

Surgical treatment of symptomatic post-slipped capital femoral epiphysis deformity: a comparative study between hip arthroscopy and surgical hip dislocation with or without intertrochanteric osteotomy

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Abstract

Purpose Our primary research question was to investigate the severity of deformity and articular damage as well as outcomes in patients undergoing hip arthroscopy compared with open surgery for the treatment of symptomatic slipped capital femoral epiphysis (SCFE) deformity.

Methods Retrospective review of surgical treatment of symptomatic SCFE deformity with a minimum one-year follow-up. Patients were divided into three groups: the arthroscopic group, surgical hip dislocation (SHD) group and SHD with femoral osteotomy (SHD+ITO) group. Deformity severity was quantified. Hip outcome was assessed by the modified Merle d'Aubigné Postel (MDP) scores.

Results There were more severe slips treated by SHD and SHD+ITO. There was more severe deformity in the SHD+ITO group than the arthroscopy group ($p < 0.001$). There were more full thickness acetabular cartilage defects in the SHD and the SHD+ITO groups ($> 40\%$) compared with the

arthroscopy group (11%; $p = 0.03$). The SHD+ITO and SHD group had lower MDP scores compared with the arthroscopy group both before and after surgery but no difference was detected in the amount of improvement from surgery across groups ($p > 0.05$). Moderate and severe SCFEs had worse preoperative scores but improvement was not different compared with mild SCFEs ($p > 0.05$).

Conclusion Patients undergoing open treatment had more severe SCFE deformity with more extensive articular damage at reconstructive surgery compared with patients undergoing arthroscopy. All groups with SCFE deformity had improved pain and hip function postoperatively.

Level of Evidence III

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Introduction

Residual deformity of the proximal femur following *in situ* fixation for the treatment of slipped capital femoral epiphysis (SCFE) may lead to femoroacetabular impingement (FAI).¹⁻⁴ Post-slip FAI is associated with acetabular cartilage damage and may be a source of pain and limited function and ultimately lead to osteoarthritis (OA) of the hip.⁵⁻¹²

Surgical correction of the slip deformity can be performed at the time of fixation of the epiphysis or in a delayed fashion after epiphyseal closure if the patient becomes symptomatic. Residual deformity may be corrected by an osteoplasty of the metaphyseal bump¹³ or by a femoral osteotomy. Femoral osteotomy for post-slip deformity can be performed at the subcapital level,¹⁴

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base of the femoral neck,¹⁵ intertrochanteric level¹⁶ and subtrochanteric level.¹⁷ Contemporary techniques include osteochondroplasty through an arthroscopic approach¹⁸⁻²⁰ or through a surgical hip dislocation (SHD) approach with or without a combined proximal femoral osteotomy.^{21,22} Prior studies looking at the outcome of deformity correction after SCFE consist of case series of both open^{6,21-26} and arthroscopic techniques^{19,20,27-29} with relatively good outcomes reported for both. However, there are limited comparative studies³⁰ and the treatment of symptomatic FAI secondary to healed SCFE remains controversial.

The purposes of our study were: 1) to determine the severity of post-SCFE deformity and the pattern of intraarticular chondrolabral damage at the time of reconstructive surgery; and 2) to compare the proportion of complications, reoperations and the radiographic and functional outcomes between patients undergoing hip arthroscopy or surgical dislocation with or without femoral osteotomy for the treatment of symptomatic post-SCFE deformity.

Materials and methods

Study design and population

This is a retrospective comparative study of patients undergoing surgery for a healed SCFE deformity approved by our institutional review board. Inclusion criteria were patients undergoing surgery either via hip arthroscopy or SHD approach with a diagnosis of symptomatic deformity secondary to healed SCFE between 1 January 2003 and 30 November 2015. Exclusion criteria included no

radiographic imaging available in our imaging system, treatment of acute SCFE with the modified Dunn procedure, treatment of avascular necrosis after prior SCFE *in situ* pinning and less than one year of clinical follow-up.

We identified a total of 104 patients that underwent surgery for symptomatic post-SCFE deformity. Surgical indication was the presence of hip pain aggravated by activities requiring hip flexion with limited hip flexion and internal rotation on physical examination with corresponding abnormal femoral head-neck alignment and offset on radiographs. During the study period there was no institution protocol and it was at the discretion of the treating surgeon to determine which surgical technique was used. Out of the 104 patients, 86 (83%) patients had a minimum one-year follow-up and were included in the study. In all, 45% (39/86) of the patients were male. A total of 39 patients had surgery on their right side (45%). The mean age at the time of surgery was 17 years (SD 4; 11 to 37). The mean body mass index (BMI) at the time of surgery was 30 kg/m² (SD 6; 17 to 47) (Table 1). A total of 19 out of the 86 patients (22%) underwent treatment via an arthroscopic approach while 67 patients (78%) were treated using a SHD approach. Of patients undergoing surgical dislocation, 33 were treated without a concomitant femoral osteotomy (SHD group; 33/86; 38%) and 34 were treated by osteochondroplasty and intertrochanteric osteotomy (SHD and femoral osteotomy (SHD+ITO) group; 34/86; 40%). Procedures performed in each group are presented in Table 2. Mean follow-up for the entire cohort was 4.3 years (1.0 to 12.5). Mean follow-up for patients in the arthroscopy group was 3.3 years compared with 4.2 years for the SHD group and 5.0 years for the SHD+ITO group ($p = 0.11$).

Table 1 Demographic characteristics by slipped capital femoral epiphysis deformity surgical group

Characteristics	Arthroscopy (n = 19)	Surgical dislocation with osteoplasty (n = 33)	Surgical dislocation with osteotomy (n = 34)	p-value*
Male sex (%)	5 (26)	14 (42)	20 (59)	0.07
Affected (right) side (%)	10 (53)	13 (39)	16 (47)	0.63
Age at surgery (SD), yrs	16.0 (4.3)	18.6 (5.0)	15.4 (3.1)	0.006
BMI (SD), kg/m ²	27.1 (5.3)	28.1 (7.6)	32.0 (6.1)	0.02

BMI, body mass index.

*P-values are based on analysis of variance for continuous characteristics and a chi-squared test for binary characteristics.

Table 2 Procedures performed between surgical dislocation groups and arthroscopy group

Procedure, n (%)	Arthroscopy (n = 19)	Surgical dislocation with osteoplasty (n = 33)	Surgical dislocation with osteotomy (n = 34)
Femoral osteochondroplasty	19 (100)	33 (100)	33 (97)
Femoral osteotomy	0 (0)	0 (0)	34 (100)
Labral repair	2 (11)	10 (30)	1 (3)
Labral debridement	15 (79)	6 (18)	5 (15)
Acetabular microfracture	2 (11)	1 (3)	1 (3)
Acetabuloplasty	0 (0)	10 (30)	1 (3)
Trochanteric advancement or relative neck lengthening	0 (0)	3 (9)	4 (12)

Surgical technique

In brief, hip arthroscopy was performed using a dual-arthroscopic portal approach as described by Lee et al.²⁰ The SHD approach was performed according to the technique described by Ganz et al.³¹ Briefly, the patient is positioned in the lateral decubitus and the incision is placed in line with the greater trochanter. After opening of the fascia lata a trochanteric osteotomy is performed and the trochanteric pieces flipped anteriorly allowing exposure of the hip capsule. The hip capsule is open in line with the femoral neck and a capsulotomy is completed allowing for dislocation of the hip after the ligamentum teres is released. Full assessment of the acetabular cavity and treatment of chondral and labral pathology follows. Then osteochondroplasty of the head neck junction is performed. If there is residual deformity with impingement of the head neck junction with the hip in flexion and internal rotation despite osteochondroplasty then a flexion-derotation osteotomy is performed as previously described.²¹

Data collection

Medical records were reviewed for patient height, weight, sex and age at the time of surgery. Patient height and weight from time of surgery were used to calculate BMI. Operative notes were reviewed and procedures performed were recorded. The intraoperative labral and acetabular articular cartilage injury were recorded using the Beck classification³² as follows: Cartilage was classified as normal, malacia (roughening with some fibrillation), debonding (loss of fixation to the subchondral bone), cleavage (loss of fixation with frayed edges and thinning of cartilage, flap) and defect (full-thickness defect). Medical records were reviewed to quantify complications and reoperations. Clinical notes were reviewed preoperatively and at last postoperative follow-up for the collection of the modified Merle D'Aubigné Postel (MDP) scores.³³ The MDP scores are calculated based on pain, hip movement and ability to walk. Each parameter receives 0 (worse) to 6 (best) points and the total score is rated as good or excellent when the total score is 15 to 18 points; fair when it is 12 to 14 points; and poor when it is < 12 points.

Radiographs were assessed at the time of initial SCFE, before reconstructive surgery and in the most recent postoperative follow-up. At the time of SCFE the Southwick angle³⁴ was measured on the frog lateral radiographs. SCFE was classified as mild (0° to 29°), moderate (30° to 59°) and severe (≥ 60°). At the time of surgery we measured the tilt angle³⁵ to assess for residual head-neck misalignment and the Tönnis grade of OA.³⁶ The radiographic parameters assessed before surgery and at most recent visit included the alpha angle as described by Leunig et al¹⁹ and the femoral neck/shaft angle.

Statistics analysis

Differences in preoperative and postoperative continuous characteristics were assessed across treatment groups using analysis of variance with *post hoc* Tukey's test to determine pairwise differences between groups. Differences in categorical characteristics across treatment groups were assessed using chi-squared analysis. All tests were two-sided and p-values < 0.05 were considered significant.

Results

A total of 83 of 86 hips (97%) had data on SCFE severity at time of initial slip including 22 (27%) mild, 34 (41%) moderate and 27 (33%) severe cases. Of the 19 hips that were treated with arthroscopy, 14 (74%) were mild slips. In contrast, of the 32 hips treated with dislocation and osteotomy (SHD+ITO), 13 (41%) were moderate and 19 (59%) were severe (Fig. 1).

Overall, patients treated with arthroscopy were more likely to have less deformity of the femoral head-neck junction and a lesser degree of radiographic arthritic change as reflected by lower mean tilt, alpha angle on the frog-leg lateral radiograph, and lower mean Tönnis arthritic grade (Table 3). At the time of surgery, patients in the SHD (13/32; 41%) and SHD+ITO (13/29; 45%) groups were more likely to present with full-thickness cartilage defects compared with the arthroscopy group (2/19; 11%; $p = 0.03$) (Table 4). In general, correction of the femoral head neck concavity was achieved in the three groups, as demonstrated by no difference in the mean postoperative alpha angle on the anteroposterior and lateral radiographs between groups (Table 3).

There were no complications in the arthroscopy group (0/19; 0%), three complications in the SHD group (3/33; 9%) and 11 complications in the SHD+ITO group (11/34; 32%) ($p = 0.003$) (Table 5). There were no patients referred for total hip arthroplasty in the arthroscopy group (0/19; 0%), four patients in the SHD group (4/33; 12%) and four patients in the SHD+ITO group (4/34; 12%) ($p = 0.29$).

Patients treated by arthroscopic surgery had higher mean MDP scores before surgery and at final follow-up compared with patients in the SHD and SHD+ITO groups. However, there was no difference detected across the three types of intervention with respect to improvement in pain and function (postoperative minus preoperative total MDP score) (Table 6). A similar relationship was seen with respect to mild, moderate and SCFE severity and severity of symptoms with improvement in pain and function. Patients with severe SCFE tend to present with worse pain and function as assessed by the MDP scores before surgery compared with patients with mild SCFE. However, improvement assessed by delta MDP scores was

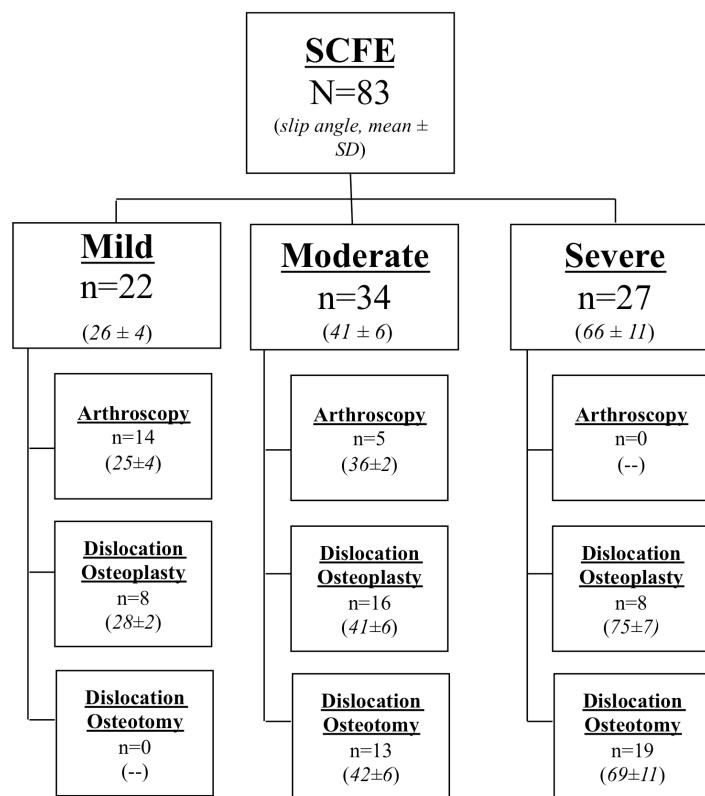


Fig. 1 Flow chart of treatment type by slipped capital femoral epiphysis (SCFE) severity with initial SCFE slip angle summary.

Table 3 Comparison of radiographic measures across slipped capital femoral epiphysis deformity by surgical groups

	Arthroscopy (n = 19)	Surgical dislocation with osteoplasty (n = 33)	Surgical dislocation with osteotomy (n = 34)	p-value*
Mean preoperative measurement (SD), °				
Neck-shaft angle	130.3 (4.01)	128.1 (5.79)	121.2 (9.81)	< 0.001
Tilt angle	18.0 (5.68)	26.5 (8.28)	37.0 (11.97)	< 0.001
AP alpha angle	73.4 (10.54)	78.6 (16.87)	82.0 (15.27)	0.15
Lateral alpha angle	71.6 (9.47)	80.6 (11.95)	81.2 (13.65)	0.02
Mean postoperative measurement (SD), °				
Neck-shaft angle	130.6 (3.82)	128.2 (5.38)	135.7 (14.13)	0.007
AP alpha angle	58.7 (11.97)	58.7 (13.67)	61.6 (15.46)	0.65
Lateral alpha angle	54.1 (6.57)	51.7 (9.97)	57.6 (13.38)	0.09

AP, anteroposterior

*p-values are based on analysis of variance with each radiographic measurement as a dependent variable and treatment group as an independent factor variable.

independent of SCFE severity as reflected by no difference in the improvement between patients with mild, moderate or severe SCFE (Table 7).

Discussion

Here we present a comparative study of patients with symptomatic post-SCFE deformity treated with an arthroscopic versus a SHD approach with or without femoral osteotomy. While patients undergoing arthroscopic

osteochondroplasty had slightly higher function at follow-up compared with patients undergoing open hip surgery, patients undergoing open hip surgery had more severe slips at initial presentation and more severe deformity before surgery. They also had worse acetabular cartilage damage and more radiographic signs of arthritic changes at time of reconstructive surgery. We found that patients treated with open and arthroscopic approaches benefit similarly from surgical treatment as reflected by no differences in hip pain and function improvement between the groups.

Table 4 Cartilage and labral injury seen at time of surgery by group

Classifications, n (%)	Arthroscopy (n = 19)	Surgical dislocation with osteoplasty (n = 32)*	Surgical dislocation with osteotomy (n = 29)**
Beck cartilage classification			
Defect	2 (11)	13 (41)	13 (45)
Debonding***	5 (26)	6 (18)	2 (6)
Malacia	11 (58)	10 (30)	9 (26)
Normal	1 (5)	3 (9)	5 (15)
Beck labral classification			
Ossification	0 (0)	3 (9)	0 (0)
Full-thickness tear	3 (16)	7 (21)	2 (6)
Detachment	0 (0)	4 (12)	4 (12)
Degeneration	14 (74)	16 (48)	13 (38)
Normal	2 (11)	2 (6)	10 (29)

* one patient in the surgical dislocation osteoplasty group did not have intraarticular findings described for classification

** five patients in the surgical dislocation osteotomy group did not have intraarticular findings described for classification

*** given the description in operative reports we were unable to differentiate debonding and cleavage from the Beck classification

Table 5 Complications and reoperations

Group	Complication (n)	Reoperation (n)
Arthroscopy	None (0)	Revision arthroscopic femoral osteoplasties for residual cam deformity (2)
Surgical dislocation with osteoplasty*	Chronic regional pain syndrome (1)	Total hip arthroplasty (1)
	Heterotopic ossification (1)	Greater trochanteric refixation (2)
	Greater trochanter non-unions (2)	Intertrochanteric osteotomy (2)
		Hip arthroscopy for revision femoral osteochondroplasty (4)
Surgical dislocation with osteotomy	Sciatic nerve palsy (1)	Revision osteochondroplasty with greater trochanteric advancement (1)
	Heterotopic ossification (1)	Bone grafting for delayed or nonunion of femoral osteotomy (2)
	Chronic regional pain syndrome (1)	Open revision femoral osteochondroplasty (3)
	Avascular necrosis (2)	
	Chondrolysis (3)	
	Femoral delayed or non-unions (3)	

*complications (4 in 3 patients)

Table 6 Merle D'Aubigne (MD) scores by slipped capital femoral epiphysis treatment and time point

MD domain	Preoperative		Postoperative		Change	
	Mean (SD)	p-value	Mean (SD)	p-value	Mean (SD)	p-value*
Pain						
Arthroscopy	4.4 (0.77)	-	5.5 (0.84)	-	1.1 (0.94)	-
SHD	4.2 (0.77)	0.26	4.9 (1.13)	0.05	0.7 (1.26)	0.26
SHD+ITO	4.3 (0.68)	0.55	5.0 (1.17)	0.12	0.7 (1.19)	0.27
Walking						
Arthroscopy	5.7 (0.58)	-	5.9 (0.23)	-	0.3 (0.65)	-
SHD	5.5 (0.62)	0.37	5.6 (0.70)	0.19	0.2 (0.87)	0.69
SHD+ITO	5.2 (0.97)	0.02	5.3 (1.09)	0.01	0.1 (1.18)	0.68
Mobility						
Arthroscopy	5.3 (0.45)	-	5.9 (0.46)	-	0.6 (0.60)	-
SHD	4.5 (0.67)	0.001	5.5 (0.80)	0.06	1.0 (0.90)	0.19
SHD+ITO	4.4 (0.96)	< 0.001	5.2 (0.84)	0.002	0.8 (1.15)	0.56
Total						
Arthroscopy	15.4 (1.21)	-	17.4 (1.21)	-	2.0 (1.60)	-
SHD	14.2 (1.4)	0.006	16.0 (2.42)	0.05	1.8 (2.54)	0.83
SHD+ITO	13.9 (1.61)	0.001	15.6 (2.72)	0.009	1.7 (2.72)	0.65

SHD, surgical hip dislocation; SHD+ITO, surgical hip dislocation and intertrochanteric osteotomy

*p-values are based on analysis of variance with the MD domain at each time point as a dependent variable and treatment group as an independent factor variable.

Recent studies have reported encouraging outcomes of contemporary surgical approaches including hip arthroscopy^{18-20,27-29,37} and SHD^{6,21-26} but limited comparative data is available. Our findings demonstrated that symptomatic improvement can be achieved after arthroscopy for mild

deformity and after surgical dislocation with or without an osteotomy for moderate and severe deformities. Balakumar et al³⁰ compared the results of surgical treatment following moderate and severe SCFE in 12 patients undergoing a femoral neck osteotomy though a SHD approach

Table 7 Merle D'Aubigne (MD) scores by slipped capital femoral epiphysis severity and time point

MD domain	Preoperative		Postoperative		Change	
	Mean (SD)	p-value	Mean (SD)	p-value	Mean (SD)	p-value*
Pain						
Mild	4.6 (0.67)	-	5.3 (1.03)	--	0.7 (1.09)	-
Moderate	4.1 (0.81)	0.02	5.2 (1.00)	0.73	1.1 (1.18)	0.22
Severe	4.3 (0.59)	0.11	5.0 (1.02)	0.42	0.8 (1.09)	0.77
Walking						
Mild	5.7 (0.46)	-	5.9 (0.35)	--	0.1 (0.56)	-
Moderate	5.6 (0.61)	0.49	5.6 (0.81)	0.31	0.1 (1.01)	0.76
Severe	4.9 (1.00)	< 0.001	5.4 (0.97)	0.05	0.5 (1.05)	0.20
Mobility						
Mild	5.0 (0.79)	-	5.7 (0.65)	--	0.7 (0.70)	-
Moderate	4.7 (0.77)	0.20	5.6 (0.60)	0.75	0.9 (0.85)	0.40
Severe	4.3 (0.81)	0.003	5.2 (0.89)	0.03	1.0 (1.13)	0.37
Total						
Mild	15.3 (1.16)	-	16.8 (1.76)	--	1.5 (1.47)	-
Moderate	14.4 (1.42)	0.03	16.4 (2.16)	0.53	2.0 (2.48)	0.44
Severe	13.4 (1.48)	< 0.001	15.7 (2.43)	0.07	2.2 (2.58)	0.31

*P-values are based on analysis of variance with the MD domain at each time point as a dependent variable and severity group as an independent factor variable.

with those of ten patients treated with arthroscopic osteochondroplasty. Although both approaches improved the modified Harris hip scores, patients undergoing open treatment had less pain and better function after surgery when compared with those treated by arthroscopy. Moreover, arthroscopic osteochondroplasty improved the femoral head and neck morphology, however, patients had persistent external rotation deformity secondary to the retroversion in SCFE.

We found that the patients undergoing more invasive open treatments had more severe slips at their initial injury and worse post-slip healed deformity at the time of reconstructive surgery as assessed by preoperative radiographic variables. Patients in this study did not consistently have preoperative MRI to assess for articular cartilage and labral damage before surgery because of metal artifact associated with the screw in the femoral head. Furthermore, we did not have a systematic analysis of preoperative rotational deformity for all patients. While our findings may be due to selection bias and reflect the indications for each procedure at our institution, they also illustrate the difficulty in comparing case series data on patients with healed SCFE deformity. Future studies comparing the outcomes of surgical treatment for post-slip FAI need to attempt to compare patients with similar deformity and intra-articular chondral damage as assessed by plain radiographs, MRI and CT imaging.

In this study we observed a high proportion of cartilage damage in patients with mild, moderate or severe SCFE deformity. The high proportion of advanced cartilage damage is in line with previous studies.^{6-8,20} Intraarticular pathology was more extensive and more often observed in patients with more severe deformity. Notably, > 40%

of patients treated with SHD presented with full-thickness acetabular cartilage defects representing advanced cartilage damage in this young patient population. It is possible that early intervention, by means of osteochondroplasty at the time of SCFE pinning in mild SCFE as previously reported independently by Leunig et al¹⁹ and by Lee et al,²⁰ or by early realignment in more severe deformity, would reduce the articular damage associated with the deformity and have a positive impact in the long term but this warrants further investigation.

Our results confirm that patients with symptomatic FAI after *in situ* pinning for SCFE benefit from surgical treatment as reflected by improvement in MDP scores at most recent follow-up compared with preoperative scores in the three treatment groups. Although patients with severe SCFE had more pain and worse function before and after surgery, there were no differences in overall improvement between the groups. We found a higher proportion of major complications in patients undergoing SHD with or without femoral osteotomy compared with those undergoing arthroscopic osteochondroplasty which is in line with previous literature suggesting arthroscopic treatment of post-slip FAI has lower complications.^{18,20-22,24,25,28,29} We believe that our results of higher complications and reoperations reflect the more severe pattern of deformity and articular chondral damage in patients undergoing a more complex surgical procedure. Radiographic correction of the post-slip deformity was also successfully achieved with the three surgical strategies. Hips treated with SHD with or without osteotomy had worse preoperative deformity but no difference between groups were observed in alpha angles on postoperative imaging. This is similar to prior studies looking at alpha angle correction in arthroscopic and open treatment of FAI secondary to SCFE.^{18,22,25,28,29}

This study has several limitations. Given that it was retrospective in nature we were limited to what was available in our medical record. In addition, the treatment options were not randomized or chosen by a standardized protocol. It was at the discretion of the treating surgeon to determine which approach was used. Therefore, there is a selection bias in that patients with more deformity were likely indicated for open surgery. This may help explain prior findings that supported higher complication and revision rates in patients undergoing surgical dislocation compared with arthroscopy. While we obtained > 80% follow-up of our patient cohort at a minimum of one year after surgery, there is a broad range of clinical follow-up from one to over 12 years from surgery. There is also a follow-up bias in that the surgical dislocation was performed at our centre before arthroscopy was available and, therefore, we have more surgical dislocation patients with longer follow-up. Longer followup of patients treated with surgical dislocation and the more severe pattern of deformity and cartilage damage at the time of surgery explain the reason all of the patients referred for arthroplasty were in the surgical dislocation group.

Our findings should help guide the orthopaedic surgeon in their decision making for a patient who presents with symptomatic FAI secondary to a post-slip deformity after *in situ* pinning. Based on our results, osteochondroplasty of the femoral head-neck junction with repair of associated chondrolabral injury should be considered for the treatment of hips with mild radiographic deformity and only slight limitation of hip internal rotation in flexion. Patients with moderate and severe SCFE deformity with obligatory external rotation in flexion benefit from open SHD with osteochondroplasty of the femoral head and a modified flexion-derotation osteotomy to improve the range of impingement-free movement and the external rotation deformity. Families and patients with moderate and severe deformity should be counselled about the high proportion of advanced cartilage damage and the relatively higher risk of complications and reoperations. Given the high proportion of advanced cartilage damage in moderate and severe SCFE, early reconstruction at the time of the SCFE diagnosis may be considered, however, further comparative studies are necessary to establish if this strategy improves the long-term outcomes compared with late reconstruction in the symptomatic patient.

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COMPLIANCE WITH ETHICAL STANDARDS

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No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

OA LICENCE TEXT

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ETHICAL STATEMENT

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved as a retrospective comparative study by our institutional review board.

Informed consent: Was not obtained from subjects in this retrospective study.

ICMJE CONFLICT OF INTEREST STATEMENT

JDW reports grants from Arthrex Inc, outside the submitted work; and is a member of the Editorial Board of Arthroscopy and a committee member of the *American Orthopedic Society for Sports Medicine*.

YJK reports personal fees from Imagen, non-financial support from Orthopediatrics, outside the submitted work; and is a member of the Editorial Board of *Orthopedic Reviews, Osteoarthritis and Cartilage, and Journal of Hip Preservation Surgery*.

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AUTHOR CONTRIBUTIONS

JDW: Study design, Review of patient records, Data analysis, Writing of the manuscript.

MPM: Study design, Review of patient records, Data analysis, Writing of the manuscript.

NU: Study design, Review of patient records, Data analysis, Writing of the manuscript.

PEM: Study design, Data analysis, Statistical methods, Writing of the manuscript.

YJK: Study design, Manuscript writing.

MBM: Study design, Manuscript writing.

YMY: Study design, Manuscript writing.

ENN: Study design, Review of patient records, Data analysis, Writing of the manuscript.

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