Evidence-Based Treatment for Slipped Upper Femoral Epiphysis

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Abstract

Slipped upper femoral epiphysis (SUFE), though not common, is an important paediatric disorder. It has a reported incidence of 1–10 per 100,000. Some aspects of management of SUFE are controversial and evolving with advancing surgical skills and expertise. The infrequency of cases, the various classifications in use, the various surgical treatments, and lack of robust evidence for outcomes, has resulted in the lack of clear, evidence-based recommendations for treatment. The following review examined the current evidence for treating SUFE and concluded that pinning in situ is the best treatment for mild and moderate stable slip (grade B). Surgical dislocation may give better results than pinning in situ for severe stable slip (grade C). Urgent gentle reduction, capsulotomy and fixation is the best current treatment for unstable slip (grade C). Routine prophylactic pinning of the contralateral asymptomatic side is not recommended (grade C)

Keywords

SUFE • SCFE • Slipped • Stable slip • Unstable slip • Loders classification • AVN • Osteonecrosis • FHO • Slipped upper femoral epiphysis

Background

Slipped upper femoral epiphysis (SUFE) is one of the most important paediatric and adolescent hip disorder. Incidence is 1–10:100,000. Patients usually presented with painful hip and or knee with affected leg is short and externally rotated (Fig. 6.1). The plain x-ray is usually diagnostic (Fig. 6.2). The cause is poorly understood, it is believed that increased shear forces and/or weak growth plate (the physis) in adolescence predispose to slips.

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Although rare, endocrine disorders must be considered in every patient with SUFE. Loder [1] identified two types of SUFE; idiopathic type and atypical type where there is an underlying endocrine disorders or other aetiology. He studied the demographics of 433 patients with 612 SUFEs (285 idiopathic, 148 atypical) and found that weight and age were predictors for atypical SUFE and he recommended the *age-weight test:* the test was defined as negative when age younger than 16 years and weight ≥50th percentile and positive when beyond these boundaries. The probability of a child with a negative test result having an idiopathic SUFE was 93 %, and the probability of a child with a positive test result having an atypical SCFE was 52 %.

Slipped upper femoral epiphysis was traditionally classified as (1) pre-slip: patient has symptoms with no anatomical displacement of the femoral head, (2) acute: there is an abrupt displacement through the proximal physis with symptoms and signs developing over a short period of time (<3 weeks), (3) Chronic: present with pain in the groin, thigh, and knee of more than 3 weeks, often ranging from months to years and (4) acute on chronic: initially, patient

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has chronic symptoms, but develops acute symptoms as well following a sudden increase in the degree of slip [2, 3].

However, in a classic paper by Loder [4, 5] a new, clinically more relevant classification was introduced. SUFE was classified based on the patient weight-bearing status into stable when patient is able to ambulate and bear their weight and unstable when patient is unable to ambulate with or without crutches. In his series of 55 SUFEs, Loder showed that avascular necrosis (AVN) developed in 47 % of unstable slips but none of stable hips. However, unintentional reduction of the slip occurred in 26 unstable slips (out of 30) and in only 2 of the stable slips (out of 25). [4]. Several other papers confirmed Loder's findings [6, 7–9].

Fig. 6.1 A child with SUFE. A clinical photograph of a child with SUFE, notice the short and externally rotated left leg (mimic fracture neck of femur). Patient was investigated and treated for knee pain

Fig. 6.2 A pelvis x-ray with left slipped upper femoral epiphysis. The x-ray shows a severe slipped upper epiphysis

Grading the severity of the slip is usually based on the radiographic findings. The Southwick angle is the most commonly used [10]. The angle is measured on the lateral view of the both hips by drawing a line perpendicular to a line connecting the posterior and anterior tips of the epiphysis at the physis. The angle between the perpendicular line and the femoral shaft line is called the lateral epiphyseal shaft angle. The Southwick angle is the difference between the lateral epiphyseal shaft angle of the slipped and the non slipped sides (Fig. 6.3). In patients with bilateral involvement, 12° is subtracted from each of the measured lateral epiphyseal angles. Mild slip (grade I) has an angle difference of less than 30°, moderate slip (grade II) has an angle difference of between 30 and 50 degrees and severe slip has a difference of over 50 degrees.

Treatment aim is to prevent progression of the slip without complications. Reduction of the slip to near anatomical position is desirable but this is tempered by the higher risk of AVN and chondrolysis (CL) which are surrogates for bad outcomes. The choice of treatment depends on the type of slip, its severity, and surgical expertise.

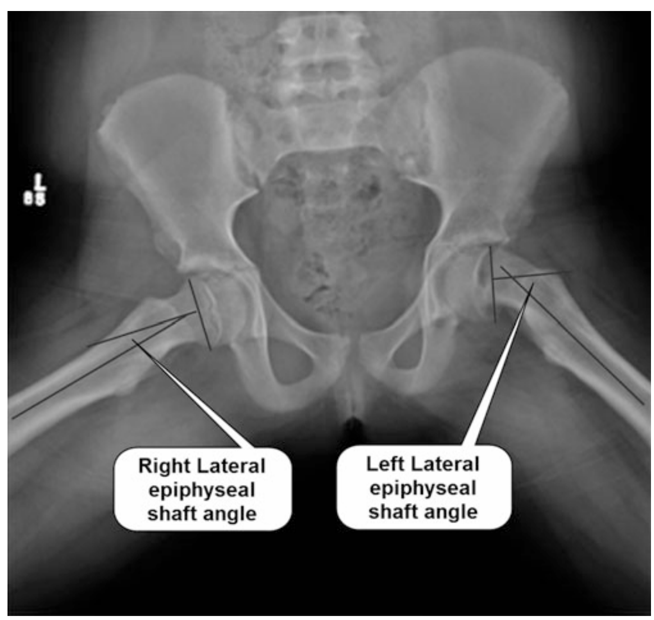

Fig. 6.3 SUFE radiological grading. The Southwick angle is the difference between the lateral epiphyseal shaft angle of the slipped and the non slipped sides. Mild slip (grade I) has an angle difference of less than 30°, moderate slip (grade II) has an angle difference of between 30° and 50° and severe slip has a difference of over 50°

What Is the Best Treatment for a Stable Slip?

There is a consensus that the best treatment for mild and most moderate stable slip is pinning-in-situ (PIS) using a single cannulated screw (SS). This has been supported by a comprehensive review paper by Loder [11]. If the slip is severe, pinning can be technically difficult. Gentle reduction is often unsuccessful in a stable slip and forceful reduction is contraindicated as this increase the risk of AVN. The options are either PIS with re-alignment procedure later if remodeling is suboptimum or primary corrective osteotomy.

Realignment procedures can be performed at one of three levels: subcapital, femoral neck and intertrochanteric region. The ability to correct a deformity is greatest with subcapital osteotomy (where the CORA is), least with an intertrochanteric osteotomy. The risk of AVN is the highest with subcapital osteotomy and the lowest with intertrochanteric osteotomy.

We performed an extensive literature search for the best available evidence to support various treatments of stable slips. We could not find level I or II evidence. There were 16 comparative studies and several case series with a follow-up more than a year. With a few exceptions all these studies were unmatched; mild and moderate slips were treated with pinning whereas severe slips were treated with reduction (either close or open reduction) and stabilisation undermining the comparison between pinning in situ and reduction.

Tables 6.1 and 6.2 show that pinning using a single screw has the lowest rates of AVN and chondrolysis (CL) and even a better patient's satisfaction when compared with traditional corrective osteotomies namely Dunn's and Fish osteotomies. One point needs further emphasis that patient who had corrective osteotomies were more likely to have severe slips and their outcomes are less favourable anyway.

In the last two decades, the femoro-acetabular impingement (FAI) has become widely recognized as an orthopaedic condition that requires treatments to prevent future osteoarthritis (OA) and premature artificial hip replacement. Ganz (Ganz et al. [54, 55] has been a pioneer in spreading the understanding of the condition and its treatment. He described a new technique of surgical dislocation of the hip involving tro-

Table 6.1 Pooled summary of studies of stable slips treatments

Intervention	Hips	AVN (%)	CL (%)	Satisfactory patients result[a]
Hip spica	101	8 (7.9 %)	21 (20.8 %)	NR
Epiphysiodesis	485	14(2.9 %)	8 (1.6 %)	67 (67 %) excellent 6 (6 %) good 10 (10 %) fair 7 (7 %) poor 7 (7 %) failure
Pinning using single screw	525	8(1.5 %)	12 (2.3 %)	113 (47 %) excellent 86 (36 %) good 19 (8 %) fair 10 (4 %) poor 11 (5 %) failure
Pinning using multiple pins	273	6(2.2 %)	11(4 %)	76 (67 %) excellent 19 (17 %) good 0 (0 %) fair 16 (14 %) poor 3 (3 %) failure
Physeal osteotomy	545	63(11.6 %)	51 (9.4 %)	131 (28 %) excellent 210 (45 %) good 46 (10 %) fair 72 (16 %) poor 3 (6 %) failure
Ganz surgical dislocation	81	3(3.7 %)	2 (2.5 %)	52 (87 %) excellent 2 (3 %) good 0 (0 %) fair 5 (8 %) poor 1 (2 %) failure
Base of neck osteotomy	92	2(2.1 %)	6 (6.5 %)	22 (60 %) excellent 11 (30 %) good 2 (5 %) fair 2 (5 %) poor
Inter-trochanteric osteotomy	336	5 (1.5)	16 (4.8 %)	121 (44 %) excellent 105 (38 %) good 35 (13 %) fair 15 (5 %) poor

[a]Satisfactory patients result based on closely related rating such as Heyman and Herndon classification, Harris hip score or Iowa hip scores.

Table 6.2 studies of various interventions in stable slips

Study	Rx	Patients	Hips	AVN	CL	FAI	OA	Patient satisfaction	Others	Notes
Hip Spica										
Betz [12]	Spica	32	37	0	5	NR	NR	NR		0 acute, 8 acute on chronic and 29 chronic 25 mild, 7 moderate and 5 severe All stable slips
Carney (Carney et al. [13])	Spica		47	8	6			IHS for chronic slips 81 and 71for acute slips		4 acute and 43 chronic. Spica with closed reduction (16 hips) resulted in a mean IHS of 65 points, 6 AVN and 2 CL. Spica cast without reduction (26) resulted in a mean IHS of 83 points, 2 AVN and 4 CL.
Meier (Meier et al. [14])	Spica	13	17	NR	10	NR	9	NR	3 pressure sores 3 Further slipping	
Total		NA	101	8	21					
Epiphysiodesis										
Adamczyk (Adamczyk et al. [15])	Epi	225 (+43)	278 (+45)	4 (+3)	0 (+1)	NR	NR	NR	17 further slipping (+6) 4 deep infection 12 re-operation	45 acute, 0 acute on chronic and 278 chronic Outcomes of acute slips are bracketed
Rao (Rao, et al. [16])	Epi	43	46	3	2	NR	NR	NR	3 infections 7 cases of transient anterolateral thigh hypesthesia 44 hetertopic ossification.	18 unstable (excluded) and 46 stable slips. The average operating time and blood loss per hip were 122 ± ?4 min and 426 ± 238 ml, respectively.
Schmidt (Schmidt et al. [17])	Epi	33	40	1	1	NR	NR	HHS 35 excellent 1 good 2 fair 2 poor	1 femoral neck fracture 1 subt-rochanteric hip fracture 2 coxa vara	31 mild, 9 moderate, 0 severe. 6 unstable and 34 were stable. The average time 1 h 57 min and blood loss averaged 360 ml.
Szypryt (Szypryt et al. [18])	Epi	25	30	2	3	NR	7	MSC 12 excellent 5 good 8fair 4 poor	3 wound infection	1 acute, 13acute-on-chronic, 16 chronic. 0 mild, 12 moderate, 18 severe
Zahrawi (Zahrawi et al. [19])	Epi		28	0	0	NR	NR	HHC 20 excellent 0 good 0 fair 1 poor 7 failure	4 wound infection 2 graft failure 1 further slipping 6 needed further surgery	Severity (mean slip angle 30) LOS 21 Duration of surgery 150 min Blood loss 500 ml

Total		NA	467	13	7			67 (67 %) excellent 6 (6 %) good 10 (10 %) fair 7 (7 %) poor 7 (7 %) failure		
Pinning Using Screws										
Alshryda (Alshryda et al. [7])	Pinning(PIS) (SS)	36	36	1	1	NR	NR	NR	1 loss of fixation	Unstable and uncertain hips were excluded
Aronson [20]	Pinning(PIS) (SS)	34	43	1	0	NR	1	HHC 27 excellent 12 good 2 fair 2 poor	2 loss of fixation 1 Sub-trochanteric fracture 2 failed screw removals	6 acute and 37chronic. 27 mild, 8 moderate and 8 severe
Aronson [21]	Pinning(PIS) (SS)	44	58	1	0	NR	1	HHC 33 excellent 21 good 2 fair 2 poor	2 loss of fixation 1 Sub trochanteric fracture No further slipping.	8 acute, 0 acute-on-chronic, and 50 chronic. 38 mild, 10 moderate and 10 severe.
Blanco (Blanco et al. [22])	Pinning (PIS) (SS)	80	43	0	0	NR	NR	NR	2 Metalware problems 1 reoperation	1 acute , 6 acute on chronic, 36 chronic 23 mild, 12 moderate , 8 severe 1 CRIF
Carlioz [88]	Pinning (PIS) (SS)	34	38	0	2	NR	NR	31 good 10 fair 2 bad 3 Failure	1 Sub-trochanteric fracture	6 patients underwent reduction (1 AVN excluded). Authors did not use “Excellent” in outcomes
Gonzalez-Moran (Gonzalez-Moran et al. [23])	Pinning (PIS) (SS)	25	31	1	0	NR	NR	NR	1 wound infection 3 metalware problems	All received two weeks of skin longitudinal traction then pinning in situ without manipulation 22 case had a single screw and 9 had 2 screws 11 acute, 6 acute on chronic and 14 chronic 1 preslip, 17 mild, 11 moderate and 2 severe
Herman (Herman et al. [24])	Pinning(PIS) (SS)	11	11	0	1	NR	NR	HHS (95 points) 11 excellent 0 good 0fair 0 poor	No further slipping.	4 acute, 11 acute-on-chronic, and 6 chronic.
Kenny [25]	Pinning(PIS) (SS)	40	53	0	1	NR	1	HHC (31)58 % excellent (19)36 % good (2)4 % fair (1)2 % a poor	1 Sub-trochanteric fracture No further slipping.	3 acute, 8 acute-on-chronic and 35 chronic. 80 % mild, 12 % moderate and 2 % severe

(continued)

Table 6.2 (continued)

Study	Rx	Patients	Hips	AVN	CL	FAI	OA	Patient satisfaction	Others	Notes
Koval [26]	Pinning(PIS) (SS)	49	67	2	7	NR	2	NR	1 Growing off fixation 1 Stress fracture of the femoral neck	12 acute, 1 acute-on-chronic, 67 chronic. 55 mild, 19 moderate and 6 severe. 3 CRIF (1AVN)
Lim (Lim et al. [27])	Pinning (PIS) (SS)	13	13	1	0			Aadalen criteria 8excellent 2good 2fair 0 poor 1failure		All underwent preoperative traction All acute or acute on chronic Severity: mean 30° (range 0°-60°).
Novais (Novais et al. [28])	Pinning (PIS) (SS)	15	15	1				HHC 3 excellent 1good 1fair 3 poor 7failure	2 metalware problems 1 further slipping	All patients had stable severe slip revealed better deformity correction with the modified Dunn procedure compared with in situ pinning
Souder (Souder et al. [29])	Pinning (PIS) (SS)		64	0	0	NR	NR	NR	3 metalware problems 1 infection 1 further slipping	Ganz surgical dislocation 7 Unstable cause 3 AVN excluded
Ward (Ward et al. [30])	Pinning(PIS) (SS)	42	53	0	0	NR	NR	NR	Neither chondrolysis nor avascular necrosis developed. 1 HO 2 Metalware problems	2 acute, 3 acute-on-chronic and 48 chronic. 19 mild, 25 moderate and 9 severe 5 CRIF
Total (%)		NA	525	8	12	NA	0.02 %	113 (47 %) excellent 86 (36 %) good 19 (8 %) fair 10 (4 %) poor 11 (5 %) failure		
Pinning Using Multiple Pins										
Aronson [20]	Pinning (MPF)	39	54	2	3	NR	18	HHC 27 excellent 13 good 0 fair 13 poor 1Failure	13 patients had pin protruded through the back of the neck	4 acute and 50 chronic. 34 mild, 14 moderate and 6 severe
Blanco (Blanco et al. [22])	Pinning (MPF)		25	1	0	NR	NR	NR	8 Metalware problems 1 Growing off 4 reoperation	1 Preslip, 4 acute, 6 acute on chronic, 12 chronic 11 mild , 9 moderate, 4 severe. 7 CRIF

Carney (Carney et al. [13])	Pinning (MPF)		37	3	1	NR	NR	IHS for chronic slips 86 and 93 for acute slips		3 acute and 34 chronic. Reduction and pinning resulted in a mean ISH of 75 points, 2 AVN, 1 CL. pinning in situ resulted in a mean IHS of 85 points, 1 AVN, 0 CL.
Dreghorn (Dreghorn et al. [31])	PIS (MPF)		66	0	2	NR	0	NR	1 Growing off fixation	51 mild, 14 moderate and 1 severe
Gonzalez-Moran (Gonzalez-Moran et al. [23])	Pinning (MPF)	28	31	0	3	NR	NR	NR	4 wound infection 9 metalware problems	1 acute, 4 acute on chronic and 26 chronic 0 preslip, 15 mild, 12 moderate and 4 severe
Zahrawi (Zahrawi et al. [19])	PIS (MPF)		60	0	2	NR	NR	HHC 49 excellent 6 good 0 fair 3 poor 2 failure	2 metalware problems 1 further slipping 3 wound infection 2 needed further surgery	Severity (mean slip angle 22) Chronicity and stability NR LOS 17 Duration of surgery 90 min Blood loss 250 ml
Total			273	6	11			76 (67 %) excellent 19 (17 %) good 0 (0 %) fair 16 (14 %) poor 3 (3 %) failure		
Physeal Osteotomy										
Alshryda (Alshryda et al. [7])	PO	7	7	2	1	NR	NR	NR	Hip dislocation	15 unstable hips were excluded (5 AVN)
Barros [32]	PO	23	23	3	2	NR	NR	MSC 9 excellent 9 good 1 fair 4poor	1 metalware problem 0 infection	0 acute, 3 acute-on-chronic, 20 chronic. 0 mild, 0 moderate, 23 severe
Broughton (Broughton et al. [33])	PO	115	115	14	14	1	17	Overall 67 good 9fair 19poor		0 acute, 38 acute-on-chronic, 77 chronic. 0 mild, 15 moderate, 100 severe Patients satisfaction (G/F/B) in the acute-on-chronic (27/5/6); in the chronic with open growth plate (59/3/8) in the chronic slip with closed growth plate (1/1/5) .
Carlioz [88]	PO	26	27	0	3	NR	NR	20 good 3 fair 4 bad 3 Failure	Septic arthritis	

(continued)

Table 6.2 (continued)

Study	Rx	Patients	Hips	AVN	CL	FAI	OA	Patient satisfaction	Others	Notes
Carney (Carney et al. [13])	PO		14	3	6	NR	NR	IHS for chronic slips 76 and 50 for acute slips		26 moderate or severe slips
DeRosa(DeRosa et al. [34])	PO	23	27	4	8	NR	NR	MSC 0 excellent 19 good 4fair 4poor	2 loss of fixation	1 CRIF before PO went into AVN 0 mild, 0 moderate, 27severe
Dreghorn (Dreghorn et al. [31])	PO		3	1	0	NR	0	NR	1 wound infection	0 mild, 5 moderate and 6 severe
Diab (Diab et al. [35])	PO	11	11	2	0	1	NR	NR		
Dunn [36]	PO	69	73	9	3	NR	2	55 good 6 fair 12 poor		Several hips were manipulated under GA somewhere else (CRIF) 0 acute, 33 acute-on-chronic, 40 chronic.
Fish [37]	PO	61	66	3	1	NR	6	55 excellent 6 good 2fair 3poor		0 acute, 16 acute-on-chronic, 50 chronic. Chronic slips (0 mild, 23 moderate, 27 severe)
Fron (Fron et al. [38])	PO	46	50	6	3	NR	NR	34 excellent 10 good 2fair 4 poor	2 hematomas 2 infections 3 pseudarthroses of the greater trochanter 1 HO	0 acute, 17 acute-on-chronic, 30 chronic. 0 mild, 0 moderate, 50 severe
Jerre [39]	PO	22	22	5	1	NR	6	HHC 5 excellent 4 good 1 fair 8 poor	4 THR 1 Hip arthrodesis	1 acute, 1 acute-on-chronic, 20 chronic. 10 mild, 6 moderate, 0 severe, 6 none
Nishiyama [40]	PO	15	18	1	1			13 excellent 1good 1 fair 0poor		0 acute, 0 acute-on-chronic, 18 chronic. 0 mild, 0 moderate, 18 severe
Szypryt (Szypryt et al. [18])	PO	23	23	4	0	NR	5	MSC 15 excellent 2 good 1fair 4 poor	2 wound infection Metalware problems 10	1 acute, 16 acute-on-chronic, 6 chronic. 0 mild, 0 moderate, 23 severe
Velasco (Velasco et al. [41])	PO	65	66	6	8			22 good 16 moderate (fair) 10 poor		8 acute, 29 acute-on-chronic, 29 chronic. All moderate or severe (although table II showed that angles $<30°$ in 5 hips) Full set data in 48 hips

Total			545	63	51			131 (28 %) excellent 210 (45 %) good 46 (10 %) fair 72 (16 %) poor 3 (6 %) failure		
Ganz Surgical Dislocation										
Madan (Madan et al. [42])	PO/G	11	11	0	1	NR	NR	HHS (90.3) NAHS(91.0)		17 unstable hips were excluded (4 AVN) 0 acute, 0 acute-on-chronic, 11 chronic. 3 had previous operations
Masse (Masse et al. [43])	PO/G	18	18	0	0		0	HHS (98.2) 18 excellent 0 good 0 fair 0 poor 0 failure	1 metalware problem	2 unstable hips excluded (no AVN) 2mild, 4 moderate, 12 severe
Novais (Novais et al. [28])	PO/G	15	15	1	NR	NR	NR	HHC 7 excellent 2 good 0 fair 5 poor 1 failure	2 metalware problems	
Souder (Souder et al. [29])	PO/G	NR	10	2	1	NR	NR	NR	1 metalware problems	From a total of 17 hips, 7 were unstable, 2 of these unstable hips went into AVN
Ziebarth (Ziebarth et al. [44])	PO/G	27	27	0	0	1		HHS (96.5) 27 excellent 0 good 0 fair 0 poor 0 failure		25 patients from series A and 2 from series B. 5 unstable/uncertain hips excluded 0mild, 15 moderate, 12 severe
Total			81	3	2			HHS (95) 52 (87 %) excellent 2 (3 %) good 0 (0 %) fair 5 (8 %) poor 1 (2 %) failure		

(continued)

Table 6.2 (continued)

Study	Rx	Patients	Hips	AVN	CL	FAI	OA	Patient satisfaction	Others	Notes
Base of Neck Osteotomy										
Abraham (Abraham et al. [45])	BNO	32	36	0	5	NR	NR	MSC 22 excellent 11 good 2 fair 2poor	5 metalware problems	0 mild, 14 moderate, 22 severe
Kramer (Kramer et al. [46])	BNO	55	56	2	1	NR	NR	NR	5 infections (1required arthrodesis) 2 metalware problems 1 needed distal transfer of the greater trochanter to increase abductor power.	Authors attributed the AVN to falls that patients had. All moderate and severe
Total		87	92	2	6	NA	NA	MSC 22 (60 %) excellent 11 (30 %) good 2 (5 %) fair 2 (5 %) poor		
Intertrochanteric Osteotomy										
Ireland [47]	ITO	32	35	0	NR	NR	4	28good 5fair 2poor		All severe
Kartenbender (Kartenbender et al. [48])	ITO	35	39	2	NR	NR	3	MSC 10 excellent 17 good 7fair 4poor		All severe
Parsch (Parsch et al. [49])	ITO	130	130	1	3	NR	NR	IHS Group A + B (96 hips) 67 Excellent 24 Good 3fair 4 poor Groups C HIS 93.9	8 femoral fractures	0 mild, 111 moderate, 19 severe Authors defined the series into 3 cohorts: A (47 hips; 40 moderate), B (49 hips; 40 moderate) and C (34 hips; 31 moderate). These combined together in this paper
Rao (Rao et al. [50])	ITO	27	29	0	1			MSC 23 excellent 0 good 3fair 1 poor	2 wound infection 1delayed union 1 hip subluxation However, the patient was asymptomatic	0 mild, 10 moderate, 19 severe

Salvati (Salvati et al. [51])	ITO	21	24	1	6	NR	NR	NR	1 infection 1 loss of fixation 1 delayed union 1bone cyst	All severe slips
Schai (Schai et al. [52])	ITO	51	51	1	NR	NR	7	Jerre Criteria 31 good 15 fair 5poor		All moderate (slip angle >30° < 60°)
Southwick [53]	ITO	26	28	0	6	NR	NR	21 excellent 5 good 2 fair 0poor	1 infection 3 further operations	All moderate and severe
		290	336	5	16			121 (44 %) excellent 105 (38 %) good 35 (13 %) fair 15 (5 %) poor		

AVN avascualr necrosis, *BNO* base of neck osteotomy, *CL* chondrolysis, *CRIF* closed reduction and internal fixation, *NR* not reported or suboptimum reporting to provide useful information, *HHS* harris hip score or modified Harris hip score; Excellent 90 to 100 points; good 80 to 89 points; fair 70 to 79 points; and poor <70 points, *HHC* heyman and herndon classification, *ITO* inter-trochanteric or peri-trochnateric osteotomy, *PO* physeal osteotomy, *IH* iowa hip-rating system. Excellent 90 to 100 points; good 80 to 89 points; fair 70 to 79 points; and poor <70 points, *MSC* modified Southwick criteria, *NAHS* non Arthritic Hip scores chanteric flip osteotomy and anterior capsulotomy preserving the blood supply to the femoral head. Although the technique has similarities to the Dunn's osteotomy [36], hence it is also called the modified Dunn osteotomy, it poses less risk to femoral head blood supply. Six studies (81 hips) assessed the outcomes of surgical dislocation in stable slip. The crude AVN rate and CL were 3.7 % and 2.5 % respectively. Ninety percent had excellent to good results. The Harris hip score (HHS) [56] was the commonest score used in these studies and the mean was 95 points. These are promising preliminary results; however, most experts in the technique express a long learning curve and good results have not been reproduced in every centre (Alves et al. [57]).

What Is the Best Treatment for Unstable Sufe?

In his classic paper, Loder coined the term of "unstable slip". He recognized two types of slips: unstable one where the patient has such severe pain that walking is not possible even with crutches, regardless of the duration of the symptoms and stable slips where the patient can walk with or without crutches. However, this has been misquoted and misapplied in several studies.

Treatment of unstable slip is essentially the same for stable slips; however, there are two important issues to consider:

1. Being unstable, there is an opportunity for spontaneous or unintentional reduction of the severity of the slip.
2. The risk for AVN is very high (50 %). It is interesting how this high risk of AVN influences surgeons' choices differently; some adopted a minimum intervention (PIS) to prevent this risk from going up while others advocated an aggressive approach (open reduction of the slip) to reduce this high risk of AVN.

An extensive literature search revealed 23 studies that provide useful data on the outcome of unstable slips. The studies are summarised in Table 6.3. The crude AVN rates are shown in Table 6.4. The AVN rates as a surrogate for bad outcomes are comparable among various interventions with the exceptions of open reduction and internal fixation which has the lowest AVN rate of 5 %.

Eight four patients with unstable slips were treated with gentle open reduction and fixation within 24 h of the presentation. Four (5 %) only developed AVN. It is of note that this finding was heavily driven by one study (Parsch et al. [58]) of 64 patient and 3 only developed AVN. However, excluding the data of the study did not change the fact that AVN rate was significantly lower in the open reduction and internal fixation group.

The true definition of slip instability has been debated and not yet been satisfactorily defined or agreed on. Ziebarth (Ziebarth et al. [59]) found that clinical stability of SUFE as defined by Loder does not correlate with intra-operative stability. They retrospectively reviewed 82 patients with SUFE treated by open surgery and introduce the concept of "intra-operative stability" which is either intact or disrupted. They found complete physeal disruption at open surgery in 28 of the 82 hips (34 %). With classification as acute, acute-on-chronic, and chronic, the sensitivity for disrupted physes was 82 % and the specificity was 44 %. With the classification of Loder (stable and unstable) the values were 39 % and 76 %, respectively.

Kallio (Kallio et al. [60, 61]) stated that a stable slip should imply an adherent physis during weight-bearing, active leg movements, or gentle joint manipulation. Physeal instability implies that the displaced epiphysis can move in relation to the metaphysis. In a study of 55 SUFEs, he found that physeal instability is better indicated by joint effusion and inability to bear weight. A slip is very unlikely to be unstable in a child who is able to bear weight and has no sonographic effusion. This uncertainty about the definition of instability should be considered when reading the above results.

How Soon Should We Treat Slipped Upper Femoral Epiphysis?

This question is probably more relevant to unstable slips rather than stable because of the low AVN rate in stable slip. The timing of surgery in unstable slip remains controversial. Given the rarity of the condition, most studies that investigated the timing of surgery and outcome are underpowered to answer such a question. Lowndes et al. [8] in a meta-analysis of 5 studies (130 unstable SUFEs; 56 were treated within 24 h and 74 were treated after 24 h of symptoms onset) found that the odds for developing AVN if treatment occurs within 24 h were half if treatment occurs after 24 h. Although the difference was large, it was not statistically significant (P = 0.44) and may be a chance finding.

Peterson et al. ([62])showed early stabilisation within 24 h was associated with less AVN (3/42 = 7 %) in comparison with those stabilised after 24 h (10/49 = 20 %). Kalogrianitis et al. ([63])showed that AVN developed in 50 % (8/16) of the unstable SUFE in their series. All but one were treated between 24 and 72 h after symptom onset. They recommend immediate stabilization of unstable slips presenting within 24 h. If this is not possible, then delaying the operation until at least a week has elapsed. In contradiction, Loder [5] noted more AVN in patients treated within 48 h (7/8 versus 7/21).

Our findings supported Kalogrianitis's findings; there were 210 patients with unstable slips who had their operation within 24 h. Twenty eight (13 %) developed AVN in comparison to (38/95) 40 % and (5/53) 9 % for those who had their operation between 24 and 72 h and those who had their operation after 72 h respectively.

Table 6.3 Studies of various interventions in unstable slips

Study	Hips	Rx	Time	R	Type of reduction	AVN	CL	Others	Notes
Alshryda (Alshryda et al. [7])	22	7 PIS	> 48 h	Y	Spontaneous	2			Severity (2:2:3)
		15 PO (Fish)	> 48 h	Y	OR	5		2 loss of fixation Hip dislocation	Severity (0:1:14)
Alves (Alves et al. [57])	12	6 CRIF	24.3 h (±7.9 h)	Y	CR	2			Severity (1:3:1)
		6 PO/G	22.2 h (±7.9 h)	Y	OR	4			Severity (2:2:?)
Aronson [75]	15	9 CRIF	<24 h	Y	CR	2			All patients went on traction.
		6 ORIF	<24 h	Y	OR	0			All patients went on traction. Authors described a new controlled open reduction and stabilisation using 2 screws
Biring (Biring et al. [76])	25	PO	NR	Y	OR	3		4 Chondrolysis	
Chen (Chen et al. [77])	30	CRIF	<24 h	Y	CR	4	1	1 slip progression	Severity (13:9:8) + 16 percutaneous, 5 open capsulotomy
Fallath [78]	14	CRIF	28 h (range 3.5–72 h).	Y	2 spontaneous, 9 CR 2 PIS	3			10 single screw, 3 Knowles pin, 1 two screws 7acute and 7 acute-on-chronic All AVN in the CR group; fixed with a single screw and duration of symptoms (72, 19 and 36 h)
Gordon (Gordon et al. [79])	16	12 CRIF	7 < 24 h 3 < 72 h	Y	CR	2			Severity (2:4:6) 1 AVN within 24 h and another 168 h
		4 ORIF	<24 h		4 OR	0			Severity (0:4:0) All patients had capsulotomy and 2 screws
Kalogrianitis (Kalogrianitis et al. [63])	16	14 PIS 2PO	5 < 24 h 7 > 24 < 72 h 3 > 8 days	Y	Spontaneous	8			5 < 24 h (1 AVN) 7 > 24 < 72 h (7 AVN) 3 > 8 days (no AVN) No AVN in PO Severity (2:6:8) 10 acute and 6 acute-on-chronic 6 AVN are type III and 2 type II
Kennedy (Kennedy et al. [80])	27	18 pinning	Traction ranged from <24 h to 6 days	Y	1 Spontaneous 14 CR 3PIS	2			19 two screws, 7 single screw, 1 AVN in a mild and the second is in a severe one. Both had traction of <24 h
		9 ORIF		Y	9 OR	2			1 AVN had a failed PIS which was treated with OR and osteotomy. It was moderate slip. The second AVN was severe

(continued)

Table 6.3 (continued)

Study	Hips	Rx	Time	R	Type of reduction	AVN	CL	Others	Notes
Lim (Lim et al. [27])	24	13 PIS	Traction for 6 days	N	PIS	1			All acute or acute on chronic
		11 CRIF	11	Y	CR	1			2 of the 14 hips were stable but not clear which group Severity (16:7:1)
Loder (Loder et al. [5])	30	26 CRIF	4 ± 3.8 d		4 PIS 26 CR	14			17 acute or 13 acute on chronic Severity (2:9:19) AVN group from presentation to operation was (2 ± 1.8 d) and for non AVN groups (6 + 3.8d) (P = 0.0004). AVN (4/5 hips) that were operated within 24 h and (10/25) were operated after 24 h. AVN (7/8 hips) that were operated within 48 h and (7/22) were operated after 48 h.
Madan (Madan et al. [42])	17	17 PO/G	Traction 11 days	Y	OR	4			9 acute, 8 acute-on-chronic All severe
Palocaren (Palocaren et al. [81])	27	PIS	16 < 24 h 3 < 48 h 3 < 72 5 > 120 h		Spontaneous PIS	6			16 < 24 h (4 AVN) 3 < 48 h (1 AVN) 3 < 72 (1 AVN) 5 > 120 h
Parsch (Parsch et al. [58])	64	64 ORIF	49 < 24 h 15 > 224 h	Y	OR	3		4 metalware problems	Severity (20:24:20) AVN1 (moderate slip, within 24 h), AVN2 (severe slip, > 24 h) AVN3 (severe slip, > 24 h)
Peterson (Peterson et al. [62])	91	91 CR	42 < 24 h 12 > 24 < 48 h 7 > 48 < 72 h 30 > 72 h		41 CRIF 4 spica 31 Epi + spica 15 Epi + IF	13			42 < 24 h (3 AVN) 12 > 24 < 48 h (3 AVN) 7 > 48 < 72 h (4 AVN) 30 > 72 h (3 AVN) 41 CRIF (4 AVN) 4 spica (3 AVN) 31 Epi + spica (2 AVN) 15 Epi + IF (4 AVN) Severity (5:67:19)
Phillips (Phillips et al. [82])	14	12 CRIF 2 PO	<24		12 CRIF 2 PO	0			Severity (0:3:11)
Rao (Rao et al. [16])	18	Epi	4 > 2w traction		OR	1		1 Chondrolysis	Severity (6:7:5) AVN in moderate
Rhoad (Rhoad et al. [83])	10	Pinning	NR	R	8 Spontaneous 2 PIS	5		1 Chondrolysis (and AVN in same patinets) in PIS group	2 PIS (1 AVN)

Sankar (Sankar et al. [84])	70	16 PIS	40 < 24 h 12 < 24 > 48 h 18 > 48	N		3			40 < 24 h (10 AVN) 12 < 24 > 48 h (2 AVN) 18 > 48 (2 AVN)
		38 CRIF		Y	Spontaneous	10			
		8 PO		Y	OR	1			
		8 PO/G		Y	OR	0			Excluded from the final count as some may be a duplicate Sankar's study (Sankar, Vanderhave et al. 2013)
Sankar (Sankar et al. [85])	27	PO/G	20 < 24 h 4 < 48 h 3 > 72 h 35.9 h (Range, 6 to 184 h).	R	27 OR	7		4 metalware problems	20 < 24 h (4 AVN) 4 < 48 h (2AVN) 3 > 72 h (1AVN)
Seller (Seller et al. [86])	29	MPF	<48 h	Y	CR	2		1 Chondrolysis 8 outgrow fixation 4 subtrochanteric osteotomy	
Souder (Souder et al. [29])	14	7 PIS	NR	N		3			
		7 PO/G	NR	Y	OR	2			
Tokmakova (Tokmakova et al. [87])	36	Pinning	NR		21 reduced. 15 unclear	21			Severity (8:20:8) 1 AVN in mild slip 14 AVN in moderate slips 6 AVN in severe slip All AVN patients had reduction 8 in acute slips and 13 in chronic slip
Ziebarth (Ziebarth et al. [44])	12	PG/O	NR	Y	OR	0		0 Chondrolysis	Severity (3:3:4:2)

Table 6.4 Pooled summary of studies of unstable slips treatments

Interventions	Hips	AVN (%)
Epiphysiodesis	64	7 (11 %)
Pinning in situ	115	38(33 %)
Closed reduction and pinning	269	71(26 %)
Open reduction and internal fixation	84	4 (5 %)
Physeal osteotomies (Dunn's or Fish)	59	10 (17 %)
Ganz surgical dislocation	70	13(18 %)
Total	661	143 (22 %)

Should We Treat the Contralateral Non Slipped, Asymptomatic Side?

This is also controversial. One of the main the reason for this controversy is the uncertainty about the incidence of the contralateral slip. The quoted risk of contralateral slip varies from 18 % to 60 %. Jerre (Jerre et al. [39]) reviewed 100 patients treated for SUFE to evaluate the incidence of bilateral slipping of the epiphysis at an average follow-up time of 32 years. Fifty nine patients (59 %) were judged to have had a previous bilateral SCFE; in 42 of these 59 patients (71 %), slipping of the contralateral hip was asymptomatic. In 23 patients (23 %), the diagnosis of bilateral slipping was established at primary admission, in 18 (18 %) later during adolescence, and in 18 (18 %) not until the patients were reexamined as adults and the primary radiographs were reviewed. He concluded that the incidence of bilateral slipping of the epiphysis in patients with SCFE is approximately 60 % in Sweden.

In another long term study of 155 slips by Carney (Carney et al. [13]) the slip was bilateral in 31 patients (25 %). In 14/31patients both hips were symptomatic at presentation. The rest apart from one developed within one year.

Stasikelis et al. [64] performed a retrospective review 50 children who had unilateral SUFE to determine parameters that predict the later development of a contralateral slip. They found that the modified Oxford bone age was strongly correlated with the risk of development of a contralateral slip; contralateral slip developed in 85 % of patients with a score of 16, in 11 % of patients with a score of 21, and in no patient with a score of 22 or more. The modified Oxford bone age is based on appearance and fusion of the iliac apophysis, femoral capital physis, greater and lesser trochanters. Recently, calcaneal scoring (Nicholson et al. [65]) was used to predict an elevated risk of contralateral SUFE. The obvious disadvantage is the need for a calcaneal x-ray.

A recent paper (Phillips et al. [66]) examined the posterior slope angle (PSA) in 132 patients as a predictive for developing a contralateral slip. The mean was 17.2° ± 5.6° in 42 patients who had subsequently developed a contralateral slip, which was significantly higher (P = 0.001) than that of 10.8° ± 4.2° for the 90 patients who had had a unilateral slip. If a posterior sloping angle of 14° were used as an indication for prophylactic fixation, 35 (of 42 = 83.3 %) would have been prevented, and 19 (of 90 = 21.1 %) would have been pinned unnecessarily (Fig. 6.4).

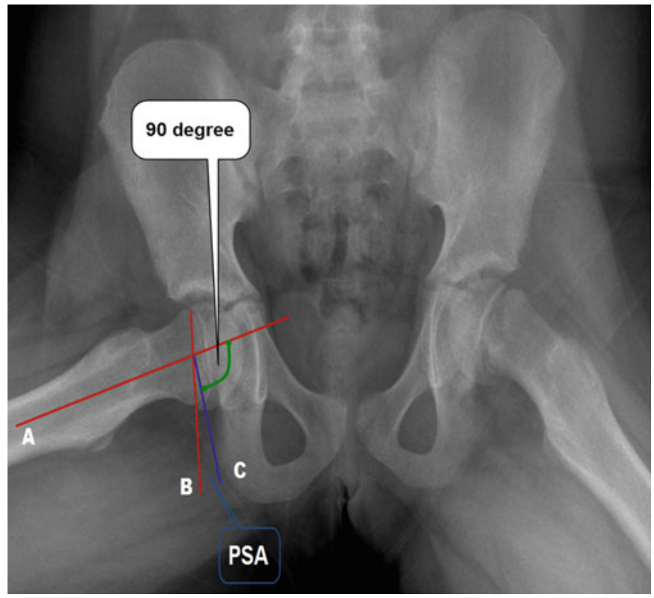

Fig. 6.4 Posterior slope angle. The posterior sloping angle (*PSA*) measured by a line (*A*) from the center of the femoral shaft through the center of the metaphysis. A second line (*B*) is drawn from one edge of the physis to the other, which represents the angle of the physis. Where lines *A* and *B* intersect, a line (*C*) is drawn perpendicular to line *A*. The *PSA* is the angle formed by lines *B* and *C* posteriorly as illustrated

Prophylactic pinning is not devoid of risk and it should be weighed against the benefit. The proponents and opponents have some evidence to support their views (Jerre et al. [67]; Sankar et al. [68]; Clement et al. [69]). Most studies showed that the average risk of contralateral lateral slip is around 18 % (Larson et al. [70]; Baghdadi et al. [71]). Most were mild slips and when treated they rarely went to develop AVN. Risk of prophylactic pinning is in the region of 5 % including AVN and peri-prosthetic fractures (Sankar et al. [68]; Baghdadi et al. [71]; Kroin et al. [72]).

We recommend a pragmatic approach for contralateral pinning where the following factors play a role in decision making:

1. Age of the child (<10 years is associated with a higher risk of bilaterality).
2. Slips associated with renal osteodystrophy and endocrine disorders (a high incidence of bilaterality)

3. Poor compliance of the child and family.
4. The nature of current slip (very bad slip occurred over a very short period of time may justify pinning the other side)

What Are the Natural History and Long Term Outcomes of Slipped Upper Femoral Epiphysis?

Natural history is the usual course of development of a disease or condition, especially in the absence of treatment. This is difficult to establish in SUFE simply because most published series reported patients who were treated. There were a few cross sectional studies that reported on the outcomes of what were presumed as untreated slips. Even if these were true slips, they were probably mild stable slips that would pursue a different natural course from most other slips. Most studies used AVN as a surrogate for bad outcome. Although AVN is rare in stable slips, bad outcome is not uncommon in severe stable slips. Larson et al. [73] reviewed 33,000 hip replacement performed in their centre between 1954 and 2007 and found SUFE was the indication in 38 hips (in 33 patients). The main reasons for hip replacement in this subset were AVN or chondrolysis in 25 hips and degenerative changes and/or impingement in 13 hips. All slips underwent either pin fixation (27) or primary osteotomy (9). Mean time from slip to hip replacement was 7.4 years in patients with AVN or chondrolysis and 23.6 years in patients with degenerative change ($P < 0.0002$). Mean age at arthroplasty was 20 years in the AVN or chondrolysis group and 38 years in the degenerative group ($P < 0.0001$). Sixteen hips (42 %) required revision arthroplasty at a mean of 11.6 years postoperatively, most commonly for component loosening and/or polyethylene wear. Kaplan Meier 5-year survival free from revision for all causes was 87 % overall and 95 % in the total hip arthroplasty subset.

Carney [74] published a series of 31 untreated chronic SUFE with a long term follow-up (ranged from 26 to 54 years). Authors stated the reasons for no treatments were not always clear from the medical records but included family refusal, delayed presentation or treating the more serious side. There were 17 mild, 11 moderate and 3 severe. The mean IHS was 89 points (92 points in mild slips, 87 points in moderate slips and 75 points in severe slips). All severe and moderate slips showed radiographic features of OA in contrast to 13 % of those with mild slip. Complications were occurred in 4 slips (1 AVN and 2 further displacements developed 3 severe slips and 1 chondrolysis in 1 mild slip.

In another series, Carney (Carney et al. [13]) reported on 155 SUFEs in 124 patients after 41 year follow up. Forty-two percent of the slips were mild; 32 % were moderate; and 26 % were severe. Various treatments methods were used (see Table 6.4). They found that there is mild deterioration that is related to the severity of the slip and complications of treatment (Fig. 6.5). Realignment was associated with a risk of substantial complications and adversely affects the natural course of the disease (Fig. 6.6).

A summary of recommendations is given in Table 6.5.

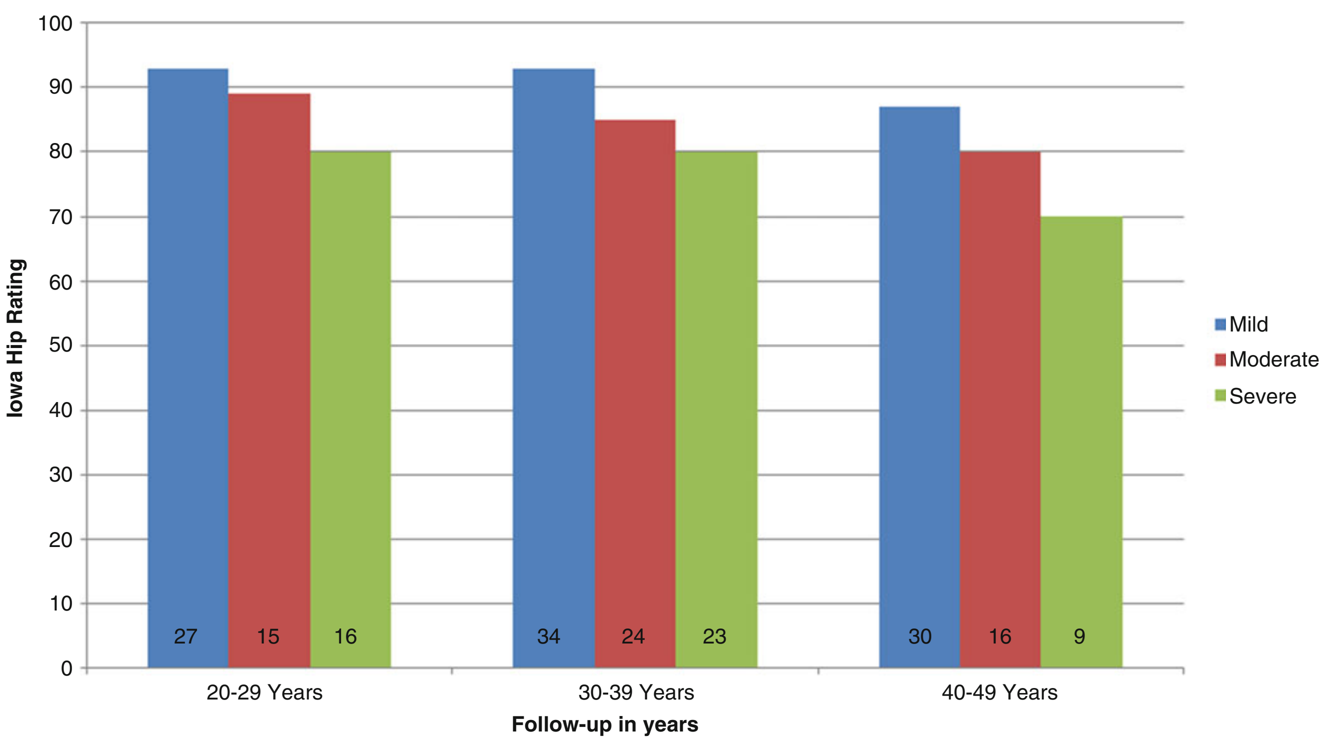

Fig. 6.5 Long-term follow-up of treated slipped upper femoral epiphysis (Adapted from Carney (Carney et al. [13]))

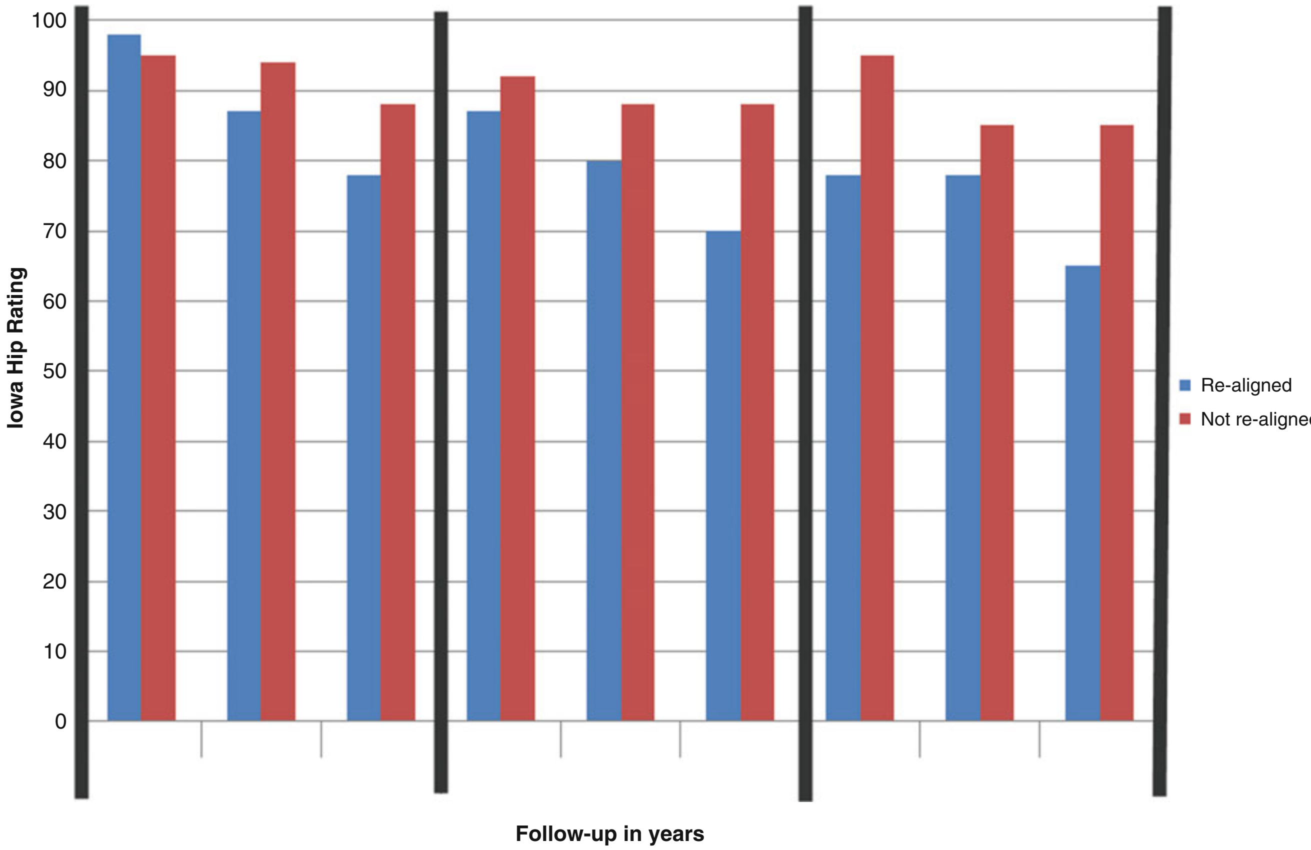

Fig. 6.6 Long-term follow-up of treated slipped upper femoral epiphysis (Adapted from Carney (Carney et al. [13]))

Table 6.5 Summary of recommendations

Clinical questions	Grade of Recommendation
Pinning in situ is the best treatment for mild and moderate stable slip.	B
Surgical dislocation may give a better results than pinning in situ for severe stable slip	C
Urgent gentle reduction, capsulotomy and fixation is the best current treatment for unstable slip	C
Routine prophylactic pinning of the contralateral asymptomatic side is not recommended	C

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