Forbes J Med 2021;2(2):99-107
doi: 10.5222/forbes.2021.92485

Remodeling in Patients with in Situ Fixation for a Slipped Capital Femoral Epiphysis

Femur Başı Epifiz Kayması Nedeniyle in situ fiksasyon Uygulanan Hastalarda Remodelasyon

Ismail Eralp Kacmaz, Meliksah Uzakgider, Vadym Zhamilov, Can Doruk Basa, Ali Reisoglu, Haluk Agus

Cite as: Kacmaz IE, Uzakgider M, Zhamilov V, Basa CD, Reisoglu A, Agus H. Remodeling in patients with in situ fixation for a slipped capital femoral epiphysis. Forbes J Med. 2021;2(2):99-107.

ABSTRACT

Objective: This study has investigated the amount of bone remodeling in patients with a slipped capital femoral epiphysis (SCFE) treated with in situ fixation until closure of the epiphysis and the factors affecting remodeling.
Method: Patients who underwent surgery for SCFE between January 2010 and January 2015 were retrospectively screened: Twenty-four male and 7 female patients (mean age 12.6 ± 1.9 years) were included in the study. Gender, age, history, and laterality of trauma, duration of hip pain (acute, chronic, acute on chronic background), and hip radiographs were evaluated. The Southwick and alpha angles were measured, and the factors affecting remodeling were assessed. The statistical analyses were conducted using SPSS 25.0 (IBM Corp., Armonk, NY); 95% confidence levels were calculated and $p < 0.05$ was considered to indicate statistical significance.
Results: The preoperative displacement angles measured on the anteroposterior and lateral radiographs were 15.03° ± 9.1° and 25.93° ± 14.1° and at the last follow-up they were 11.63° ± 8.7° and 21.6° ± 12.1°, respectively. The alpha angles measured on the lateral radiographs preoperatively and at the end of follow-up were 52.33° ± 11.6° and 47.87° ± 11.8°, respectively. Significant remodeling was reflected in the angles measured on the anteroposterior and lateral X-ray images. Greater preoperative displacement angle was associated with less remodeling.
Conclusion: Preoperative displacement affects the degree of postoperative remodeling. In patients with severe epiphyseal displacement, open reduction is an option but in situ pinning should be considered in that it is less invasive and more physiological.

Keywords: Slipped capital femoral epiphyses, bone remodeling, femoroacetabular impingement, adolescent

ÖZ

Amaç: Bu çalışmada femur başı epifiz kayması (FBEK) nedeniyle in situ fiksasyon uygulanan hastalarda epifiz kapanana kadar oluşan remodelasyon miktarı ve buna etki eden faktörler araştırılmıştır.
Yöntem: Ocak 2010- Ocak 2015 tarihleri arasında FBEK nedeniyle opere edilen hastalar retrospektif olarak tarandı. Yaş ortalaması 12,6 ± 1,9 olan 23 erkek ve 7 kız hasta çalışmaya dahil edildi. Hastaların cinsiyet, yaş, taraf, travma öyküsü ve kalça röntgenleri değerlendirildi. Röntgenlerde Southwick ve alfa açıları ölçüldü. Kalça ağrısı süresine göre hastalar üç gruba (akut, kronik, kronik zeminde akut) ayrıldı. İstatistiksel analizler SPSS 25.0 (IBM Corp., Armonk, NY) program ile; % 95 güven aralığında ve $p < 0.05$ istatistiksel anlamlılık gösterdiği kabul edilerek yapıldı.
Bulgular: Ön arka ve yan grafilerde ölçülen deplasman açıları ameliyat öncesi sırasıyla ortalama 15,03° ± 9,1° ve 25,93° ± 14,1°; epifiz kapandıktan sonra ise 11,63° ± 8,7° ve e°'idi. Alfa açıları ise ameliyat öncesinde ve epifiz kapandıktan sonra sırasıyla 52,33° ± 11,6° ve 47,87° ± 11,8°'idi. Ön arka ve yan grafilerde ölçülen deplasman açılarına göre istatistiksel anlamlı remodelasyon saptandı. Ameliyat öncesindeki deplasman açısının fazla olması daha az remodelasyonla ilişkili bulundu.
Sonuç: Ameliyat öncesindeki deplasman miktarı remodelasyonu etkilemektedir. Ciddi epifizyal deplasmanı olan hastalarda açık redüksiyon bir seçenek olmasına rağmen in situ fiksasyon daha az invaziv ve daha fizyolojik olması nedeniyle göz önünde bulundurulmalıdır.

Anahtar kelimeler: Femur başı epifiz kayması, kemik remodelasyonu, femoroasetabular sıkışma, adolesan

Received/Geliş: 24.05.2021
Accepted/Kabul: 22.06.2021
Publication online: 13.08.2021

Sorumlu Yazar/
Corresponding Author:
Ali Reisoglu
Department of Orthopaedics and Traumatology, Tepecik Training and Research Hospital, İzmir, Turkey
drreisoglu@gmail.com
ORCID: 0000-0002-1061-6488

I.E. Kacmaz 0000-0002-2736-140X
V. Zhamilov 0000-0002-8486-5858
C.D. Basa 0000-0003-1300-7685
H. Agus 0000-0003-2831-3642
Department of Orthopaedics and Traumatology, Tepecik Training and Research Hospital, İzmir, Turkey

M. Uzakgider 0000-0001-7098-2642
Department of Orthopaedics and Traumatology, Bozyaka Training and Research Hospital, İzmir, Turkey

© Telif hakkı Forbes Tıp Dergisi. Logos Tıp Yayıncılık tarafından yayınlanmaktadır.
Bu dergide yayınlanan bütün makaleler Creative Commons 4.0 Uluslararası Lisansı (CC-BY) ile lisanslanmıştır.
© Copyright Forbes Journal of Medicine. This journal published by Logos Medical Publishing.
Licenced by Creative Commons Attribution 4.0 International (CC BY)

INTRODUCTION

Slipped capital femoral epiphysis (SCFE) is the most common hip disorder in adolescents. It typically occurs as a result of external rotation of the femoral neck metaphysis together with anterior and proximal translation of the epiphysis.[1-3] While SCFE usually presents as a stable epiphyseal injury [2, 4, 5], its natural history is poorly understood.[6] In situ fixation with a single screw is the preferred treatment. [1, 7, 8] Possible complications, particularly in unstable fractures, include avascular necrosis, chondrolysis, femoroacetabular impingement (FAI), and degeneration of the hip joint. [2, 4, 9-11] While gentle manipulative reduction does not negatively affect the functional outcome, both forced and open reduction of unstable fractures can cause avascular necrosis, acetabular cartilage, and labrum damage. [9, 12] Additionally, osteomyelitis and non-union are potential complications in patients with SCFE treated with open reduction. [13] Therefore, in situ fixation remains the preferred treatment of SCFE. [1]

In situ fixation is associated with two important complications: FAI and leg length discrepancy. [2, 4] The amount of preoperative displacement is a determinant of FAI [14], and a cam-type FAI is a factor in the development of osteoarthritis, due to damage to the cartilage and to the acetabular labrum. [4] FAI may also be a consequence of the natural course of the disease in untreated cases or when treatment consists of in situ fixation. [2] The femoral head epiphysis constitutes 15% of the lower limb length and closes at around 16–18 years of age. Due to the lengthening and remodeling capacity of the femoral neck, surgeons prefer minimally invasive surgery. [2] Given its advantages but also its potential complications, in situ fixation requires careful decision-making as well as accurate prediction of the remodeling potential after the procedure.

We hypothesized that in patients operated on for SCFE, the remodeling capacity remains intact until the epiphysis closes. This study has investigated the amount of remodeling until closure of the epiphysis in patients with an open proximal femoral epiphysis and SCFE treated with in situ fixation. We also examined the factors that affect remodeling at this site.

METHODS

The study was performed retrospectively at a Training and Research Hospital Orthopedics and Traumatology Clinic. The study protocol was approved by the Hospital Clinical Research Ethics Committee (date: 08.12. 2020, no.: 2020 / 10-38). Pediatric patients admitted to the emergency department with hip pain between January 2010 and January 2015 were retrospectively screened.

In our clinic, pediatric patients with pain and a limited range of motion of the hip joint on physical examination and X-ray images of the femoral head epiphysis showing its detachment from the proximal femoral metaphysis are diagnosed with SCFE. All pediatric patients (n = 55) diagnosed with SCFE who subsequently underwent in situ fixation surgery were included in the study. Patients with a difference in the measurements of displacement angles on the X-rays taken before and on the first day after surgery (n = 5) were not included in the study under the assumption that closed reduction had been achieved. Additionally, patients whose control X-ray images were not available (n = 12) and those treated with open reduction (n = 8) were also excluded from the study. Ultimately, 30 patients who underwent in situ fixation and were followed up until epiphyseal closure were included in the study.

In our clinic, in situ fixation surgery is performed under fluoroscopic guidance with the patient laid on a radiolucent table after sterile conditions are achieved. A Kirschner wire is inserted after determining the line passing through the center of the femoral neck as shown on anteroposterior (AP) and lateral frog images. After the length and central position of the K-wire are checked with fluoroscopy, the screw length is measured and 6.5-mm partially threaded cannulated stainless-steel screws are used for the fixation. Care is taken to fit more than three screw threads into the proximal femoral epiphysis and advance the

screw up to 2.5 mm from the subchondral bone.[4, 15] Insertion of a single pin in central position is the standard method. However, in cases where the patient was overweight or the epiphyseal separation line is perpendicular to the ground plane, the surgeon preferred insertion of two pins to increase stability.

Gender, age of the patients at the time of surgery, history, and laterality of the trauma, and duration and pattern of hip pain (acute, chronic, acute- on-chronic) were evaluated. According to the temporal classification of hip pain in the literature, patients with symptoms of < 3 weeks duration were assigned to the acute group, those with symptoms persisting for > 3 weeks to the chronic group, and those with acute exacerbations and chronic pain to the acute- on- chronic group.[16] Standard pelvis AP (patient in the supine position with the lower limbs internally rotated 15–25° from the hip) and frog leg lateral (patient in the supine position with the lower limbs at ~30–40° knee flexion and the hips abducted at 45°) radiographs were taken of all enrolled patients. In our clinic, all patients are followed up with annual x-ray controls until the epiphysis of the femoral head is closed. The radiographs of the patients were evaluated preoperatively, on the first postoperative day, and after closure of the femoral head epiphysis (Figures 1, and 2). Intra- and inter-observer reliability were evaluated based on radiographic measurements of AP, lateral and alpha angles in 10 randomly selected patients repeated twice with an interval of one month by two orthopedic specialists with 10 years of professional experience. A two-way mixed effects model and intraclass correlation coefficients (ICC) were used to evaluate agreement and differences between intra- and inter-observer measurements.

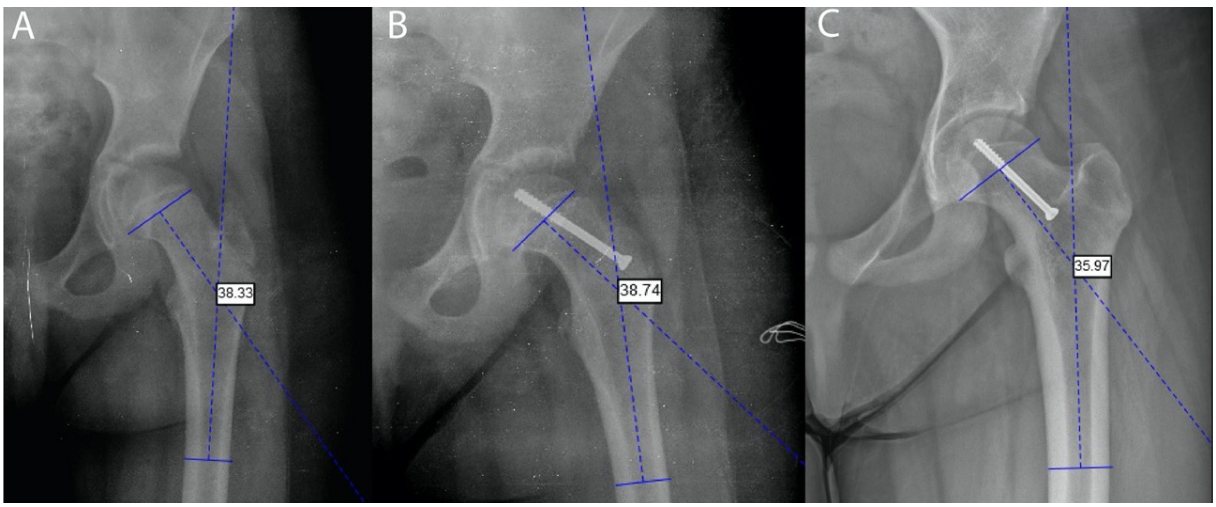

Fig. 1: Anteroposterior (AP) displacement; (A) preoperative, (B) first postoperative day, (C) after closure of the femoral head epiphysis

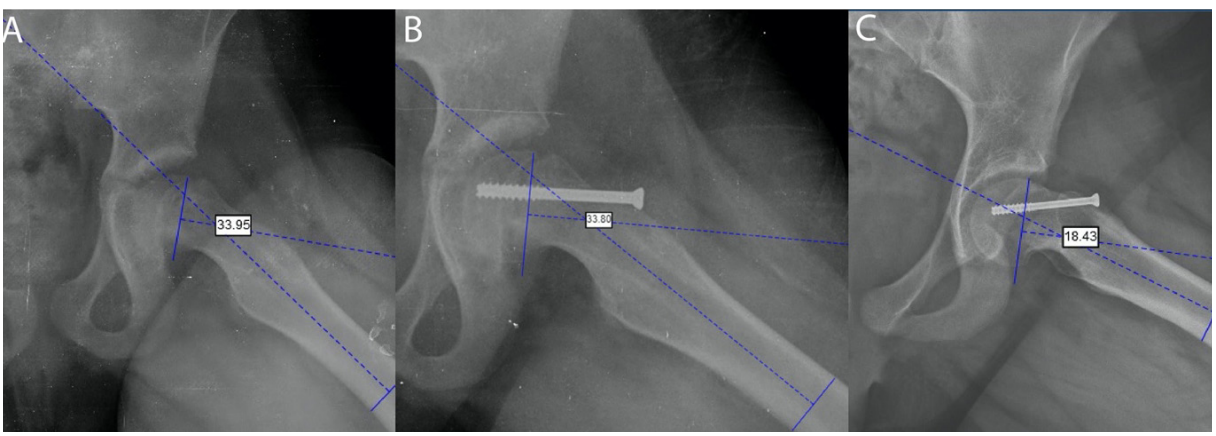

Fig. 2: Lateral displacement: (A) preoperative, (B) first postoperative day, (C) after closure of the femoral head epiphysis

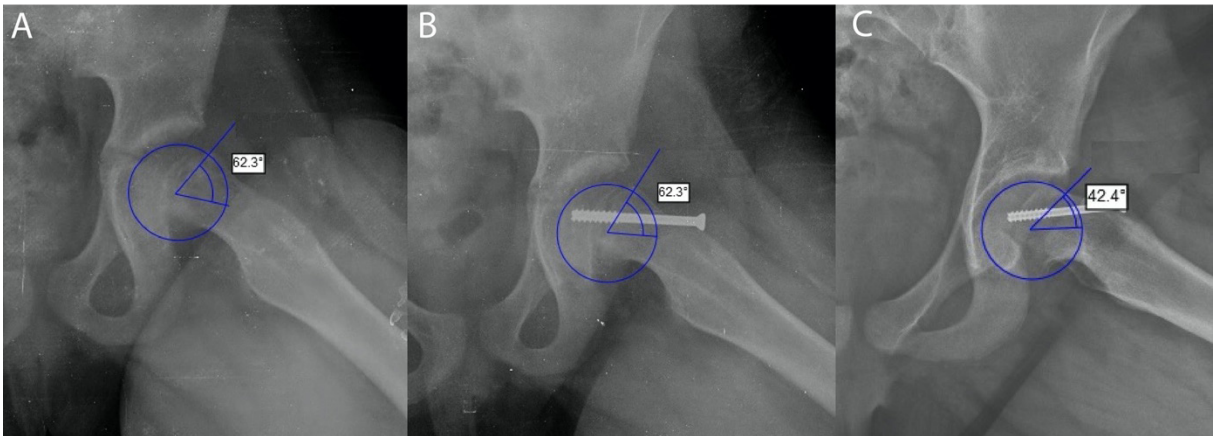

Fig. 3: Alpha angle: (A) preoperative, (B) first postoperative day, (C) after closure of the femoral head epiphysis

Closure of the femoral head epiphysis was assessed according to the Oxford staging system. [17] The amounts of displacement of epiphyseal-shaft angle on AP and lateral radiographs were measured numerically and classified according to Southwick classification which was described in 1967. [18] Additionally, alpha angle was measured on lateral radiographs (Figure 3) The alpha angle was measured as described by Nötzli et al. (2002). The alpha angle is defined as the angle formed between the axis of the neck and a line connecting the center of the femoral head to the anterior extent of the concavity of the femoral neck. [19, 20] The measurement values on the preoperative and final control radiographs were compared, and the degree of postoperative remodeling in the femoral head epiphysis was determined. A cut -off value of 35° was determined for preoperative epiphyseal-shaft angle according to a previous study, to form two groups for the comparison of the amount of remodeling achieved. [14] We also investigated the factors (age, sex, duration of symptoms, displacement before surgery, number of screws) which affected remodeling.

Statistical analysis

Variables were analyzed using SPSS 25.0 (IBM Corporation, Armonk, NY) and PAST 3 (paleontological statistics software package for education and data analysis). The normality of the distribution of univariate data was examined using the Shapiro-Wilk test, while the Mardia (Doornik-Hansen omnibus) test was used to examine the normality of the distribution of multivariate data. Variance homogeneity was evaluated by the Box-M test. The independent samples t test was used with bootstrap results to compare quantitative data between two independent groups. One-way analysis of variance (ANOVA) was used to compare quantitative data between more than two groups. The paired samples t test was used to compare dependent quantitative variables, and a one-way repeated measures ANOVA was used to examine the interactions of the variables with repeated quantitative measurements. The McNemar test was used with Monte Carlo simulation to compare dependent two-category variables. Pearson's correlation test was used to examine the correlations between variables. Fisher's exact test was used to compare of categorical variables with the Monte Carlo simulation technique. Quantitative variables are expressed as the mean ± standard deviation (SD) and median in tables, while categorical variables are shown as n (%). Additionally, 95% confidence levels were calculated and $p < 0.05$ was taken to indicate statistical significance.

RESULTS

According to the NICHD, Eunice Kennedy Shriver National Institute of Child Health and Human Development classification system, 7 patients (6 males, 1 female) were in mid-childhood and 23 patients (17 males, 6 females) were in early adolescence. The mean follow-up period was 49.44 ± 24.7 (min = 24; max = 96) months. Data concerning the age, laterality and duration of symptoms of the patients included in the study are given in Table 1.

Table 1. Distribution of demographic data by duration of injury.

	Acute (n = 11)	Chronic (n = 12)	Acute on Chronic (n = 7)	Total (n = 30)
Age	12.55 ± 2.42	12.58 ± 1.73	12.71 ± 1.98	12.6 ± 1.99
Sex (Female/Male)	2/9	2/10	3/4	7/23
Right/Left	8/3	7/5	3/4	18/12

The displacement angles measured on AP and lateral radiographs taken before the operation, and at the last follow-up and the alpha angles measured on lateral radiographs are given in Table 2. Intra- and inter-observer reliability were determined to be excellent (ICC: 0.975–0.996) and good (ICC: 0.860–0.995), respectively.

Table 2. Displacement angles and amounts of remodeling measured on anteroposterior and lateral radiographs before surgery and at the final follow- up visit.

Anteroposterior	Preoperative	15.03 ± 9.13
	Final follow up	11.63 ± 8.71
	Remodeling	–3.40 ± 4.03
p ^{GLM}		< **0.001**
Lateral	Preoperative	25.93 ± 14.05
	Final follow up	21.60 ± 12.14
	Remodeling	–4.33 ± 5.94
p ^{GLM}		< **0.001**
Alpha	Preoperative	52.33 ± 11.60
	Final follow up	47.87 ± 11.79
	Remodeling	–4.47 ± 11.88
p ^{GLM}		**0.048**

GLM, General Linear Model-repeated ANOVA (Wilks' Lambda); SD, standard deviation.

One and two screws were applied in 22 and 8 patients, respectively. In two patients, the screw was removed after the epiphyses closed. The remaining patients still had implants at their last check-up. In our clinic, to avoid failed reduction, care is taken not to remove the screw before the epiphyseal line has closed.

When patients were grouped according to the Southwick classification, all patients were included in the mild group both preoperatively and postoperatively, according to measurements made from anteroposterior radiographs. When the lateral radiographs of the patients were grouped according to the Southwick classification, SCFE was mild in 19 and moderate in 11 cases before surgery. In 5 of these 11 patients, after surgery SCFE improved to mild, as defined according to the radiological classification.

Patients were grouped according to duration of injury. Angular corrections measured on anteroposterior and lateral radiographs ($p < 0.001$ and $p = 0.041$) in acute cases, and on lateral radiographs ($p = 0.01$) only in chronic

Table 3. Degrees of remodeling according to duration of injury.

		Acute (n = 11)	Chronic (n = 12)	Acute on Chronic (n = 7)	P
Anteroposterior	Preoperative	14.91 ± 8.09	13.08 ± 9.24	18.57 ± 10.72	0.491 ^{A}
	Final follow up	10.91 ± 8.26	9.67 ± 8.48	16.14 ± 9.41	0.304 ^{A}
	Remodeling	–4.00 ± 2.19	–3.42 ± 5.11	–2.43 ± 4.58	0.741 ^{RA}
***p*-value** ^{GLM}		< **0.001**	0.163	0.317	
Lateral	Preoperative	23.91 ± 13.12	23.00 ± 12.70	34.14 ± 16.36	0.247 ^{A}
	Final follow up	21.36 ± 11.77	19.25 ± 11.22	26.00 ± 14.74	0.552 ^{A}
	Remodeling	–2.55 ± 5.61	–3.75 ± 4.16	–8.14 ± 7.93	0.202 ^{RA}
***p*-value** ^{GLM}		**0.041**	**0.010**	0.139	
Alpha	Preoperative	53.18 ± 12.13	51.17 ± 12.92	53.00 ± 9.75	0.903 ^{A}
	Final follow up	49.55 ± 15.90	44.67 ± 7.50	50.71 ± 10.61	0.484 ^{A}
	Remodeling	–3.64 ± 11.44	–6.50 ± 14.13	–2.29 ± 9.07	0.714 ^{RA}
***p*-value** ^{GLM}		0.210	0.035	0.530	

GLM, General Linear Model-repeated ANOVA (Wilks' Lambda) A, One-way ANOVA.

cases, were statistically significant. When the same evaluation was performed with the Southwick classification, five of eleven Southwick moderate cases on lateral radiographs improved to mild, but this change was not significantly associated with the duration of injury ($p = 0.36$).

No statistically significant differences were observed in terms of remodeling between the groups of patients (acute, chronic, acute- on-chronic) according to the duration of injury (Table 3). No statistically significant associations were observed between the number of screws applied and remodeling status.

No statistically significant associations were observed between gender or age of the patients at the time of injury and degree of remodeling. However, evaluation of Southwick angle and alpha angles measured on lateral radiographs revealed a significant inverse relation between the amount of displacement before surgery and remodeling (Southwick, $p < 0.001$; alpha, $p = 0.005$) (Table 4).

A comparison of patients with an angulation of < 35° in the epiphysiolysis line in lateral X-rays and those with an angulation of > 35° revealed that remodeling was significantly less successful in patients with a preoperative displacement of > 35° ($p = 0.031$). Radiological chondrolysis or avascular necrosis was not detected in any patient.

DISCUSSION

In this study, significant improvements compared to the preoperative values were detected in the postoperatively measured displacement angles on AP and lateral X-rays. Consistent with the literature, in situ fixation in our patients was accompanied with postoperative remodeling. [1, 14, 21-23] Reinhart et al. reported that the maximum remodeling occurred during the first year after surgery. [7] Thus, the follow-up period (mean 49.44 ± 24.7 months) with annual x-ray control in this study was likely sufficient to evaluate remodeling.

In situ fixation is still the preferred method of treatment of SCFE. [1] Based on a case series with 38 years of follow-up, Wensaas et al. concluded that the results of in situ fixation were satisfactory in patients with chronic SCFE. [10] Accadbled et al. reported the results of 222 patients with 11.2 years of follow-up and also concluded that in situ fixation was a reasonable form of treatment, particularly for displacements of < 35° on lateral X-rays. [14] Several studies have also demonstrated epiphyseal healing histologically. Guzzanti et al. compared pre- and postoperative biopsies from their patients and showed histologically that physical organization had occurred [24], thus supporting the use of in situ fixation to stabilize the epiphysial cartilage and to refrain from premature physeal closure. [24] Sailhan et al. demonstrated radiologically that near-normal development can be achieved after in situ fixation with a single partially grooved screw. [25] Epiphyseal healing and remodeling after surgery are important issues in in situ fixation. Consistent with the literature, radiological union was observed in all patients in this study. However, union does not indicate successful treatment; rather, it must be accompanied by remodeling.

In a study of 70 SCFE cases followed for an average of 7.1 years, Jones et al. did not find significant associations between age or gender of the patients, and remodeling. [11] In a multicenter

Table 4. Correlation between remodeling and age and preoperative displacement.

	r	p
Remodeling AP × Age	–0.295	0.113
Remodeling Lateral × Age	0.009	0.963
Remodeling Alpha × Age	0.111	0.558
Remodeling AP × Preoperative AP	–0.323	0.082
Remodeling Lateral × Preoperative Lateral	–0.510	0.004
Remodeling Alpha × Preoperative Alpha	–0.496	0.005

Pearson's Correlation Test, r, Correlation Coefficient; AP, anteroposterior.

study conducted in 2013 on 69 hips, patient's age of 11.1 years and alpha angle of 21° were determined as cutoff values for the development of residual cam deformity after remodeling. [26] Growth and remodeling in the femoral neck were reported to continue as long as the epiphysial cartilage remained active, but this potential decreased with age. [2, 26] Thus, the development of FAI is more common in patients over the age of 11 years. [26]

No significant correlations were found between gender or age of the patient and remodeling. There have also been no reports of a relation between gender of the patients, and remodeling potential. The lack of correlation between age and remodeling can be explained by the advanced age (mean: 12.6 ± 1.9 years) of the patients included in this study.

The use of a 6–7 mm cannulated screw for in situ fixation is accepted for the management of both stable and unstable cases with SCFE. [2, 21] The use of multiple screws does not provide superior stability over a single screw and may even increase the rates of complications including avascular necrosis and chondrolysis. [27] In this study, the effects of using two screws on remodeling were investigated, but no significant effect was observed compared to the group treated using only a single screw. In a study conducted by Stambough et al. in 1986, complications were evaluated in 80 SCFE patients divided into two groups according to the number of pins (Group 1: ≥ 3 pins; Group 2: ≤ 2 pins). Three cases of avascular necrosis, five cases of chondrolysis, and one case of subtrochanteric fracture had occurred in Group 1, whereas in one patient in Group 2 as a complication only a broken pin had been detected, The authors concluded that use of multiple pins increases the risk of complications but they had not evaluated remodeling status. [28] In a 2019 review published by Aprato et al., the use of multiple screws was shown to increase the risk of avascular necrosis, but there are no reports in the literature on the potential biomechanical or clinical advantage of multiple screws. [29] Further studies are required to investigate the superiority of multi-pin application in terms of remodeling in larger series.

Jones et al. reported that there is no statistically significant relationship between symptom duration and remodeling. [11] However, there is no clear information about this relationship in the literature. In the present study, patients were divided into three groups according to the duration of injury as acute, chronic, and acute-on- chronic. In the acute injury group, significant differences were found on both anteroposterior and lateral radiographs. In the group with chronic injury, there was a significant difference only in the measurements performed on the lateral radiographs. Remodeling was observed on the lateral radiographs in all three groups, and no statistically significant differences were observed among the groups. The lack of a significant association between the duration of injury and remodeling may have been due to the small number of patients in each group.

Some reports have suggested that the success of remodeling decreases with an increasing amount of displacement before surgery. In a 7-year follow-up study that included 70 hips, Jones et al. concluded that in 75% of their cases with preoperative displacement of ≤ 40° they had achieved satisfactory remodeling. [11] In this study, evaluation of Southwick and alpha angles on lateral radiographs indicated a statistically significant inverse correlation between preoperative displacement and remodeling; while greater preoperative displacement angle was associated with less successful postoperative remodeling.

Alpha and Southwick angles measured on lateral radiographs are related to FAI. In a multicenter study, Akiyama et al. detected residual cam deformity at a rate of 29.4% despite remodeling. [26] They demonstrated that displacement of > 21° before surgery increased the risk of deformity. [26] In a long-term (mean 11.2 years) study involving 222 patients, Accadbled et al. concluded that open reduction is more appropriate in cases with displacement of > 50° and in situ fixation in patients with displacement of < 35°. [14] In some studies, the threshold of displacement for the

development of FAI was 35° as determined on the preoperative lateral X-rays. [2, 23, 30]

Similar to these previous reports, in the present study patients in the group with preoperative displacement of ≥ 35° exhibited significantly less remodeling than the group with displacement of < 35°.

In cases with severe displacement, Samelis et al. reported that in situ stabilization was not sufficient to reverse the damage to the acetabulum caused by a deformed femoral neck, due to the decreased remodeling capacity. [2] Mahran et al. recommended open reduction procedures in stable cases and in unstable cases in which displacement is > 30°. [1]

In this study, patients with severe displacement exhibited less remodeling. Therefore, open reduction seemed to be preferable in cases with displacement angles of > 35° before surgery. Nevertheless, caution is required when making treatment decisions due to the risks of complications, such as avascular necrosis, acetabular cartilage, and labrum damage in the femoral head in cases with open reduction. [9, 12]

This study had some limitations. The number of patients included in the study is limited. The most important clinical consequences of failed remodeling are FAI and related hip pain. The main purpose of this study was not to investigate the presence of FAI, which could not be evaluated due to the retrospective design of the study. Rather, our aim was to radiologically assess the amount of remodeling and the factors affecting it. However, evaluations based on radiographic measurements may be biased by the X-ray position and the relativity of the measurements. This risk was minimized by excluding inappropriate X-rays and by determining the intra- and inter-observer agreement prior to the study. Further randomized prospective studies in larger series will provide insight into this issue.

CONCLUSION

In pediatric patients undergoing in situ fixation in the treatment of SCFE, significant remodeling occurs until the epiphyseal lines are closed. Our study has revealed that greater preoperative displacement results in less remodeling. Patients with a displacement of > 35° had significantly less remodeling than those with < 35° displacement. Therefore, in cases of severe epiphyseal displacement, open reduction can be applied because limited remodeling is expected. However, in situ pinning may be a less invasive and more physiological method than open reduction for less severe epiphyseal displacement, given the risk of complications such as avascular necrosis and chondral damage.

Ethics Committee Approval: S.B.U. Tepecik Training and Research Hospital Clinical Research Ethics Committee (12.08.2020 / 10-38)
Conflict of Interest: None
Funding: None
Informed Consent: Informed consent was obtained

REFERENCES

1. Mahran MA, Baraka MM, Hefny HM. Slipped capital femoral epiphysis: a review of management in the hip impingement era. SICOT J. 2017;3:35. doi:10.1051/sicotj/2017018.
2. Samelis PV, Papagrigorakis E, Konstantinou AL, Lalos H, Koulouvaris P. Factors Affecting Outcomes of Slipped Capital Femoral Epiphysis. Cureus. 2020;12(2):e6883. doi:10.7759/cureus.6883.
3. Vanhegan IS, Cashman JP, Buddhdev P, Hashemi-Nejad A. Outcomes following subcapital osteotomy for severe slipped upper femoral epiphysis. Bone Joint J. 2015;97-B(12):1718-25. doi:10.1302/0301-620X.97B12.35259.
4. Peck K, Herrera-Soto J. Slipped capital femoral epiphysis: what's new? Orthop Clin North Am. 2014;45(1):77-86. doi:10.1016/j.ocl.2013.09.002.
5. Loder RT, O'Donnell PW, Didelot WP, Kayes KJ. Valgus slipped capital femoral epiphysis. J Pediatr Orthop. 2006;26(5):594-600. doi:10.1097/01.bpo.0000230331.96157.14.
6. Mathew SE, Larson AN. Natural History of Slipped Capital Femoral Epiphysis. J Pediatr Orthop. 2019;39(Issue 6, Supplement 1 Suppl 1):S23-S7. doi:10.1097/BPO.0000000000001369.
7. Reinhardt M, Stauner K, Schuh A, Steger W, Schraml A. Slipped capital femoral epiphysis: long-term outcome and remodelling after in situ fixation. Hip Int. 2016;26(1):25-30. doi:10.5301/hipint.5000298.
8. Allen MM, Rosenfeld SB. Treatment for Post-Slipped Capital Femoral Epiphysis Deformity. Orthop Clin North Am. 2020;51(1):37-53.

doi:10.1016/j.ocl.2019.08.008.

9. Roaten J, Spence DD. Complications Related to the Treatment of Slipped Capital Femoral Epiphysis. Orthop Clin North Am. 2016;47(2):405-13. doi:10.1016/j.ocl.2015.09.013.
10. Wensaas A, Svenningsen S, Terjesen T. Long-term outcome of slipped capital femoral epiphysis: a 38-year follow-up of 66 patients. J Child Orthop. 2011;5(2):75-82. doi:10.1007/s11832-010-0308-0.
11. Jones JR, Paterson DC, Hillier TM, Foster BK. Remodelling after pinning for slipped capital femoral epiphysis. J Bone Joint Surg Br. 1990;72(4):568-73. https://doi.org/10.1302/0301-620X.72B4.2380205
12. Upasani VV, Matheney TH, Spencer SA, Kim YJ, Millis MB, Kasser JR. Complications after modified Dunn osteotomy for the treatment of adolescent slipped capital femoral epiphysis. J Pediatr Orthop. 2014;34(7):661-7. doi:10.1097/BPO.0000000000000161.
13. Schai PA, Exner GU, Hansch O. Prevention of secondary coxarthrosis in slipped capital femoral epiphysis: a long-term follow-up study after corrective intertrochanteric osteotomy. J Pediatr Orthop B. 1996;5(3):135-43. doi:10.1097/01202412-199605030-00001.
14. Accadbled F, Murgier J, Delannes B, Cahuzac JP, de Gauzy JS. In situ pinning in slipped capital femoral epiphysis: long-term follow-up studies. J Child Orthop. 2017;11(2):107-9. doi:10.1302/1863-2548-11-160282.
15. Guzzanti V, Falciglia F, Stanitski CL. Slipped capital femoral epiphysis in skeletally immature patients. J Bone Joint Surg Br. 2004;86(5):731-6. doi:10.1302/0301-620x.86b5.14397.
16. Millis MB. SCFE: clinical aspects, diagnosis, and classification. J Child Orthop. 2017;11(2):93-8. doi:10.1302/1863-2548-11-170025.
17. Acheson RM. The Oxford method of assessing skeletal maturity. Clin Orthop. 1957;10:19-39.
18. Southwick WO. Osteotomy through the lesser trochanter for slipped capital femoral epiphysis. J Bone Joint Surg Am. 1967; 49(5):807-35. Available from: https://pubmed.ncbi.nlm.nih.gov/6029256/. https://doi.org/10.2106/00004623-196749050-00001
19. Notzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. J Bone Joint Surg Br. 2002;84(4):556-60. doi:10.1302/0301-620x.84b4.12014.
20. Boyle MJ, Lirola JF, Hogue GD, Yen YM, Millis MB, Kim YJ. The alpha angle as a predictor of contralateral slipped capital femoral epiphysis. J Child Orthop. 2016;10(3):201-7. doi:10.1007/s11832-016-0732-x.
21. Falciglia F, Aulisa AG, Giordano M, Guzzanti V. Fixation in slipped capital femoral epiphysis avoiding femoral-acetabular impingement. J Orthop Surg Res. 2017;12(1):163. doi:10.1186/s13018-017-0663-3.
22. Nectoux E, Decaudain J, Accadbled F, Hamel A, Bonin N, Gicquel P, et al. Evolution of slipped capital femoral epiphysis after in situ screw fixation at a mean 11 years' follow-up: a 222 case series. Orthop Traumatol Surg Res. 2015;101(1):51-4. doi:10.1016/j.otsr.2014.12.004.
23. Fujii Y, Endo H, Mitani S, Akazawa H, Tetsunaga T, Miyake T, et al. Residual Femoral Deformity and Femoroacetabular Impingement after Intertrochanteric Osteotomy for Slipped Capital Femoral Epiphysis. Acta Med Okayama. 2017;71(4):315-23. doi:10.18926/AMO/55308.
24. Guzzanti V, Falciglia F, Stanitski CL, Stanitski DF. Slipped capital femoral epiphysis: physeal histologic features before and after fixation. J Pediatr Orthop. 2003;23(5):571-7. https://doi.org/10.1097/01241398-200309000-00002
25. Sailhan F, Courvoisier A, Brunet O, Chotel F, Berard J. Continued growth of the hip after fixation of slipped capital femoral epiphysis using a single cannulated screw with a proximal threading. J Child Orthop. 2011;5(2):83-8. doi:10.1097/00004694-200309000-00002.
26. Akiyama M, Nakashima Y, Kitano T, Nakamura T, Takamura K, Kohno Y, et al. Remodelling of femoral head-neck junction in slipped capital femoral epiphysis: a multicentre study. Int Orthop. 2013;37(12):2331-6. doi:10.1007/s00264-013-2047-6.
27. Karol LA, Doane RM, Cornicelli SF, Zak PA, Haut RC, Manoli A, 2nd. Single versus double screw fixation for treatment of slipped capital femoral epiphysis: a biomechanical analysis. J Pediatr Orthop. 1992;12(6):741-5. doi:10.1097/01241398-199211000-00008.
28. Stambough JL, Davidson RS, Ellis RD, Gregg JR. Slipped capital femoral epiphysis: an analysis of 80 patients as to pin placement and number. J Pediatr Orthop. 1986;6(3):265-73. doi:10.1097/01241398-198605000-00002.
29. Aprato A, Conti A, Bertolo F, Masse A. Slipped capital femoral epiphysis: current management strategies. Orthop Res Rev. 2019;11:47-54. doi:10.2147/ORR.S166735.
30. Murgier J, de Gauzy JS, Jabbour FC, Iniguez XB, Cavaignac E, Pailhe R, et al. Long-term Evolution of Slipped Capital Femoral Epiphysis Treated by in Situ Fixation: A 26 Years Follow-up of 11 Hips. Orthop Rev (Pavia). 2014;6(2):5335. doi:10.4081/or.2014.5335.