al. avascular necrosis developed between 3 months and 8 months after surgical treatment^[5] Thus,

our follow-up interval of at least 1 year is valid and reproducible.

Evaluating all the hips (unilateral and bilateral), a strong relation was present between the initial slip degree and the development of AVN. After statistical analysis, a single step increase in slip degree was found to increase AVN formation 10 times. When the relation between slip chronicity and AVN formation was evaluated, although the risk of AVN development is higher in acute slips, this relation was not as strong as the relation between AVN and slip degree. This finding is consistent with Rattey et al.^[12] however contradicts with Loder et al^[7] and Fallath and Letts.^[6] This may be due to investigation of only acute and instable slips in the study of Loder et al. and low numbers of reported AVN in the study of Fallath and Lett.

Avascular necrosis of the femoral head is a dreadful and severe complication of SCFE. Since the epiphyseal growth plate has a potential of blocking the delicate and weak blood flow that is passing through the capsule and femoral neck, AVN is mainly a problem of childhood and adolescence. During progression of SCFE, movement of the femoral head tears the capsule and bends and stretches the blood vessels severely.^[9] The relation between AVN and the slip degree that was reported in our study may be due to disruption of the arterial circulation because of the movement of epiphysis relative to metaphysis. Adaptive changes occur in the stretched vessels and they shortens.^[9] Attempts to reduce the slip during surgery stretches the adopted vessels and increases AVN risk. In a study done on iinstable slips, the AVN ratio was reported to be 13 % when reduction wasn't done however the ratio increased to 38% when reduction tried.^[17] The relatively low percentage of AVN formation (4.5 %) in this study may be due to not trying reduction before or during the operation.

In two studies that evaluated the relation between AVN and the position of fixation screws, supero-lateral location of the screws was proposed to increase AVN formation.^[18,19] The position of the screws was

not evaluated in detail in the current study. However, as far as we learned from the medical reports, there was no reported pin penetration to the joint and also there was no case that needed pin revision due to erroneous pin position.

The relation between AVN and slip degree was present when unilateral and bilateral slips was evaluated separately. There was no relation between AVN and chronicity of the slip in bilateral slips. This indicates that the acuteness of the slip is not a very important concern in bilateral slipping however one should be careful about the slip degree. On the other hand, both the chronicity and the degree of the slip is important for the development of AVN in unilateral slips.

Another important finding is that while the incidence of AVN is 11.4 % in unilateral slips, this was 1.9% in bilateral slips. This may be due to the low probability of having two sided AVN in the same patient having bilateral slipping. To our knowledge, there is no study in the literature that compared AVN formation in unilateral and bilateral slips. Thus, it is not possible to compare our findings with others. Mobility and weight bearing will be more limited in bilateral slipping than unilateral slipping. This may be one of the reasons for less AVN formation in unilateral slips. The relation between mobility and increased joint capsule rupture and stretching of the epiphysial arteries thus high incidence of AVN formation supports this hypothesis.^[20] Besides, although there was no statistically significant difference, the lower slip degree of the bilateral slips corresponding to unilateral slips may be a factor for lower incidence of AVN formation in bilateral slipping. Loder et al reported slip stability as the most important factor for AVN formation.^[5] Slip stability was not evaluated in our study. The high amount of iinstable slips in unilateral SCFE may be another factor for high amount of AVN formation in unilateral slips.

As a result, there is a high correlation between the amount of slip degree and AVN formation. Although there is another relation between the acuteness of the slip and AVN formation, this rela-

tion was not as strong as the slip degree. For this reason, closer observation is required for AVN formation in patients having high slip degree.

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