

NATIONAL INSTITUTE FOR HEALTH AND CARE EXCELLENCE

INTERVENTIONAL PROCEDURES PROGRAMME

Interventional procedure overview of open reduction of slipped capital femoral epiphysis

The capital femoral epiphysis is part of the rounded end (ball) at the top of the thigh bone (femur), which fits into the socket of the hip joint. During growth, this can slip from its normal position, causing pain, limping and deformity. Open reduction is a surgical operation to fix the slipped epiphysis back in its correct position.

Introduction

The National Institute for Health and Care Excellence (NICE) has prepared this interventional procedure (IP) overview to help members of the Interventional Procedures Advisory Committee (IPAC) make recommendations about the safety and efficacy of an interventional procedure. It is based on a rapid review of the medical literature and specialist opinion. It should not be regarded as a definitive assessment of the procedure.

Date prepared

This IP overview was prepared in March 2014.

Procedure name

- Open reduction of slipped capital femoral epiphysis

Specialist societies

- British Society for Children's Orthopaedic Surgery
- Chartered Society of Physiotherapists
- Association of Paediatric Chartered Physiotherapists
- Royal College of Paediatrics and Child Health
- British Orthopaedic Association.

Description

Indications and current treatment

The capital femoral epiphysis forms part of the ball-and-socket joint of the hip. In children and adolescents the ball and shaft of the femur are connected by a layer of soft cartilage, known as the growth plate, which allows for growth and hardens at adulthood. A slipped capital femoral epiphysis (SCFE) results in the displacement of the femoral head, usually posteriorly and inferiorly in relation to the femoral neck and within the confines of the acetabulum. This can cause knee and/or hip pain, limping and considerable deformity.

Treatment options depend on the severity of the slip. Treatment of mild-to-moderate slips usually involves percutaneous in situ fixation, with or without prophylactic pinning of the contralateral hip using cannulated screws or Kirschner wires. For more severe acute slips, treatment options include open fixation of the growth plate using a bone graft combined with early intertrochanteric osteotomy to allow a full range of hip movement, or closed reduction and in situ fixation with cannulated screws or Kirschner wires.

What the procedure involves

Open reduction of SCFE aims to relocate the capital femoral epiphysis and centre its position in the acetabulum, while minimising the risk of avascular necrosis by preserving blood vessels to the epiphysis.

The procedure can be done in a variety of ways (some with eponymous names such as the Dunn, Bernese and Ganz approaches). Most involve a cuneiform (wedge-shaped) osteotomy of the femoral neck. An important point of technique is whether or not the hip is surgically dislocated during the procedure. This is done to create an extended retinacular flap, to provide extensive subperiosteal exposure of the circumference of the femoral neck, and so protect the blood supply to the epiphysis, minimising the risk of avascular necrosis.

With the patient under general anaesthesia, an anterior or anterolateral approach is used to expose the hip and a capsulotomy is performed; at this stage, the hip may be dislocated surgically. A section of bone is then removed from the metaphysis of the femoral neck. Reduction is performed by adducting and rotating the limb, realigning the epiphysis in its normal position in the acetabulum. The realigned femoral neck is then secured with 1 or 2 cannulated screws or Kirschner wires.

Slipped capital femoral epiphysis classification

There are 3 main ways of describing SCFE:

1. Stability (Loder) classification: slips are categorised as stable or unstable:

- Stable: the patient is able to weight-bear with or without crutches.
- Unstable: the patient is unable to walk without crutches.

2. Temporal classification: slips are categorised as acute, chronic or acute-on-chronic based on the duration of symptoms.

- Acute: symptoms persist for less than 3 weeks.
- Chronic: symptoms persist for more than 3 weeks.
- Acute-on-chronic: acute exacerbation of long-standing symptoms.

3. Southwick angle classification: slips are categorised according to the difference between the femoral head-shaft angle of the affected hip and that of the contralateral hip.

- Mild: less than 30°.
- Moderate: 30° to 60°.
- Severe: more than 60°.

Outcome measures

Modified Hall and Southwick evaluation system

The modified Hall and Southwick evaluation system combines subjective outcomes, clinical assessments of mobility and radiographic imagery. Cases are graded according to the lowest of 3 categories.

Grade	Subjective	Mobility	Radiographic
Excellent	No pain or limp; full activity	>90% normal; <20° deficit in any single plane	Round head, with congruent surfaces and normal joint space
Good	Slight pain on exertion; trace of limp; full activity	75–90% normal; <40° deficit in any single plane	No congruity or joint space narrowing; no cysts; slight hump
Fair	Moderate pain on exertion; function restricted; definite limp	50–75% normal; <60° deficit in any single plane	Slight incongruity or joint space narrowing; mild degenerative change but viable head
Poor	Constant pain; severely restricted activity	<50% normal; >60° deficit in any single plane	Severe incongruity or joint space narrowing; marked degenerative disease or vascular necrosis

Harris Hip Score

The Harris Hip Score was developed to assess the results of hip surgery. The scale consists of 4 domains: pain, function, absence of deformity and range of motion. Scores range from 0 to 100 with higher scores indicating better outcomes. The 'modified Harris Hip score' omits points for range of motion and absence of deformity, resulting in a score range of 0 to 91.

Hip disability and Osteoarthritis Outcome Score

The Hip disability and Osteoarthritis Outcome Score (HOOS) was developed to assess a patient's perspective on their hip and associated problems in an adult population. The scale consists of 5 domains: pain, other symptoms, activities of daily living, function in sports and recreation, and hip-related quality of life. Scores range from 0 to 100 with higher scores indicating better outcomes.

Non-Arthritic Hip Score

The Non-Arthritic Hip Score (NAHS) is a validated disease-specific questionnaire. It consists of 20 questions and is divided into 4 domains: pain, other symptoms, physical function and participation in sports. Each item is scored from 0–4 and the scores are added together to obtain a raw score that is multiplied by 1.25 to obtain an overall hip score. Thus, overall scores range from 0 to 100 with higher scores indicating better outcomes.

The Western Ontario and McMaster Universities Arthritis Index

The Western Ontario and McMaster Universities Arthritis Index (WOMAC) is used to assess patients with osteoarthritis of the knee or hip. The Likert scale version of the questionnaire evaluates 3 domains: pain (score range 0–20); stiffness (score range 0–8) and physical function (score range 0–68). The total score ranges from 0 to 96 with lower scores indicating better outcomes. In the 100 mm visual analogue scale version of the questionnaire, scores range from 0 to 100 with lower scores indicating better outcomes.

Alpha angle

The alpha angle is a useful radiographic measurement for quantifying the head–neck junction deformity. This angle is most accurate when measured on MRI; however, it can also be measured using plain films. The alpha angle is formed by a line drawn from the centre of the femoral head through the centre of the femoral neck, and a second line from the centre of the femoral head to the femoral head/neck junction, found by the point by which the femoral neck diverges from a circle drawn around the femoral head. A normal alpha angle is approximately 45°, whereas alpha angles above 55° indicate femoro-acetabular impingement.

Literature review

Rapid review of literature

The medical literature was searched to identify studies and reviews relevant to open reduction of slipped capital femoral epiphysis. Searches were conducted of the following databases, covering the period from their commencement to 26 February 2014: MEDLINE, PREMEDLINE, EMBASE, Cochrane Library and other databases. Trial registries and the Internet were also searched. No language restriction was applied to the searches (see appendix C for details of search strategy). Relevant published studies identified during consultation or resolution that are published after this date may also be considered for inclusion.

The following selection criteria (table 1) were applied to the abstracts identified by the literature search. Where selection criteria could not be determined from the abstracts the full paper was retrieved.

Table 1 Inclusion criteria for identification of relevant studies

Characteristic	Criteria
Publication type	Clinical studies were included. Emphasis was placed on identifying good quality studies. Abstracts were excluded where no clinical outcomes were reported, or where the paper was a review, editorial, or a laboratory or animal study. Conference abstracts were also excluded because of the difficulty of appraising study methodology, unless they reported specific adverse events that were not available in the published literature.
Patient	Patients with slipped capital femoral epiphysis.
Intervention/test	Open reduction.
Outcome	Articles were retrieved if the abstract contained information relevant to the safety and/or efficacy.
Language	Non-English-language articles were excluded unless they were thought to add substantively to the English-language evidence base.

List of studies included in the IP overview

This IP overview is based on 428 patients from 9 case series.

Other studies that were considered to be relevant to the procedure but were not included in the main extraction table (table 2) have been listed in appendix A.

Table 2 Summary of key efficacy and safety findings on open reduction of slipped capital femoral epiphysis

Study 1 Broughton NS (1988)

Details

Study type	Case series
Country	United Kingdom
Recruitment period	1950 to 1984
Study population and number	Patients with severe SCFE n=110 patients; 115 hips
Age and sex	Mean male age, 14.5 years; mean female age, 12.25 years; 70% male
Patient selection criteria	Inclusion criteria: patients with severe SCFE were included. The average slip angle was 61° (range 33–90°) Exclusion criteria: not reported
Technique	Open reductions involved a cuneiform osteotomy without surgical dislocation of the hip.
Follow-up	Mean 12 years 11 months (range 2–33 years)
Conflict of interest/source of funding	Not reported

Analysis

Follow-up issues: 23 hips were followed up for more than 20 years (average 25 years 6 months).

Study design issues: All procedures were performed at the same centre. No further details were reported.

The criteria for assessing outcome were divided into 3 categories:

	Good	Fair	Poor
Subjective	No complaint, normal function	Occasional hip consciousness, full function	More than hip consciousness, some limitation of function, any secondary operation
Clinical	Normal range of movement	Flexion range $\geq 90^\circ$, no fixed deformity	Flexion $< 90^\circ$, any fixed deformity
Radiological	Good reduction; head contour, joint space and bone texture all normal	Notch or flattened head but no narrowing of joint space or progression of above changes	Narrow joint space, cysts, density changes, osteophytes or other changes

Study population issues: Study included a heterogeneous patient population: of the 115 hips reviewed, 70 were chronic with an open growth plate, 38 were acute-on-chronic and 7 were chronic with a partially fused growth plate.

Other issues: Authors did not state if surgical dislocation was performed.

Key efficacy and safety findings

Efficacy				Safety			
Number of patients analysed: 110 patients; 115 hips (70 chronic slips; 38 acute-on-chronic; 7 chronic)				Proportion of patients with complications (%) [n/N]			
Outcomes for patients with chronic slips and open growth plates (n=70)							
	Good (%) [n/N]	Fair (%) [n/N]	Poor (%) [n/N]	Chronic + open growth plate	Acute-on-chronic	Chronic + fused growth plate	
Subjective	88.6 [62/70]	1.4 [1/70]	10.0 [7/70]	Early complications			
Clinical	84.3 [59/70]	4.3 [3/70]	11.4 [8/70]	AVN alone (%) [n/N]	2.9 [2/70]	15.8 [6/38]	14.3 [1/7]
Radiological	71.4 [50/70]	14.3 [10/70]	14.3 [10/70]	AVN and chondrolysis ^a (%) [n/N]	1.4 [1/70]	7.9 [3/38]	14.3 [1/7]
Outcomes for patients with acute-on-chronic slips (n=38)				Chondrolysis alone ^b (%) [n/N]	7.1 [5/70]	2.6 [1/38]	42.9 [3/7]
	Good (%) [n/N]	Fair (%) [n/N]	Poor (%) [n/N]	Subluxation after trivial injury (%) [n/N]	1.4 [1/70]	0	0
Subjective	73.7 [28/38]	13.2 [5/38]	13.2 [5/38]	Overall early complication rate (%) [n/N]	12.9 [9/70]	26.3 [10/38]	71.4 [5/7]
Clinical	71.1 [27/38]	13.2 [5/38]	15.8 [6/38]	Late complications			
Radiological	55.3 [21/38]	18.4 [7/38]	26.3 [10/38]	Osteoarthritis (%) [n/N]	1.4 [1/70]	2.6 [1/38]	14.3 [1/7]
Outcomes for patients with chronic slips and partially fused growth plates (n=7)				Osteoarthritis after acetabuloplasty (%) [n/N]	1.4 [1/70]	0	0
	Good (%) [n/N]	Fair (%) [n/N]	Poor (%) [n/N]	Overall late complication rate (%) [n/N]	2.8 [2/70]	2.6 [1/38]	14.3 [1/7]
Subjective	28.6 [2/7]	14.3 [1/7]	57.1 [4/7]	^a 2 out of the 5 hips with AVN and chondrolysis were arthrodesed 3 years postoperatively, whereas 3 became symptomatic degenerative hips: 1 patient had a total hip replacement at 21 years postoperatively.			
Clinical	14.3 [1/7]	14.3 [1/7]	71.4 [5/7]	^b Degenerative changes were reported in 88% (8/9) of hips with chondrolysis-alone; 7 of these hips exhibited significant symptoms.			
Radiological	14.3 [1/7]	0 [0]	85.7 [6/7]	Hip pain was observed in 2.9% (2/70) of patients with chronic slips and open growth plates at follow-up; however, no clinical or radiographic abnormalities were identified (time not reported).			
				Hip pain was observed in 5.3% (2/38) of patients with acute-on-chronic slips at follow-up; however, no clinical or radiographic abnormalities were identified (time not reported).			
Abbreviations used: AVN, avascular necrosis; SCFE, slipped capital femoral epiphysis							

Study 2 Velasco R (1997)

Details

Study type	Case series
Country	Switzerland
Recruitment period	1958 to 1992
Study population and number	Patients with moderate to severe SCFE n=65 patients (66 hips)
Age and sex	Mean male age, 14.2 years; mean female, age 12.2 years; 59% male
Patient selection criteria	Inclusion criteria: patients with epiphyseal gliding angles graded moderate to severe were included. Exclusion criteria: not reported
Technique	60 hips were treated by cuneiform osteotomy without surgical dislocation of the hip. In 6 patients, the reduction of the femoral head was achieved without wedge resection of the femoral neck. Patients were admitted immediately and kept on bed rest until the next available time in the operating schedule. Hips were stabilised with 3 Kirschner nails introduced along the femoral neck. Postoperatively the leg was kept in a slightly abducted position and neutral rotation using pillows. Bed rest varied according to the period of the operation: 8 months for procedures performed before 1972; 6 months for procedures performed between 1972 and 1985; 4 months for procedures performed after 1985. Pin removal was performed on average 3 years after the operation.
Follow-up	Mean 16 years
Conflict of interest/source of funding	Not reported

Analysis

Follow-up issues: 47 patients (48 hips) out of 65 patients (66 hips) were followed up for more than 10 years. No details reported on the differences between patients with long-term follow-up and those without.

Study design issues: All patients were treated at a single centre.

Postoperative results were graded by combining clinical assessments and radiological evaluations as follows:

Good result	No radiological signs of degeneration (grade 0), no pain or discomfort, unrestricted activities, free range of motion.
Moderate result	Only mild signs of degenerative hip disease (grade I), clinical complaints of fatigue, limited to strong physical activities, no restriction in daily life and work, range of motion limited to a maximum of 20° compared with the healthy side.
Poor result	Significant radiological signs of degenerative hip disease (grade II and III), limitations of daily activities, pain, range of motion decreased by >20° compared with the healthy side.

Study population issues: Study included a heterogeneous patient population: 8 slips were acute, 29 were acute-on-chronic and 29 were chronic. In 6 patients, reduction of the femoral head was achieved without wedge resection of the femoral head.

Other issues: Closed reductions were not attempted in any patients.

Key efficacy and safety findings

Efficacy	Safety										
<p>Number of patients analysed: 65 patients (66 hips)</p> <p>Clinical outcomes for patients with <10 years follow-up (18 hips):</p> <ul style="list-style-type: none"> • Good results were reported in 83% (15/18) of hips. • Moderate results were reported in 17% (3/18) of hips. • No hips were rated as poor. <p>Clinical outcomes for patients with >10 years follow-up (48 hips):</p> <ul style="list-style-type: none"> • Good results were reported in 45.8% (22/48) of hips. • Moderate results were reported in 33.3% (16/48) of hips. • Poor results were reported in 20.8% (10/48) of hips. • Equal leg lengths were reported in 45.8% (22/48) of patients at follow-up. • The average leg length discrepancy was -0.4 cm (patients with AVN were excluded). <ul style="list-style-type: none"> ○ No hips required surgical correction. 	<p>Complications observed within 12 months of surgery (66 hips):</p> <table border="1" data-bbox="865 300 1372 485"> <thead> <tr> <th>Complication rate</th> <th>% (n/N)</th> </tr> </thead> <tbody> <tr> <td>AVN alone</td> <td>3.0 (3/66)</td> </tr> <tr> <td>AVN and chondrolysis</td> <td>7.6 (5/66)</td> </tr> <tr> <td>Chondrolysis alone</td> <td>4.5 (3/66)</td> </tr> <tr> <td>Overall complication rate</td> <td>15.2 (10/66)</td> </tr> </tbody> </table> <ul style="list-style-type: none"> • All hips with early complications subsequently developed osteoarthritis: 1 hip developed grade I osteoarthritis, 2 developed grade II osteoarthritis and 7 developed grade III osteoarthritis. • Pin penetration was reported in 4.5% (3/66) of hips. • Subcutaneous wound infections were reported in 3% (2/66) of hips. • Permanent partial paralysis of the sciatic nerve was reported in 1 patient. <p>Complications observed after 10 years of surgery (48 hips):</p> <ul style="list-style-type: none"> • Osteoarthritis was reported in 39.6% (19/48) of all hips at follow-up assessment: 18.8% (9/48) of hips developed grade I osteoarthritis, 6.3% (3/48) developed grade II osteoarthritis and 14.6% (7/48) developed grade III osteoarthritis. • Further operations were required in 20.8% (10/48) of hips. These included 4 arthrodeses, 3 total hip replacements and 3 intertrochanteric correction osteotomies. 	Complication rate	% (n/N)	AVN alone	3.0 (3/66)	AVN and chondrolysis	7.6 (5/66)	Chondrolysis alone	4.5 (3/66)	Overall complication rate	15.2 (10/66)
Complication rate	% (n/N)										
AVN alone	3.0 (3/66)										
AVN and chondrolysis	7.6 (5/66)										
Chondrolysis alone	4.5 (3/66)										
Overall complication rate	15.2 (10/66)										
Abbreviations used: AVN, avascular necrosis; SCFE, slipped capital femoral epiphysis											

Study 3 Parsch K (2009)

Details

Study type	Case series
Country	Germany
Recruitment period	1983 to 2001
Study population and number	Patients with acute unstable SCFE n=64 patients
Age and sex	Range 8–16 years; 58% male
Patient selection criteria	Inclusion criteria: patients with acute unstable slips (confirmed by radiographic imagery) and documentation of joint effusion were included. Exclusion criteria: not reported
Technique	Authors did not explicitly state if surgical dislocation was performed: however, it is understood that open reduction was performed without dislocation of the hip. Most patients (76.6%) had emergency surgery within 24 hours of symptom onset. Patients had an anterior arthrotomy with a longitudinal capsulotomy to evacuate any joint effusion or haematoma. An initial Kirschner wire was introduced into the femoral neck, stopping before the metaphyseal border of the slip, and open reduction was performed. The previously inserted Kirschner wire was then advanced to temporarily fix the epiphysis on to the metaphysis. Subsequently, 2 or 3 additional Kirschner wires were introduced to achieve stable fixation.
Follow-up	Mean 4.9 years
Conflict of interest/source of funding	None reported: authors received no external funding

Analysis

Follow-up issues: All 64 patients were followed up for <12 months, whereas 60 of the 64 patients were followed up for >12 months; 47 were examined in person and 13 were contacted by post. Reasons were not provided for lack of long-term follow up in 4 patients. No information was provided on when outcomes were measured.

Study design issues: 8 surgeons used the same surgical protocol to perform the procedure.

Study population issues: Study population was heterogeneous in terms of the degree of slip: 20 slips were categorised as mild (<30°), 24 slips were moderate (31–50°) and 20 slips were severe (51–90°). 76.6% (49/64) of patients had surgery within 24 hours of symptom onset.

Other issues: In this study, 9 out of 20 unstable slips would have been classified as stable using the Loder classification system.

- Iowa Hip Scores – range from 0 to 100 with higher scores indicating better outcomes.
- Authors did not state if surgical dislocation was performed.

Key efficacy and safety findings

Efficacy	Safety
<p>Number of patients analysed: 64 patients</p> <ul style="list-style-type: none"> • Slips were reduced by a mean of 32°. • The mean residual slip angle was 10.6°. • The mean Iowa Hip Score for patients with long-term follow-up (>12 months) was 94.5. 	<ul style="list-style-type: none"> • The inadvertent intra-articular positioning of a Kirschner wire was reported in 10.9% (7/64) of patients. Reoperation was required in 3 of these patients. None developed AVN or chondrolysis. • Chondrolysis and AVN was reported in 4.7% (3/64) of patients: of these patients, 1 needed an intertrochanteric corrective osteotomy, whereas another patient needed an intertrochanteric corrective osteotomy followed by a cheilectomy.
<p>Abbreviations used: AVN, avascular necrosis; SCFE, slipped capital femoral epiphysis</p>	

Study 4 Ziebarth K (2009)

Details

Study type	Case series
Country	Switzerland
Recruitment period	Not reported (recruitment started in 1998)
Study population and number	Patients with varying types of SCFE n=40 patients (30 patients from institution A and 10 from institution B)
Age and sex	Institution A: age range 10–18 years; 53% male Institution B: age range 9–14 years; 10% male
Patient selection criteria	Inclusion criteria: not reported Exclusion criteria: patients with osteonecrosis and contraindications to surgery such as renal insufficiency were excluded.
Technique	All open reductions involved a cuneiform osteotomy with surgical dislocation of the hip. Patients had a transtrochanteric surgical dislocation of the hip. When stability of the physis was uncertain, in situ pinning with 2 Kirschner wires was performed before dislocation. After complete periosteal dissection of the femoral neck, the femoral head was reduced in the acetabulum. A continuous passive motion machine was used for approximately 3 weeks, postoperatively, to minimise the risk of flexion and external rotation contracture of the treated hip. Patients were allowed to perform touchdown weight-bearing for 6–8 weeks. Implant removal was performed between 6 months and 1 year postoperatively.
Follow-up	Institution A: mean 5.4 years Institution B: mean 2.2 years
Conflict of interest/source of funding	None reported

Analysis

Follow-up issues: No patients were lost to follow-up.

Study design issues: Ten patients were included in another study in table 2 (Upasani, 2014) Different outcome measures were collected at the 2 institutions and patient populations in each institution were noted as being dissimilar.

Study population issues: The study populations were heterogeneous in relation to the stability and severity of SCFEs, as well as the duration of symptoms.

Other issues:

- Alpha angle – a normal alpha angle is approximately 45°.
- Harris Hip Score – scores range from 0 to 100 with higher scores indicating better outcomes.
- WOMAC score – lower scores indicate better outcomes.
- Merle d'Aubigné–Postel score for hip function – scores range from 3 to 18 with higher scores indicating better outcomes.

Key efficacy and safety findings

Efficacy	Safety
<p>Number of patients analysed: 40 patients (30 in institution A, 10 in institution B)</p> <p>Institute A:</p> <ul style="list-style-type: none"> • Normal alpha angles were restored in all patients; the mean alpha angle after correction was 40.6° (range 27–60°). • The mean Merle d'Aubigné–Postel score was 17.8 for treated hips and 17.7 for untreated contralateral hips. • The mean Harris Hip Score was 99.6 for treated hips and 99.5 for untreated contralateral hips. <p>Institution B:</p> <ul style="list-style-type: none"> • Mean slip angles were corrected from 56.6° preoperatively to 8.6° postoperatively (p<0.001). • The mean WOMAC score for pain was 1.2 (scores ranged from 0 to 20 with lower scores indicating better outcomes). • The mean WOMAC score for function was 3 (scores ranged from 0 to 68 with lower scores indicating better outcomes). 	<ul style="list-style-type: none"> • No patients developed osteonecrosis, chondrolysis, infection, deep vein thrombosis or nerve palsies. • Delayed union of the femoral neck was reported in 7.5% (3/40) of patients. No further details were provided. • Heterotopic ossification was reported in 7.5% (3/40) of patients. No further details were provided. • Reoperation because of residual impingement from a non-spheric deformity of the epiphysis was reported in 2.5% (1/40) of patients. • Reoperation, 6 to 8 weeks after surgery, was needed in 8% (3/40) of patients because of breakage of screw or wire fixations.
Abbreviations used: SCFE, slipped capital femoral epiphysis; WOMAC, Western Ontario and McMaster Universities Arthritis Index.	

Study 5 Madan SS (2013)

Details

Study type	Case series
Country	United Kingdom
Recruitment period	October 2004 to October 2010
Study population and number	Patients with severe SCFE n=28
Age and sex	Mean age 12.9 years; 50% male
Patient selection criteria	Inclusion criteria: Patients with severe SCFE with a lateral slip angle >50° measured either on the frog leg lateral view or in the oblique plane, were included. Exclusion criteria: not reported.
Technique	All open reductions involved a cuneiform osteotomy with surgical dislocation of the hip. Patients with unstable hips were placed on traction for a mean of 11 days. Patients with closed physis were admitted on the day of surgery. Open reduction was performed in patients with unstable epiphyses. If necessary, a shortening osteotomy of the femoral neck was performed to facilitate a tension-free reduction. In chronic cases, the callus was resected and a sub-capital realignment was performed. If the growth plate had healed, a sub-capital osteotomy was performed. The femoral head was reduced onto the neck and two 6.5 mm cannulated screws used to secure the head. Postoperatively, patients were allowed to perform touchdown weight-bearing on the operated side for 6 weeks and advised to avoid active abduction, internal rotation and passive external rotation. Radiographs were used for assessment.
Follow-up	Mean 38.6 months
Conflict of interest/source of funding	None reported

Analysis

Follow-up issues: One patient was lost to follow-up at 36 months; however, their outcome scores were included in the analyses.

Study design issues: All procedures performed by a single surgeon. The type of procedure performed depended on the stability of the slip and whether the slip was acute or chronic (see above).

Study population issues: Study included a heterogeneous patient population: study included slips of mixed stability (17 unstable; 11 stable based on the Loder classification); 5 patients had had previous surgery at another centre; 4 patients had closed growth plates; 2 participants had pre-existing avascular necrosis.

Other issues: 10 additional procedures were performed during surgery. These included pinning of the contralateral hip, hinged distraction of the hip, pelvic support osteotomy, debridement of a labral tear and contralateral epiphysiodesis. The table for radiological findings is presented as reported by the authors; it is unclear what the reported p values are referring to because the authors did not provide any additional information.

- Modified Harris Hip Score – scores range from 0 to 91 with higher scores indicating better outcomes.
- Non-Arthritic Hip Score – scores range from 0 to 100 with higher scores indicating better outcomes.
- HOOS – scores range from 0 to 100 with higher scores indicating better outcomes.

Key efficacy and safety findings

Efficacy						Safety	
Number of patients analysed: 28 (17 unstable, 11 stable)						<ul style="list-style-type: none"> AVN was reported in 11.7% (2/17) of patients with unstable SCFE and 0% of patients with stable slips. Of the 4 patients that exhibited AVN (2 diagnosed preoperatively and 2 postoperatively), 3 required arthrodiastasis via hinged distractor and 1 required a pelvic support osteotomy. Three of these patients had good outcomes. Authors did not specify which of these patients were diagnosed with AVN postoperatively. Chondrolysis was reported in 1 patient with an unstable severe slip. No postoperative infections, deep vein thrombosis, nerve palsy, heterotrophic ossification, implant failures or reoperations were reported. 	
Radiological findings on slip angle							
Slip angle		Mean±SD	95% CI	p value			
Lateral slip angle	Preoperative	59±11.6	52.1–65.0	<0.001			
	Postoperative	8±7.9	3.6–11.3	0.001			
Anteroposterior slip angle	Preoperative	33±17.9	23.9–41.8	<0.001			
	Postoperative	2±2.2	0.9–3.0	0.001			
Oblique plane angle		82±12.3	75.0–89.2	<0.001			
Correction	Lateral	51±11.9	44.3–57.5	<0.001			
	Anteroposterior	31±17.8	22.3–40.0	<0.001			
Mean modified Harris Hip scores and NAHS scores							
Score		Mean (SD)				Mean improvement (95% CI)	p value
		Preoperative	6 months	12 months	Latest		
MHHS	Unstable	5.8±10.6	80.9±18.0	78.6±25.8	88.2±10.9	82.3 (73.7–90.9)	<0.001
	Stable	39.7±10.5	68.4±34.1	84.2±16.7	90.3±6.1	50.5 (43.9–57.1)	<0.001
	Overall	19.6±19.8	76.7±24.3	80.3±22.8	89.1±9.0	68.3 (60.0–76.8)	<0.001
NAHS	Unstable	9.0±16.6	78.1±21.6	85.5±24.6	91.5±8.9	81.9 (70.9–93.0)	<0.001
	Stable	41.9±8.1	89.6±5.7	94.6±0.72	91.0±7.3	49.2 (41.4–56.9)	<0.001
	Overall	22.4±21.3	81.7±18.8	87.6±21.7	91.3±8.0	68.1 (58.6–77.6)	<0.001
<p>MHHS: 16 patients had an excellent result (MHHS>90), 8 patients had a good result (MHHS 80–90) and 3 patients had a fair result (MHHS 70–80); 1 patient had a MHHS of 63.8.</p> <p>NAHS: 18 patients had an excellent result, 6 had a good result and 4 had a fair result (range of scores in each category not reported).</p>							
Mean improvements in HOOS scores							
HOOS subscore		Mean improvement (95% CI)		p value			
Pain	Unstable	78.6 (66.3–90.8)		<0.001			
	Stable	45.7 (36.6–54.7)		<0.001			
	Overall	64.1 (54.0–74.2)		<0.001			
Symptoms	Unstable	78.0 (66.6–89.4)		<0.001			
	Stable	48.6 (29.6–67.6)		<0.001			
	Overall	64.9 (54.0–72.9)		<0.001			
Activities of daily living	Unstable	78.5 (65.4–91.6)		<0.001			
	Stable	40.9 (32.7–49.2)		<0.001			
	Overall	62.0 (51.0–73.0)		<0.001			
Sports	Unstable	n/a					
	Stable	58.1 (45.5–70.8)		<0.001			
	Overall	n/a					
Quality of Life	Unstable	74.8 (64.6–85.0)		<0.001			
	Stable	51.4 (34.5–68.2)		<0.001			
	Overall	64.5 (54.6–74.4)		<0.001			
<p>Abbreviations used: AVN, avascular necrosis; CI, confidence interval; HOOS, Hip disability and Osteoarthritis Outcome scores; MHHS, Modified Harris Hip Score; NAHS, Non-Arthritic Hip Score; SCFE, slipped capital femoral epiphysis; SD, standard deviation.</p>							

Study 6 Huber H (2011)

Details

Study type	Case series
Country	Switzerland
Recruitment period	June 2001 to November 2008
Study population and number	Patients with varying types of SCFE n=28 patients; 30 hips
Age and sex	Mean age, 12.2 years; 39.3% male
Patient selection criteria	Not reported
Technique	All open reductions involved a cuneiform osteotomy with surgical dislocation of the hip. 'Anatomical or near anatomical reductions were achieved in all cases.' If stability was in doubt, then a Kirschner wire was used for provisional fixing. Definitive fixation was achieved using 2 cortical screws or 3 Kirschner wires. In more recent cases, physiotherapy with continuous passive movement was started within 48 hours of surgery. Patients were mobilised according to their physical and cognitive abilities with crutches and touch weight-bearing. Prophylactic fixation of the contralateral hip was performed in most patients. Full weight-bearing without crutches was allowed after a mean of 12 weeks.
Follow-up	Mean 3.8 years
Conflict of interest/source of funding	Not reported

Analysis

Follow-up issues: No radiographic imagery was performed on some patients. WOMAC scores were obtained from all patients.

Study design issues: Procedures were performed by 5 different surgeons at 2 different institutions.

Study population issues: Study population was heterogeneous in relation the severity of slips; 3 mild (<30°) 17 moderate (30–50°) and 10 severe (>50°) according to the Loder classification system. No patients had had fixation in situ before the procedure. In some patients, physiotherapy with continuous passive movement was started within 48 hours of surgery

Other issues:

- Alpha angle – a normal alpha angle is approximately 45°.
- A visual analogue version of the WOMAC score was used to evaluate 3 domains (pain, stiffness and function). For each domain scores ranged from 0 to 100 with lower scores indicating better outcomes.
- Harris Hip Score – scores range from 0 to 100 with higher scores indicating better outcomes.

Key efficacy and safety findings

Efficacy	Safety
<p>Number of patients analysed: 27 patients (29 hips)</p> <p>Radiographic imagery</p> <ul style="list-style-type: none"> • Postoperative lateral radiographs showed a mean slip angle of 5.2°. • Postoperative lateral radiographs showed a mean alpha angle of 41.4°: 5 patients had an alpha angle >50°. <p>Clinical outcome measures:</p> <ul style="list-style-type: none"> • All hips showed flexion of 90° or more, at final follow-up (excluding case of AVN). • Mean internal rotation in the 90° flexed hip was 33.3° and the mean external rotation was 49.8° (excluding case of AVN). <p>Functional Scores:</p> <ul style="list-style-type: none"> • The mean postoperative Harris Hip Score was 97.8. <ul style="list-style-type: none"> ○ Excellent results were reported in 28 hips (scores≥95), whereas a poor result was reported in 1 hip (score=56). • Mean postoperative WOMAC scores were 5.9 for pain, 10.4 for stiffness and 5.7 for function. 	<ul style="list-style-type: none"> • No nerve injuries, deep wound infections or haematomas were reported in any patients. • AVN was reported in 3.7% (1/27) of patients at 6-week follow-up. • Reoperation, because of implant failures, was reported in 14.8% (4/27) of patients.
<p>Abbreviations used: AVN, avascular necrosis; SCFE, slipped capital femoral epiphysis; WOMAC, Western Ontario and McMaster Universities Arthritis Index.</p>	

Study 7 Slongo T (2010)

Details

Study type	Case series
Country	Switzerland
Recruitment period	April 2004 to June 2007
Study population and number	Patients with various types of SCFE n=23 patients
Age and sex	Median age 11.9 years; 60.9% male
Patient selection criteria	Inclusion criteria; not reported Exclusion criteria: patients who had previous surgery for SCFE were excluded.
Technique	All open reductions involved a cuneiform osteotomy with surgical dislocation of the hip. Prophylactic fixation of the contralateral hip was performed on all patients. Postoperative, partial weight-bearing with crutches was allowed, with specific instruction from the physiotherapist. A continuous passive motion machine was used postoperatively. Some patients required outpatient continuous passive motion if hip flexion of 90° could not be achieved before hospital discharge. Removal of implants was not recommended for asymptomatic patients.
Follow-up	Mean 29 months
Conflict of interest/source of funding	Not reported

Analysis

Follow-up issues: No patients lost to follow-up.

Study design issues: All procedures were performed by 1 surgeon.

Study population issues: Study population was heterogeneous in terms of stability (20 stable, 3 unstable [8 unstable intraoperatively]), type (14 acute-on-chronic, 9 chronic), severity (6 mild, 8 moderate, 9 severe) and duration of symptoms (2–224 days).

Other issues:

- Alpha angle – a normal alpha angle is approximately 45°
- Harris Hip Score – scores range from 0 to 100 with higher scores indicating better outcomes.
- Merle d'Aubigné–Postel score for hip function – scores range from 3 to 18 with higher scores indicating better outcomes.

Key efficacy and safety findings

Efficacy	Safety																						
<p>Number of patients analysed: 23 patients</p> <ul style="list-style-type: none"> Satisfactory results were reported in 86.9% (20/23) of patients. <p>Radiological results</p> <table border="1" data-bbox="81 346 836 493"> <thead> <tr> <th rowspan="2"></th> <th colspan="2">Mean±SD</th> </tr> <tr> <th>Preoperative</th> <th>Postoperative</th> </tr> </thead> <tbody> <tr> <td>Slip angle (degrees)*</td> <td>47.6±19.21</td> <td>4.6±2.91</td> </tr> <tr> <td>Alpha (degrees)</td> <td>NR</td> <td>37.5±7.36</td> </tr> </tbody> </table> <p>*Statistically significant differences were observed between preoperative and postoperative slip angles (p<0.0001).</p> <p>Clinical findings</p> <table border="1" data-bbox="81 630 836 798"> <thead> <tr> <th rowspan="2"></th> <th colspan="2">Mean±SD</th> </tr> <tr> <th>Treated hips</th> <th>Contralateral hips</th> </tr> </thead> <tbody> <tr> <td>Flexion (degrees)</td> <td>107.3±23.4</td> <td>114.8±7.3</td> </tr> <tr> <td>Internal rotation (degrees)</td> <td>37.8±13.38</td> <td>35.6 (13.67)</td> </tr> </tbody> </table> <ul style="list-style-type: none"> No statistically significant differences were observed between treated and contralateral hips (p values>0.33). No leg-length discrepancy was reported in 95.7% (22/23) of patients at follow-up. Normal muscle strength was reported in 95.7% (22/23) of patients at follow-up. The mean Harris Hip Score was 99 at follow-up. The mean Merle d'Aubigné–Postel score was 17 at follow-up. 		Mean±SD		Preoperative	Postoperative	Slip angle (degrees)*	47.6±19.21	4.6±2.91	Alpha (degrees)	NR	37.5±7.36		Mean±SD		Treated hips	Contralateral hips	Flexion (degrees)	107.3±23.4	114.8±7.3	Internal rotation (degrees)	37.8±13.38	35.6 (13.67)	<ul style="list-style-type: none"> Osteoarthritis was reported in 4.5% (1/23) of patients (severity of osteoarthritis not reported). Femoral head osteonecrosis was reported in 4.5% (1/23) of patients. Reoperation was required in 1 patient to correct a prominent Kirschner wire, approximately 6 weeks after the initial surgery.
		Mean±SD																					
	Preoperative	Postoperative																					
Slip angle (degrees)*	47.6±19.21	4.6±2.91																					
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Internal rotation (degrees)	37.8±13.38	35.6 (13.67)																					
Abbreviations used: NR, not reported; SCFE, slipped capital femoral epiphysis; SD, standard deviation.																							

Study 8 Sankar WN (2014)

Details

Study type	Case Series
Country	United States
Recruitment period	Not reported
Study population and number	Patients with unstable SCFE n=27
Age and sex	Mean age 12.6 years; 63% male
Patient selection criteria	Inclusion criteria: not reported Exclusion criteria: Patients with less than 1 year follow-up and those with underlying endocrinopathies or syndromes were excluded.
Technique	All open reductions involved a cuneiform osteotomy with surgical dislocation of the hip. Postoperative weight-bearing was protected for 6 to 8 weeks then physical therapy involving gait training and strengthening was initiated. Patients were advised to refrain from vigorous physical activity for 6 months.
Follow-up	Mean 22.3 months
Conflict of interest/source of funding	'No external funding was received for this study'.

Analysis

Follow-up issues: No patients were lost to follow-up.

Study design issues: Procedures were performed by 5 paediatric orthopaedic surgeons. The type of fixation varied according to surgeon and included threaded Kirschner wires, 4.5 mm screws and 6.5 mm cannulated screws. Four (15%) patients presented with a stable slip on the contralateral side, which was treated by in situ screw fixation. Two patients had previously had in situ fixation of a contralateral slip and 5 patients with an unaffected contralateral hip elected for prophylactic pinning.

Study population issues: none identified

Other issues:

- Pain scores – scores range from 0 to 10 with lower scores indicating less pain.
- Satisfaction scores – scores range from 0 to 100 with higher scores indicating more satisfaction.
- Modified Harris Hip Score – scores range from 0 to 91 with higher scores indicating better outcomes.
- University of California Los Angeles activity score – scores range from 0 to 10 with higher scores indicating more physical activity.

Key efficacy and safety findings

Efficacy	Safety																		
<p>Number of patients analysed: 20</p> <p>Postoperative outcomes of patients who did not develop AVN (mean, n=20)</p> <table border="1" data-bbox="94 336 771 667"> <thead> <tr> <th>Outcome measure (mean)</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>Slip angle (degrees)</td> <td>6</td> </tr> <tr> <td>Flexion (degrees)</td> <td>103</td> </tr> <tr> <td>Internal rotation in flexion (degrees)</td> <td>25</td> </tr> <tr> <td>External rotation in flexion (degrees)</td> <td>48</td> </tr> <tr> <td>Pain scores (mean)</td> <td>0.3</td> </tr> <tr> <td>Satisfaction scores</td> <td>9.71</td> </tr> <tr> <td>Modified Harris Hip Score</td> <td>88.0</td> </tr> <tr> <td>UCLA activity score</td> <td>9.3</td> </tr> </tbody> </table>	Outcome measure (mean)	Value	Slip angle (degrees)	6	Flexion (degrees)	103	Internal rotation in flexion (degrees)	25	External rotation in flexion (degrees)	48	Pain scores (mean)	0.3	Satisfaction scores	9.71	Modified Harris Hip Score	88.0	UCLA activity score	9.3	<ul style="list-style-type: none"> • AVN was reported in 26% (7/27) of patients at a mean of 21.4 weeks. • Broken implants were reported in 15% (4/27) of patients at a mean of 12.3 weeks: All these patients needed revision fixation: 1 patient developed AVN; 3 healed successfully. • Implant removal was needed in 30% (8/27) of patients: reasons for removal include joint penetration associated with AVN (n=5), core decompression for AVN (n=1), total hip arthroplasty (n=1) and revision surgical dislocation and osteoplasty for residual deformity due to AVN (n=1).
Outcome measure (mean)	Value																		
Slip angle (degrees)	6																		
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Modified Harris Hip Score	88.0																		
UCLA activity score	9.3																		
<p>Abbreviations used: AVN, avascular necrosis; SCFE, slipped capital femoral epiphysis ; UCLA, University of California Los Angeles</p>																			

Study 9 Upasani VV (2014)

Details

Study type	Case Series
Country	United States
Recruitment period	September 2001 to August 2012
Study population and number	Patients with various types of SCFE n=43
Age and sex	Mean age 12 years; 42% male
Patient selection criteria	Inclusion criteria: not reported Exclusion criteria: not reported
Technique	All open reductions involved a digastric trochanteric flip osteotomy with surgical dislocation of the hip through a z-shaped arthrotomy. Femoral head fixation varied between surgeons and over time. The greater trochanter was fixed with 2 mm or 3.5 mm screws.
Follow-up	Mean 2.6 years
Conflict of interest/source of funding	Not reported

Analysis

Follow-up issues: 3 patients were lost to follow-up.

Study design issues: 10 patients were included in another study in table 2 (Zieberth, 2014). Procedures were performed by 4 different surgeons.

Study population issues: Study population was heterogeneous in terms of stability (17 stable, 26 unstable) and type (17 acute, 15 acute-on-chronic, 11 chronic).

Other issues: none identified.

Key efficacy and safety findings

Efficacy	Safety
Authors did not report any efficacy outcome measures	<p>Number of patients analysed: 43</p> <ul style="list-style-type: none"> Overall, complications were reported in 37% (16/43) of patients at mean follow-up of 2.6 years. AVN was reported in 23% (10/43) of patients. Additional surgical procedures were needed for 7 of these patients: 4 patients needed a femoral head/neck osteochondroplasty while 3 patients needed an intertrochanteric osteotomy. End-stage degenerative disease and severe femoral head AVN was reported in 5% (2/43) of patients. Non-union of the femoral neck was reported in 9% (4/43) of patients. All patients were treated by revision surgery. Postoperative hip dislocation was reported in 5% (2/43) of patients. Symptomatic heterotrophic ossification was reported in 1 patient. A surgical wound abscess was reported in 1 patient.
Abbreviations used: AVN, avascular necrosis	

Efficacy

Functional scores

In a case series of 64 patients treated by open reduction without dislocation, the mean Iowa Hip Score (scores range from 0 to 100 with higher scores indicating better outcomes) was 94.5 at mean follow-up of 4.9 years³.

In a case series of 40 patients treated by open reduction with dislocation, mean Merle d'Aubigné–Postel scores for hip function (scores range from 3 to 18 with higher scores indicating better outcomes) were 17.8 and 17.7 for treated hips and untreated contralateral hips respectively, at mean follow-up of 5.4 years (no p values reported)⁴.

In a case series of 28 patients treated by open reduction with dislocation, mean improvements in HOOS scores (scores range from 0 to 100 with higher scores indicating better outcomes) for pain, other symptoms, activities of daily living and quality of life were 78.6, 78.0, 78.5 and 74.8 respectively, for patients with unstable slips at mean follow-up of 38.6 months (p values <0.001). No mean HOOS scores for sports were reported. In patients with stable slips, mean improvements in HOOS scores for pain, other symptoms, activities of daily living, sports and quality of life were 45.7, 48.6, 40.9, 58.1 and 51.4 respectively (p values <0.001)⁵.

Clinical assessment

In a case series of 110 patients (115 hips) treated by open reduction without dislocation, 'good' results for subjective, clinical and radiological outcomes were reported in 89% (62/70), 84% (59/70) and 71% (50/70) of hips, respectively, in hips with chronic slips and open growth plates at mean follow-up of 12 years and 11 months. In the same study, 'good' results for subjective, clinical and radiological outcomes were reported in 74% (28/38), 71% (27/38) and 55% (21/38) of hips, respectively, in hips with acute-on-chronic slips at mean follow-up of 12 years and 11 months. In hips with chronic slips and partially fused growth plates, 'good' subjective, clinical and radiological results were reported in 29% (2/7), 14% (1/7) and 14.3% (1/7) of hips respectively¹.

Correction of deformity

In a case series of 65 patients (66 hips) treated by open reduction without dislocation, 46% (22/48) of patients had equal leg lengths at minimum follow-up of 10 years².

In a case series of 23 patients treated by open reduction with dislocation, the mean preoperative slip angle was 47.6°, whereas the mean postoperative slip angle was 4.6° (p<0.0001). In the same study, the mean degrees of flexion were 107.3° in treated hips and 114.8° in contralateral hips that were prophylactically pinned, at mean follow-up of 29 months (p value not significant). The mean

degrees of internal rotation in treated hips and contralateral hips were 37.8° and 35.6° respectively at mean follow-up of 29 months (p value not significant)⁷.

Safety

Avascular necrosis and chondrolysis

AVN without chondrolysis was reported in 3% (2/70) of hips with chronic slips and open growth plates, 16% (6/38) of hips with acute-on-chronic slips, and 14% (1/7) of hips with chronic slips and fused growth plates, in a case series of 110 patients (115 hips) treated by open reduction without dislocation. In the same study AVN plus chondrolysis was reported in 1% (1/70) of hips with chronic slips and open growth plates, 8% (3/38) of hips with acute-on-chronic slips, and 14% (1/7) of hips with chronic slips and fused growth plates. Chondrolysis alone was reported in 7% (5/70) of hips with chronic slips and open growth plates, 3% (1/38) of hips with acute-on-chronic slips, and 43% (3/7) of hips with chronic slips and fused growth plates¹.

AVN was reported in 12% (2/17) of patients with unstable slips and 0% of patients with stable slips in the case series of 28 patients treated by open reduction with surgical dislocation⁵.

AVN was reported in 5% (1/23) of patients in the case series of 23 patients treated by open reduction with surgical dislocation⁷.

AVN was reported in 26% (7/27) of patients at a mean of 21.4 weeks in a case series of 27 patients treated by open reduction with surgical dislocation⁸.

Osteoarthritis

Osteoarthritis was reported in 1% (1/70), 3% (1/38) and 14% (1/7) of hips with chronic slips and open growth plates, acute-on-chronic slips, and chronic slips and fused growth plates respectively, in the case series of 110 patients (115 hips) treated by open reduction without dislocation¹.

Osteoarthritis was reported in 40% (19/48) of hips at mean follow-up of 16 years in the case series of 65 patients (66 hips) treated by open reduction without dislocation: 19% (9/48) of hips developed grade I osteoarthritis, 6% (3/48) developed grade II osteoarthritis and 15% (7/48) developed grade III osteoarthritis².

Osteoarthritis was reported in 5% (1/23) of patients in the case series of 23 patients treated by open reduction with dislocation⁷.

Implant failures

The inadvertent intra-articular positioning of Kirschner wires was reported in 11% (7/64) of patients in the case series of 64 treated by open reduction without dislocation: reoperation was needed in 3 of these patients³.

Reoperation, 6 to 8 weeks after surgery, was needed in 8% (3/40) of patients because of breakage of screw or wire fixations in the case series of 40 patients treated by open reduction with dislocation⁴.

Reoperation because of implant failures (no other details provided) was reported in 15% (4/27) of patients in a case series of 28 patients (30 hips) treated by open reduction with dislocation⁶.

Broken implants were reported in 15% (4/27) of patients at a mean of 12.3 weeks in the case series of 27 patients treated by open reduction with surgical dislocation. All of these patients needed revision fixation: 1 patient developed AVN; 3 healed successfully⁸.

Nerve damage

Permanent partial paralysis of the sciatic nerve was reported in 1 patient in the case series of 65 patients (66 hips) treated by open reduction without dislocation².

Infection

Subcutaneous wound infections were reported in 3% (2/66) of hips in the case series of 65 patients (66 hips) treated by open reduction without dislocation².

Other complications

Non-union of the femoral neck was reported in 9% (4/43) of patients in a case series of 43 patients treated by open reduction with dislocation. All patients were treated by a revision surgery⁹.

Heterotrophic ossification was reported in 8% (3/40) of patients in the case series of 40 patients treated by open reduction with dislocation. No further details were provided⁴.

Validity and generalisability of the studies

- No randomised controlled trials were identified that assessed the efficacy of open reduction for treating SCFE.
- Most studies employed modifications of the modified Dunn approach, which involves a cuneiform osteotomy performed with surgical dislocation of the hip^{4,5,6,7,8}.
- Most studies in table 2 included heterogeneous patient populations in relation to the severity and stability of slips.
- The study with the longest available follow-up reported a mean follow-up of 16 years.

- None of the studies used clinical assessment by observers blinded to the treatment modality.

Existing assessments of this procedure

There were no published assessments from other organisations identified at the time of the literature search.

Related NICE guidance

There is currently no NICE guidance related to this procedure.

Specialist advisers' opinions

Specialist advice was sought from consultants who have been nominated or ratified by their specialist society or royal college. The advice received is their individual opinion and does not represent the view of the society.

Mr Mark Flowers, Mr James Hunter (British Society for Children's Orthopaedic Surgery).

- One specialist adviser has performed the procedure at least once, whereas the other specialist adviser performs the procedure regularly.
- One specialist adviser described the procedure as a minor variation on an existing procedure, which is unlikely to alter that procedure's safety and efficacy. The other specialist adviser described the procedure as established practice and no longer new.
- Both specialist advisers stated that 10–50% of specialists were engaged in this area of work.
- Comparator treatments include pinning (fixation) in situ.
- Specialist advisers did not highlight any additional adverse events reported in literature.
- Specialist advisers listed stiffness and fracturing around implants as anecdotal adverse events.
- Specialist advisers highlighted non-union of the femoral neck as a theoretical adverse event.

- Specialist advisers listed key efficacy outcomes as gait parameters, pain scores, Pediatric Outcomes Data Collection Instrument (PODCI) scores, non-arthritic hip scores, satisfactory radiological features (Stulberg I/II), the incidence of salvage procedures, prevention of secondary arthritis, and a lack of leg-length discrepancies.
- Specialist advisers stated that the main uncertainty surrounding the procedure involves the occurrence of avascular necrosis.
- Both specialist advisers considered the procedure to have a minor impact on the NHS.

Patient commentators' opinions

NICE's Public Involvement Programme was unable to gather patient commentary for this procedure.

Issues for consideration by IPAC

There were no ongoing trials identified from research databases at the time of the literature search.

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9. Upasani VV, Matheney TH, Spencer SA, Kim YJ, Millis MB, Kasser JR. (2014) Complications after modified Dunn osteotomy for the treatment of adolescent slipped capital femoral epiphysis. *Journal of Pediatric Orthopaedics* 34 (7): 661-7

Appendix A: Additional papers on open reduction of slipped capital femoral epiphysis

The following table outlines the studies that are considered potentially relevant to the IP overview but were not included in the main data extraction table (table 2). It is by no means an exhaustive list of potentially relevant studies.

Article	Number of patients/follow-up	Direction of conclusions	Reasons for non-inclusion in table 2
Szypryt EP, Clement DA & Colton CL (1987) Open reduction or epiphysiodesis for slipped upper femoral epiphysis. A comparison of Dunn's operation and the Heyman-Herndon procedure. Journal of Bone & Joint Surgery - British Volume 69 (5): 737-742	Non-randomised comparative study n=48 patients; 53 hips (23 open reduction versus 30 epiphysiodesis plus osteoplasty) Follow-up: 5.3 years	Excellent results were reported in 68.1% (15/22) of patients treated by open reduction and 16.5% (3/18) of patients treated by epiphysiodesis plus osteoplasty. AVN was reported in 18.2% (4/22) of patients in the open reduction group and 11.1 (2/18) patients in the epiphysiodesis plus osteoplasty group.	The study compared open reduction with another procedure (epiphysiodesis) that may no longer be in use. Furthermore, studies included in table 2 report similar outcome measures.
Lowndes S, Khanna A, Emery D, Sim J & Maffulli N. (2009) Management of unstable slipped upper femoral epiphysis: a meta-analysis. British Medical Bulletin; 90:133-146	Non-randomised comparative study n=85 (49 patients treated by reduction versus 36 who were not treated by reduction) Follow-up: unclear	Patients who had received any kind of reduction had an increased risk of AVN compared with patients without reduction (OR 2.20, p=0.290). The odds of AVN was reduced for those who received treatment within 24 hours of symptom onset (OR 0.50, p=0.441).	Study combined the results of patients that were treated by any kind of reduction: the results of patients that underwent open reductions were not clearly distinguishable from other treatments.
Khan FA (1995) Treatment of slipped capital femoral epiphysis with severe displacement (report of 14 hips in 12 non Caucasian patients). African Journal of Medicine & Medical Sciences 24 (2): 189-194	Case series n=12 (10 patients treated by open reduction) Follow-up: >4 months	AVN occurred in 10% (1/10) of patients treated with open reduction. Chondrolysis was reported in 10% (1/10) of patients.	Larger case series that reported more outcome measures were included in table 2.
Pazzaglia UE, Zatti G, Raimondi GB, Migliavacca M, & Rolla P (1992) Treatment of slipped capital femoral epiphysis: evaluation of the results of extracapsular	Case series n=26 patients treated by epiphysiodesis alone or open reduction and epiphysiodesis.	Excellent subjective results were reported in 68.7% (11/16) of patients that were treated by open reduction and epiphysiodesis. Excellent clinical results	Larger case series that reported more outcome measures were included in table 2.

<p>epiphysiodesis and open reduction-epiphysiodesis.</p> <p>Italian. Journal of Orthopaedics & Traumatology 18 (2): 199-206.</p>	<p>Mean follow-up: 4.5 years</p>	<p>were reported in 56% (9/16) of patients that were treated by open reduction and epiphysiodesis.</p> <p>The complication rate was 25% (4/16) at last follow-up: 1 AVN: 3 AVN with chondrolysis.</p>	
<p>Phillips SA, Griffiths WEG & Clarke NMP (2001). The timing of reduction and stabilisation of the acute, unstable, slipped upper femoral epiphysis.</p> <p>Journal of Bone and Joint Surgery - Series B.83 (7): 1046-1049</p>	<p>Case series</p> <p>n=100 patients treated by various surgical procedures (29 patients treated by open reduction)</p> <p>Follow-up: unclear</p>	<p>The rate of AVN in patients with stable slips (all treatments) was 5% (4/86). No cases of AVN were observed in 14 with unstable slips.</p>	<p>The results of patients that underwent open reductions were not clearly distinguishable from other treatments.</p>
<p>Rebello G, Spencer S, Millis MB & Kim YJ (2009)</p> <p>Surgical dislocation in the management of pediatric and adolescent hip deformity.</p> <p>Clinical Orthopaedics & Related Research 467 (3): 724-731</p>	<p>Case series</p> <p>n=58 patients with proximal femoral hip deformities treated by various surgical treatments (5 patients treated by open reduction)</p> <p>Mean follow-up: 41.6 months</p>	<p>No complications were reported in the 5 patients underwent open reduction.</p>	<p>The results of patients that underwent open reductions were not clearly distinguishable from other treatments</p> <p>The results for patients with SCFE were not clearly distinguishable from patients with other proximal femoral hip deformities.</p> <p>Larger case series were included in table 2</p>
<p>Sankar WN, McPartland TG, Millis MB & Kim YJ (2010)</p> <p>The unstable slipped capital femoral epiphysis: risk factors for osteonecrosis.</p> <p>Journal of Pediatric Orthopedics 30 (6): 544-548.</p>	<p>Case series</p> <p>n=70 patients treated by various procedures (16 patients treated by open reduction)</p> <p>Mean follow-up: 3.2 years</p>	<p>AVN was reported in 20% (14/70) of all patients. AVN was reported in 6% (1/16) of open reduction patients, 26% (10/38) of closed reduction patients and 19% (3/16) of patients that in situ pinning alone.</p>	<p>Larger case series that reported more outcome measures were included in table 2.</p>
<p>Souder CD, Bomar JD, Wenger DR. (2014) The Role of Capital Realignment Versus In Situ Stabilization for the Treatment of Slipped Capital Femoral Epiphysis. J Pediatr Orthop. [Epub ahead of print]</p>	<p>Non randomised comparative study</p> <p>n= (71 in-situ fixation vs 17)</p> <p>Follow-up = 3 years</p>	<p>In patients with unstable SCFE, avascular necrosis with or without chondrolysis was reported in 20% (2/10) of patients treated by open reduction and in no patients treated by in-situ fixation. In patients with stable SCFE, avascular necrosis with or without chondrolysis was reported in 29% (2/7) of patients treated by open reduction and in 14% (1/7) of patients</p>	<p>A small number of patients treated by open reduction were assessed. Furthermore, no efficacy outcomes were reported. The only detailed information provided was the occurrence of avascular necrosis, which is available in studies already included in table 2.</p>

		treated by in-situ fixation.	
Fish JB. (1984) Cuneiform osteotomy of the femoral neck in the treatment of slipped capital femoral epiphysis. J Bone Joint Surg Am 66(8):1153-68.	Case series n=39 patients Follow-up = 9.75 years	Excellent postoperative results were reported in 95% (37/39) of patients at follow-up. Osteoarthritis was reported in 1 patient. Avascular necrosis was reported in 1 patient.	Limited reporting of outcome measures: the study reported outcomes narratively, in multiple case reports, and did not provide sufficient summary information.
Biring GS, Hashemi-Nejad A, Catterall A. (2006) Outcomes of subcapital cuneiform osteotomy for the treatment of severe slipped capital femoral epiphysis after skeletal maturity. J Bone Joint Surg Br. 88(10): 1379-84	Case series n=25 hips Follow-up= 8.25	The mean Iowa hip score (range from 0 to 100 with higher scores indicating better outcomes) was 93.7 at follow-up: 88% (22/25) of hips had scores above 90. The mean Harris hip score (scores range from 0 to 100 with higher scores indicating better outcomes) was 95.6 at follow-up: 88% (22/25) of hips had scores above 90. Leg length discrepancies (mean of 1.2cm) were reported in 83% (20/24) of patients. Degenerative joint changes (according to the Boyer et al., 1981 classification system) were graded as 0 in 19 hips, grade 1 in four and grade 2 in two. Avascular necrosis was reported in 12% (3/25) of patients. Chondrolysis was 16% (4 of 25).	Larger case series that employed an identical surgical approach (cuneiform osteotomy without dislocation) and reported similar outcome measures are already included in table 2.
DeRosa GP, Mullins RC, Kling TF. (1996) Cuneiform osteotomy of the femoral neck in severe slipped capital femoral epiphysis. Clinical Orthopaedics and Related Research (322) 48-60.	Case series n=27 patients Follow-up=3 years	Good, fair, and poor results, according to the modified Southwick classification system, were reported in 19, 4 and 4 patients, respectively. The 4 poor results were in patients with avascular necrosis. Avascular necrosis was reported in 15% (4/27) of hips. Joint space narrowing was reported in 30% (8/27) of patients during the postoperative follow-up period. All joint space narrowing resolved by 20 months postoperatively. All patients, including those with avascular necrosis,	Larger case series that employed an identical surgical approach (cuneiform osteotomy without dislocation) and reported similar outcome measures are already included in table 2.

		improved in joint flexion and joint internal rotation.	
Khalil AMM, Refa O, Elsherif E. (2014) Short-term outcomes of the modified Dunn procedure in the treatment of slipped capital femoral epiphysis. Current Orthopaedic Practice.25 (4): 352-355	Case series n=33 Follow-up = 2 years	"Nine patients had excellent clinical results according to the Harris Hip Score, 15 had good results, 6 had fair results, and 3 had poor results": no baseline, follow-up or changes in scores were reported. The slip angle was corrected to 4.21° (range 0-8.41). Two patients developed avascular necrosis with arthritic changes, another patient, with juvenile onset diabetes, developed an infection that required drainage and debridement.	Minimal reporting of outcome measures: Few outcome measures were reported and authors did not report numerical information about baseline, follow-up or changes in Harris Hip scores.
Loder RT & Dietz FR (2012) What is the best evidence for the treatment of slipped capital femoral epiphysis? Journal of Pediatric Orthopedics 32 Suppl-65.	Narrative review n=2308 patients treated by various surgical procedures (number of patients treated by open reduction was not reported) Follow-up: unclear	On the basis of the studies included in the review, the authors recommend that the best treatment for a stable SCFE is single screw in situ fixation, and for unstable SCFE urgent gentle reduction, decompression and internal fixation.	Study was a narrative review. The results of patients that underwent open reductions were not clearly distinguishable from other treatments.
Alves C, Steele M, Narayanan U, Howard A, Alman B & Wright JG. (2012) Open reduction and internal fixation of unstable slipped capital femoral epiphysis by means of surgical dislocation does not decrease the rate of avascular necrosis: a preliminary study. Journal of Childrens Orthopaedics 6 (4): 277-283	Case series n=12 (6 patients treated by open reduction and 6 treated by closed reduction) Follow-up: >1 year	AVN was reported in 67% (4/6) and 33% (2/6) of patients treated by open reduction and closed reduction respectively (p=0.57).	Larger case series that reported more outcome measures were included in table 2.

Appendix B: Related NICE guidance for open reduction of slipped capital femoral epiphysis

There is currently no NICE guidance related to this procedure.

Appendix C: Literature search for open reduction of slipped capital femoral epiphysis

Database	Date searched	Version/files
Cochrane Database of Systematic Reviews – CDSR (Cochrane Library)	26/02/2014	Issue 2 of 12, February 2014
Database of Abstracts of Reviews of Effects – DARE (CRD website)	26/02/2014	Issue 1 of 4, January 2014
HTA database (CRD website)	26/02/2014	Issue 1 of 4, January 2014
Cochrane Central Database of Controlled Trials – CENTRAL (Cochrane Library)	26/02/2014	Issue 1 of 12, January 2014
MEDLINE (Ovid)	26/02/2014	1946 to February Week 2 2014
MEDLINE In-Process (Ovid)	26/02/2014	February 25, 2014
PubMed	26/02/2014	n/a
EMBASE (Ovid)	26/02/2014	1974 to 2014 Week 08
BLIC	26/02/2014	n/a

Trial sources searched on 20/02/2014:

- National Institute for Health Research Clinical Research Network Coordinating Centre (NIHR CRN CC) Portfolio Database
- Current Controlled Trials metaRegister of Controlled Trials – mRCT
- Clinicaltrials.gov

Websites searched on 20/02/2014:

- National Institute for Health and Care Excellence (NICE)
- NHS England
- Food and Drug Administration (FDA) - MAUDE database
- French Health Authority (FHA)
- Australian Safety and Efficacy Register of New Interventional Procedures – Surgical (ASERNIP – S)
- Australia and New Zealand Horizon Scanning Network (ANZHSN)
- Conference websites <<add details>>
- General internet search

The following search strategy was used to identify papers in MEDLINE. A similar strategy was used to identify papers in other databases.

1	exp Epiphyses, Slipped/
2	(slipped adj4 (capital or upper) adj4 (femoral or femur) adj4 epiphysis).tw.
3	SCFE.tw.
4	SUFE.tw.
5	or/1-4
6	Orthopedic Procedures/
7	(open adj4 (reduct* or short* or treat* or procedure* or surger* or decompress*)).tw.
8	ORIF.tw.
9	Internal Fixators/
10	((internal* or pin* or screw* or plate* or rod* or nail* or wire*) adj4 fix*).tw.
11	Bone Nails/
12	Bone Plates/
13	Bone Screws/
14	Bone Wires/
15	or/6-14
16	5 and 15
17	animals/ not humans/
18	16 not 17