Purpose of review
Slipped capital femoral epiphysis is a common adolescent hip disorder. Management of chronic, stable slipped capital femoral epiphysis with in-situ screw fixation has been well defined, but controversy exists regarding management of the unstable hip disorder, the indications for prophylactic fixation of the contralateral hip and the role of osteotomy in the management of residual deformity.

Recent findings
Recent developments in the epidemiology, etiology, diagnosis and management of this hip disorder are reviewed. The importance of early diagnosis, the relationship of body mass index, the predictors for bilaterality and the role for osteotomies are reviewed and compared.

Summary
The information in this review will help clinicians identify patients at risk, understand the need for prompt diagnosis and recommend the appropriate management for both stable and unstable slipped capital femoral epiphysis. Further research is needed to better define the role of osteotomy in this disorder.

Keywords
adolescent, hip, obesity, slipped capital femoral epiphysis

Introduction
Slipped capital femoral epiphysis (SCFE) is a disorder of the proximal femoral primarily seen during the adolescent growth spurt. It is classified as stable or unstable based on the ability of the patient to walk. Single screw in-situ stabilization is the management of choice for mild, stable, chronic SCFE. Avascular necrosis (AVN) is rarely seen in stable SCFE but is a significant concern in the unstable slip. Significant controversy exists regarding the management of unstable SCFE with regard to slip reduction, timing of surgery and role for arthrotomy or joint aspiration in an attempt to reduce the occurrence of this devastating complication. The incidence may be on the rise with the increase in childhood obesity and the known association with an increased body mass index (BMI). The diagnosis is frequently delayed which is associated with an increase in slip severity. Increased slip severity is associated with a poorer long-term outcome. A number of different osteotomies have been described to address the residual deformity of the proximal femur. The exact role of these surgical procedures has yet to be defined.

Epidemiology
The incidence of SCFE varies according to sex, race, geographic location and season. Previous reports have suggested a predilection for black males living in the eastern United States. Lehmann reported that the overall incidence of SCFE in the United States for children between the ages of 9 and 16 was 10.80 cases/100,000 children. The incidence was 3.94 times higher in black children and 2.53 times higher in Hispanic children than in white children. Boys were affected much more frequently than girls (13.35 versus 8.07 cases/100,000) and higher rates were noted in the Northeast and West when compared with the South and Midwest. An increased incidence was noted north of 40° latitude in the summer and south of 40° latitude in the winter. Age of onset was lower than previous reports. This suggests both environmental and genetic factors may play a role in the development of SCFE [1**]. Brown [2] also found a significant seasonal variation in the North in both boys and girls while in the South the seasonal variation did not reach statistical significance. There was less seasonal variation in the black population. The author suggests a link with impaired vitamin D synthesis may explain these observations.

The onset of SCFE typically occurs during the adolescent growth spurt (boys 13–15 and girls 11–13) but there is a trend for children to mature at a younger age. Loder and colleagues [3] reviewed the Oxford bone age of
patients with idiopathic SCFE and compared them with a group from a decade before. They found that the recent children were chronologically younger (12.1 versus 13.2 years) but there was no difference in Oxford bone age. There was also no difference in bone age score between boys and girls. This study also reaffirmed the narrow window of bone age in SCFE which was 50% of the chronological age range.

**Etiology**

The exact cause of SCFE is unknown but both mechanical and endocrine factors have been implicated. The mechanical factors concerned are the relative or absolute retroversion of the femoral neck, an increase in acetabular depth, the relative weakness of the growth plate during this period of rapid growth, thinning of the perichondral ring during adolescence, and the orientation of the proximal femoral growth plate on the femoral neck. All or some of these factors in the obese patient and the resultant increased mechanical forces are theoretical causes for SCFE. In a finite element analysis, Fishkin and colleagues [4] demonstrated that the physis shear strain in hips with a combination of varus loading and femoral neck retroversion exceeded the reported ultimate strain values for cartilage. This suggests that the forces in the obese adolescent with femoral neck retroversion and a varus hip load may be enough to result in a slip.

The association of BMI and SCFE has been reported in a study by Manoff et al. [5]. The BMI values of 106 patients with SCFE were compared with 46 controls. In the SCFE group, 81.1% were above the 95th percentile compared with 41.3% of the control group (P < 0.0001). The authors suggested that early intervention and lifestyle modification may reduce the incidence of SCFE. Bhatia and colleagues [6] reported the mean BMI was greater in patients treated for SCFE a few years before. Papavasiou et al. [8] believed that a temporary PTH disorder may be operative during the early years of adolescence (in addition to other etiologic factors) in patients with SCFE. Bone density, though, has been shown to be greater than expected for age and sex [9]. Smida et al. [10] reported two cases of SCFE in patients receiving growth hormone for short stature. The condition has also been reported in a patient with gigantism associated with excess growth hormone [11]. The exact etiology and role of growth hormone in SCFE are still unknown.

**Classification**

There are a variety of classification systems currently utilized in describing SCFE. They can be categorized by the length of symptoms prior to presentation, the ability of the patient to walk upon presentation or the amount of displacement radiographically.

SCFE can be described as acute, acute on chronic or chronic. An acute slip is one with a symptomatic period of 2–3 weeks or less. The patient frequently presents with a sudden onset of severe hip pain from a minor traumatic event in contrast to an acute Salter I fracture which requires significant energy. The majority of patients (85%) present with a chronic SCFE which is characterized by a few months of vague hip, groin, thigh or knee pain. An acute on chronic slip is one in which the patient presents with the sudden onset of severe pain following a prodromal period consistent with a chronic slip.

A more useful classification is based on the patient’s ability to bear weight. Loder and colleagues [12] found a much higher incidence of AVN in those unable to bear weight (unstable) compared with those able to walk (stable) even with assistive devices (AVN incidence 47% versus 0%).

SCFE can be classified based on magnitude of displacement. The most popular method is that of Southwick which measures the head-shaft angle on anterior-posterior or frog-leg lateral views and comparing them with the opposite side in the case of unilateral slips or normal values (145° on anterior-posterior or 10° on lateral) [13]. A mild slip head-shaft angle differs by less than 30°, a moderate slip between 30 and 60° and a severe slip by more than 60°.

**Clinical presentation**

The typical patient with a chronic, stable SCFE is an obese adolescent with a brief history of hip, groin, thigh or knee pain. The patient will present with a mild to moderate limp, progressive out-toeing and decreased internal rotation or obligatory external rotation with hip
Slipped capital femoral epiphysis

The pain with motion is variable and therefore the clinician has to be astute and aware of the physical exam findings. There have been numerous reports in the literature regarding a delay in diagnosis, especially in those patients presenting with thigh or knee pain. Kocher and colleagues [14] reported a median delay of 8.0 weeks with knee/thigh pain, Medicaid insurance, and stable slips having longer delays. Rahme et al. [15] also found that knee or thigh pain was the most frequent ‘pitfall’ as well as radiographic misinterpretation of mild slips as being normal. They also found that a significant number of late presentations had self-referred to a chiropractor or physiotherapist and had undergone hip manipulation prior to the diagnosis being made. Katz [16] states that a ‘groin pull’ is exceedingly rare in children and that a SCFE is a diagnosis of exclusion in any child presenting with hip, thigh or knee pain or physical exam findings of out-toeing or obligate external rotation with hip flexion. Loder et al. [17] found a significant correlation between symptom duration, age and slip severity. A recent study of 108 patients revealed bilateral disease in 32% of patients [3]. These studies point to the need for increased vigilance and continued education.

The patient presenting with an unstable slip typically has a sudden onset of severe hip pain making the patient unable to walk even with crutches. There may be a history of hip, groin, thigh or knee pain and a history of minor trauma (twisting or fall insufficient to cause a hip fracture). The patient usually seeks prompt medical attention, lies with the leg externally rotated and resists any motion of the hip.

Children with atypical SCFE (renal failure, radiation therapy, endocrine disorder) frequently either present outside of the narrow age range (<10 or >16 years) or are not over 50% for weight. Loder and Greenfield [18] described the age-weight test when they found that for two patients of equal weight, those younger than 10 or older than 16 were 4.2 times more likely to have an atypical SCFE. A patient of the same age was 8.4 times more likely to have an atypical slip if they were less than the 50th percentile in weight. Recently height has been found to be the most useful in differentiating a typical from an atypical slip. Using less than the 10th percentile as a positive height test, Loder et al. [19] found a sensitivity of 75%, a specificity of 97%, a positive predictive value of 75% and a negative predictive value of 97% for identifying an atypical slip upon presentation.

Two recent reports on patients with Down’s syndrome and SCFE should be mentioned. Dietz et al. [20] found that there was a high incidence of severe slips (6/8 grade III), unstable slips (4/8), and AVN (5/8). Bosch and colleagues [21] reported a high incidence of hypothyroidism in this population (6/11), which also had a very high complication rate with four out of eight having significant femoral head deformity at maturity [21].

Treatment

The current recommended treatment of a stable SCFE is in-situ fixation with a single stainless steel cannulated screw to prevent further progression of the slip until closure of the growth plate. The screw should cross the growth plate perpendicular to the orientation of the displaced femoral head in both the anterior-posterior and lateral planes. This will necessitate a starting point that is located on the anterior aspect of the femoral neck, the exact location of which will be determined by the severity of displacement. The surgeon needs to ensure placement of the screw tip in the center of the femoral head on both the anterior-posterior and lateral views (center–center), try to engage the head with as many screw threads as possible without joint penetration and particularly avoid the superolateral portion of the femoral head because of the risk of segmental AVN with injury to the lateral epiphyseal vessel [22]. Studies have shown an increased incidence of slip progression if less than five threads cross the growth plate [23]. A recent report suggests using longer threaded screws to ensure the threads bridge the physis as too few threads in either the epiphysis or metaphysis lead to decreased stability in the experimental model [24]. It is imperative that the surgeon confirms that the tip of the screw does not violate the joint. Persistent joint penetration of the tip of the screw is the cause of iatrogenic chondrolysis. Difficulties in removing titanium screws have been described. Ilchmann and Parsch [25] found considerable disadvantages in removing a particular variety of titanium cannulated screws and recommended that their use be suspended in treating SCFE.

The surgeon may choose to place the patient on either a fracture table or radiolucent table to perform the surgical procedure. Both have described advantages and disadvantages. The fracture table allows for secure positioning of the limb and eliminates the need to manipulate the leg to obtain images. It is therefore the method of choice in the unstable slip. In the very obese patient, it may be difficult to obtain good visualization on the lateral view when on the fracture table. Total anesthetic time is generally longer and it may be difficult to position the opposite limb in the case of bilateral slips. It is always necessary to remove the limb from the traction boot at the end of the case and place the hip through a range of motion under fluoroscopic visualization, paying particular attention to the position of the tip of the screw and its relationship to the subchondral surface of the femoral head. The appearance of the tip of the screw moving towards then away (‘approach–withdraw’) from the subchondral surface has been described and should be performed before leaving the operating room. The use of a
radiolucent table has been shown to lead to shorter operative times and the results are equivalent to those with the fracture table when looking at the goal of placing the screw tip in the ‘center-center’ position [26]. There is the risk of bending the guide wire during manipulation of the limb to obtain the frog-lateral position. Stout guide wires on many cannulated screw systems have lessened the risk of this problem.

Significant controversies exist in the literature involving the best treatment for unstable SCFE. The primary concern involves lessening the risk of AVN. These controversies involve the timing of fixation, the role of reduction, the role of joint decompression (aspiration or athrotomy), the number of screws needed for fixation and more recently the role of surgical dislocation. Seller et al. [27] reported on 29 patients with unstable SCFE and had a very low incidence of AVN (6.8%) using multiple Kirshner wires. They also saw no indication for emergency surgery. Fallath and Lets [28] found no significant statistical association in 14 unstable slips with regard to time to fixation or use of reduction and concluded that a gentle reduction of unstable slips is safe. To highlight this controversy, Mooney et al. [29] conducted a survey of the Pediatric Orthopaedic Society of North America (POSNA) membership and found that 31% of members felt that unstable SCFE was an emergency compared with 57% who felt the procedure could be done on an urgent basis (<8 h). They also found that 57% used a single screw compared with 40.3% recommending two screws. In an experimental model, Snyder et al. [30] found that double-screw fixation without the perichondrium provided 43% of the stiffness and 74% of the strength of the intact physis in torsion and double the stiffness and strength of single-screw fixation (P < 0.004). Loder [31 **] recently reported his personal approach to the treatment of the child with an unstable SCFE, which is emergent treatment with a gentle repositioning of the slip, two-screw fixation, and a mini-arthroty to joint decompression.

Postoperatively, patients are generally allowed to weight bear as tolerated or with crutches for 4–6 weeks in the case of the stable slip. Most will recommend keeping the patient with the unstable slip nonweight bearing for 6–12 weeks depending on the patient’s symptoms and radiographic appearance.

Prophylactic pinning on the unslipped, contralateral hip is controversial. It is generally recommended in patients with underlying endocrine or metabolic disorders (atypical SCFE) but these are infrequent [31 **]. In the idiopathic SCFE, numerous authors have looked at a variety of factors to predict the risk of future contralateral slip when a patient presents with a unilateral SCFE. Koczwiski [32] found that more than a third of patients with unilateral SCFE developed silent, subclinical contralateral slips and that they occurred more often in patients with a more vertical orientation of the growth plate (Alsberg angle < 60°). Barrios and colleagues [33], based on radiographic hip morphometric parameters, concluded that prophylactic pinning of the healthy contralateral side should be strongly recommended in patients with an axial posterior sloping angle of the physis of over 12°. The measurement variability of the lateral head-shaft angle is significant (intraobserver variability of ±5.9°), diminishing the utility of a single radiographic measure when making a decision to prophylactically pin the opposite hip [34]. Skeletal maturity at the time of the initial slip may aid the physician in determining whether to pin the opposite hip. Stasikelis and colleagues [35] found that 85% of patients with a score of 16 developed contralateral slips in contrast to no child with a score of 22 or more. In a study of 260 patients with a unilateral SCFE, Birch and colleagues [36] have confirmed the utility of the modified Oxford bone score (OBS) in predicting a contralateral slip, finding that patients with an OBS of 16–18 had a 96% risk of developing a contralateral slip, whereas 99% of patients with a score of 21 or greater did not develop contralateral SCFE.

If the surgeon elects not to pin the opposite hip, the patient and family need to be made aware of the potential risk and to report immediately if symptoms develop.

Numerous authors have recommended primary osteotomy in conjunction with fixation of the slip. The intent of osteotomy is to restore motion, redirect the forces across the physis, and theoretically reduce the risk of degenerative arthritis. The role of primary osteotomy has not been well defined and the current recommendation is to perform an in-situ fixation of the SCFE with consideration given towards osteotomy in severe slips (slip angle > 60°). A number of authors have demonstrated remodeling after fixation, particularly in the very young with an open triradiate cartilage. Guzzanti et al. [37] described the use of a modified cannulated screw that allows for continued growth yet providing for physeal stabilization, recovery and growth.

A variety of surgical procedures have been described based on the location of osteotomy, from an intracapsular subcapital cuneiform osteotomy at the apex of the deformity, base of neck osteotomy to inter or subtrochanteric osteotomies. The risk for complications, particularly AVN or chondrolysis, is theoretically increased the more proximal the osteotomy but there is less distortion of the proximal femoral anatomy. The loss of femoral neck length with femoral neck osteotomies is of biomechanical significance as was pointed out by a study comparing flexion intertrochanteric osteotomies compared with subcapital osteotomies in chronic, severe, stable SCFE. Diab and colleagues [38] found that the flexion
intertrochanteric osteotomy was more effective in restoring proximal femoral anatomy (articulotrochanteric distance and trochanter-center of head distance) than the subcapital osteotomy although the incidence of complication rates was low in both groups. Diab et al. [39] found in a small study that a staged flexion osteotomy did improve hip range of motion, yet did not lead to any functional improvement when compared with a group of patients who underwent in-situ fixation alone.

The residual pistol-grip deformity of the proximal femur can lead to anterior impingement, labral pathology and pain [40,41]. Recognition and treatment of hip impingement may prevent the development of early hip arthritis [42]. The metaphyseal prominence can be addressed utilizing a surgical dislocation approach with or without proximal realignment. Spence et al. [40] found this to be an efficacious procedure, particularly in those that had osteoplasty and osteotomy. Espinosa and colleagues [43] found better results in patients that had labral refixation rather than resection when labral pathology was found. Hip arthroscopy offers another method to address labral pathology and the metaphyseal prominence [44].

**Conclusion**

The long-term consequences of SCFE are primarily dependent on the severity of slip in the absence of complications [45]. It is incumbent on the clinician to make a prompt diagnosis, taking into account the variety of symptoms and physical exam findings, and administering the appropriate surgical management. The chronic slip should be stabilized on an urgent basis with a percutaneous technique with the goal of avoiding persistent penetration of the hip joint with the tip of the screw while maximizing the number of threads into the epiphysis by achieving the ‘center–center’ position. The unstable slip should be managed more acutely with a gentle reduction, joint decompression via aspiration or arthroscopy, and stabilization with one or two screws. The role of prophylactic fixation is dependent on numerous factors and the surgeon should be aware of the risk factors associated with a contralateral slip. There are a variety of osteotomies which may be performed, but the evidence as to their utility in restoring function and preventing long-term hip pathology is only beginning to be elucidated.

**References and recommended reading**

Papers of particular interest, published within the annual period of review, have been highlighted as:

- of special interest
- **of outstanding interest**

Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 578).


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This article provides a comprehensive review of the major controversies which are the treatment of the unstable SCFE, the role of osteotomy in the treatment of SCFE, prophylactic fixation of the contralateral hip in children presenting with unilateral SCFE, and methods of fixation in the very young child with SCFE.


This article presents a method to address hip impingement with a surgical dislocation technique and alerts the clinician to one of the causes for continued symptoms and a poor prognosis in patients with SCFE.


