Acute Slipped Capital Femoral Epiphysis: Treatment Alternatives

Carl L. Stanitski, MD

Abstract

Acute slipped capital femoral epiphysis represents a unique type of proximal femoral epiphyseal instability. The potential for complications and unsatisfactory outcomes is high, especially due to avascular necrosis. A newly proposed classification based on epiphyseal stability provides a rational assessment of this acute physeal fracture. Improvements in imaging and fixation techniques have reduced the morbidity of this condition. Choice of treatment must be based on the surgeon's experience and expertise. Vigilance is particularly required in young patients with underlying endocrine or metabolic conditions that predispose them to bilateral hip involvement.

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Slipped capital femoral epiphysis (SCFE) is the most common adolescent hip affliction, affecting between 0.7 and 3.4 children per 100,000.[1-5] However, the growing awareness of "silent slips" suggests that this may be a major underestimation.[6-9] Acute slips occur in 5% to 10% of these children.[1-7] In the past few years there has been a tremendous growth in interest about and literature on acute SCFE as a subcategory of SCFE.

Definition

Prior to 1949, when Howorth[10] presented five cases of acute SCFE, the condition was reported in the literature only sporadically. In 1965 Fahey and O'Brien[11] reviewed 75 previously reported cases and 10 of their personal cases. A variety of treatment techniques yielded an overall satisfactory outcome in only 58% of the cases. They defined acute cases as those in which there had been prodromal symptoms for less than 3 weeks, but gave no rationale for selection of this arbitrary time period. Despite this temporal criterion, eight of their own patients had had prodromal symptoms for 1 month or more. Based on this review, they recommended early closed reduction and internal fixation as the treatment of choice.

The term "acute-on-chronic SCFE" has evolved to define slips in which the prodromata last longer than 3 weeks and which then suddenly present with an increase in pain, often associated with an episode of trauma.

Loder et al,[12] in a multicenter study of 55 slips in 54 children, recently suggested a new classification based on epiphyseal stability. Their criteria for instability include inability to bear weight because of the sudden onset of pain that is so severe that ambulation is impossible, even with walking aids. Hips were considered to be stable if ambulation was possible. The authors concluded that the magnitude of head and neck dissociation reflected the intensity of this injury. According to the temporal criteria, 35 of the patients were considered to have acute slips, and 17 were considered to have acute-on-chronic slips. According to their stability classification, 30 hips were classified as unstable and 25 as stable. Hips were usually treated with reduction and internal fixation. Twenty-six of the patients with unstable hips underwent reduction, and only 47% had satisfactory results. This poor outcome is in stark contrast to the 96% rate of satisfactory results achieved in the stable group. Like Wolff et al,[13] the authors found no association between the development of avascular necrosis and the timing of treatment following the acute event.

Others have differentiated among slips using imaging techniques.[14,15] Kallio et al,[14] using sonography, suggested three groups: acute (presence of effusion without remodeling), chronic (presence of remodeling without effusion), and acute-on-chronic (presence of both remodeling and effusion).

Similar criteria have been used on routine anteroposterior (AP) and lateral plain radiographs, combining absence of remodeling and presence of effusion as evidence of an acute slip (Fig. 1). To date, computed tomographic (CT) and magnetic resonance

Dr. Stanitski is Professor of Orthopaedic Surgery, Wayne State University, Detroit; and Chief, Department of Orthopaedic Surgery, Children's Hospital of Michigan, Detroit.

Reprint requests: Dr. Stanitski, Department of Orthopaedic Surgery, Children's Hospital of Michigan, 3901 Beaubien Boulevard, Detroit, MI 48201.

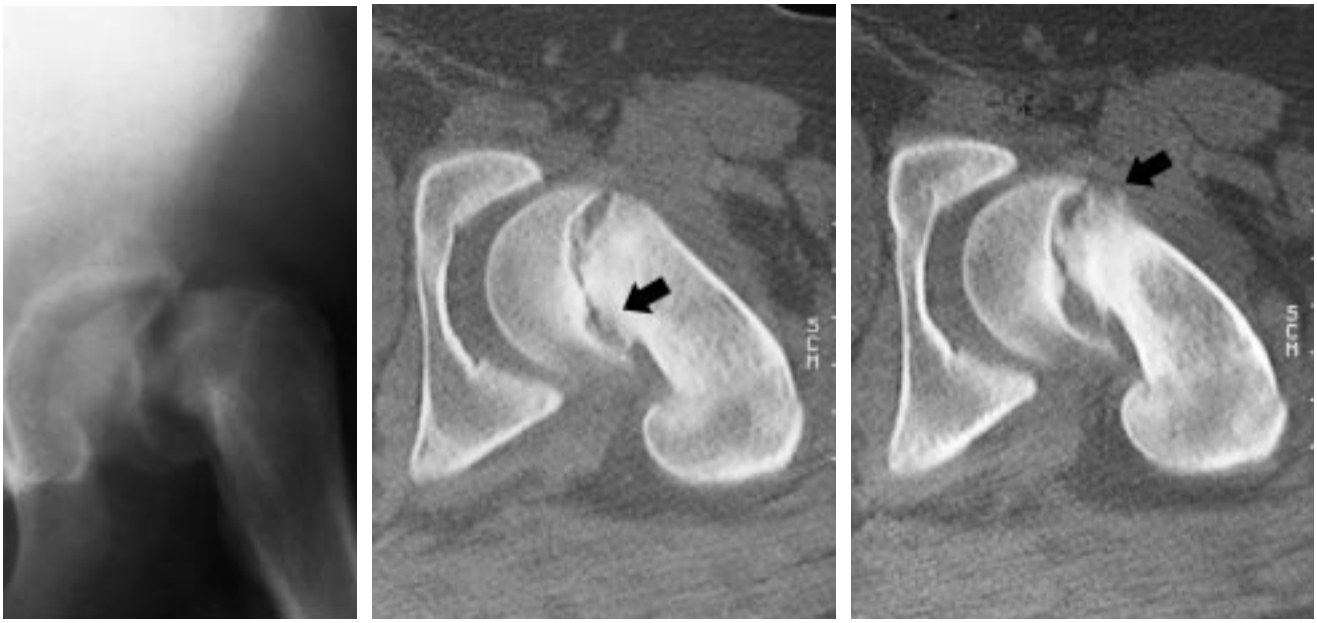


Fig. 1 Plain radiographic and CT images of the hip of a 90-kg 11-year-old girl with an acute-on-chronic SCFE. Note remodeling changes (arrows) in the femoral neck.

imaging criteria for acute versus nonacute slips have not been presented.

Epidemiology

Acute slips usually occur between ages 11 and 15 years and usually occur earlier in girls (at about 12 years, compared with 13 years for boys). In most series, boys are reported to suffer acute slips more frequently than girls, with a frequency perhaps even higher than that of chronic slips.[5-7] No ethnic or racial data specifically directed toward the prevalence of acute SCFE have been reported. Like the studies of children with chronic SCFE, all the studies of children with acute SCFE note a high preponderance of obesity (i.e., body weight greater than the second or third standard deviation for their height and age).[3,4,6,7,12] Loder et al[12] found that 60% of the children with unstable slips were obese, compared with 75% of the children with stable slips. In another study, Loder et al[16] also found no specific change in acuity of slips with changes of season.

Pathophysiology

An acute SCFE is a type I physeal fracture, with physiolysis occurring through a wide, irregular zone of hypertrophy. With approaching adolescence, the proximal femoral physeal line widens with concomitant diminution of the perichondral ring. Histologic specimens reflect changes in chondrocyte maturation, endochondral ossification, and loss of perichondral ring stability. Acute, unstable proximal femoral epiphyseal slips are rare without prodromal symptoms or sudden mechanical traumatic stress.

Following the fracture, the femoral neck assumes an anterolateral position with the proximal femoral epiphysis relatively posterior to the neck but still centrally located within the acetabulum. A reverse slip (i.e., one with displacement in the opposite direction) is extremely rare and is usually associated with some obscure disorder.

A multitude of potential causes have been suggested, among them alteration in hip mechanical forces secondary to obesity and diminution in femoral anteversion in chronic SCFE.[17-21] I compared seven acute slips with 70 chronic slips. The acute group averaged 15% more femoral neck retroversion (as measured on CT scan) on both the involved and uninvolved sides and marked retroversion compared with hips in normal age-matched control subjects.

As with SCFE in general, there has been no consistent endocrinopathy noted with acute slips,[1,22-24] although hypothyroidism or other endocrine abnormalities (e.g., those associated with a craniopharyngioma or cryptorchidism) must be considered, especially in patients under the age of 10 years. The surgeon should be wary of acute slips in children at the extremes of height for age, because of possible underlying metabolic or endocrine disorders.[23-27]

Other factors that could contribute to SCFE include Marfan's disease, use of a variety of posttransplant medications after renal transplantation, and radiation therapy.[28,29]

Presentation

The presentation of an acute unstable SCFE is a dramatic event, with sudden onset of severe hip, thigh, and / or knee pain, often following a fall or collision. The patient is unable to bear weight on the affected limb even with assistance and will often relate prodromal symptoms of varying durations prior to the acute event. Symptoms referable to the opposite hip should be sought. Obtaining a history of pertinent medical conditions (e.g., chronic diseases) and other etiologic factors (e.g., medications, radiation therapy, and diet) is also part of the evaluation.

The patient holds the involved lower extremity in external rotation and experiences severe pain with any attempt at active or passive motion about the hip. Diffuse tenderness at the hip joint and relative lower-extremity shortening are also present. The opposite hip should be examined for evidence of a "silent" chronic slip. Height, weight, body habitus, and signs of physical maturation should be assessed.

Diagnostic Imaging

The benchmark imaging studies are a standard AP radiograph of the pelvis and a lateral radiograph of the involved hip. The amount of anterolateral head-neck displacement may be graded according to the Wilson classification of percentage of epiphyseal displacement relative to femoral neck diameter[30] (Fig. 2). An alternative is measurement of the head-shaft angle, as described by Southwick.[31] With acute slips, the magnitude of slip is usually greater than 50% by the Wilson technique and more than 60 degrees by head-shaft angle measurement. It must be remembered that the radiographic image is a static depiction of the consequences of a very dynamic event; the image simply reflects the current resting position of the unstable proximal femoral epiphyseal fracture. In a true unstable acute slip, no signs of remodeling are seen at the femoral neck or epiphysis.

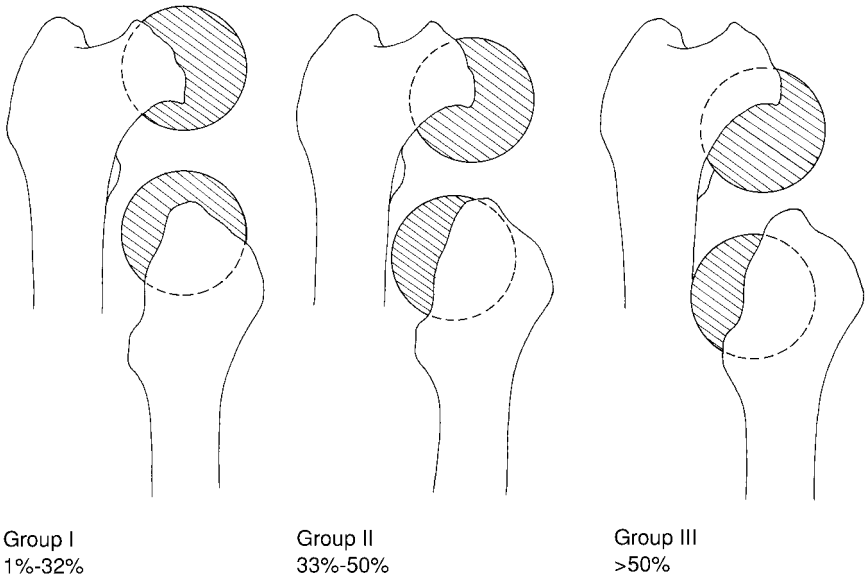


Fig. 2 Wilson classification of SCFE based on percentage of epiphyseal displacement relative to femoral neck diameter.

Avascular necrosis occurs in a high percentage of patients with SCFE.[1,3,8,12,30,32-35] Radionuclide scanning has been used to assess blood flow and establish viability of the epiphysis both preoperatively and postoperatively. Wolff et al[13] report two cases of acute SCFE that were positive postoperatively for avascular necrosis and that demonstrated avascular changes on standard radiographs at 3 months and 5 months postoperatively. Smergel et al[36] report the use of nuclear scanning in 14 patients with SCFE, two of whom had acute slips. These authors warn against the possibility of false-negative results (i.e., no evidence of femoral head perfusion but normal recovery).

Magnetic resonance imaging has not been used to establish epiphyseal marrow viability before and after surgery in a sufficient number of cases to allow assessment of its potential utility.

The use of CT scanning to assess the magnitude of deformity in chronic SCFE, as well as the amount of version of the proximal femur relative to the distal femur, has been reported by Gelberman et al,[17] Stanitski et al,[21] and Jacquemier et al.[18] Ebraheim et al[37] used CT reconstructions for improved imaging during internal fixation in cases with marked displacement. Computed tomography has also been used postoperatively to check the amount of physeal closure, but there are no data differentiating acute from nonacute slips.

Intraoperative Imaging

The use of intraoperative fluoroscopy has added immeasurably to improved visualization and efficiency during surgery. It is essen-

tial that adequate images be obtained in at least two planes 90 degrees to each other that are free of obstructions, such as operating tables. Obtaining adequate images may be difficult, particularly lateral projections in obese patients.

In a retrospective review of standard intraoperative plain radiographs, Walters and Simon[38] found that 40% of 102 patients had intra-articular protrusion of fixation devices by less than 5 mm, and an additional 22% had protrusion by more than 5 mm in the so-called silent areas, which may go unrecognized. Pizzutillo and Caviale[39] noted intra-articular penetration of fixation devices in 83 of 140 hips; in 42 of these cases, the transgression was not recognized intraoperatively. Zionts et al[40] reviewed two-plane standard radiographs of 25 patients (30 hips) treated with internal fixation. In 14 hips in 14 patients, joint penetration by fixation device, guide pin, or both was noted. The hazards of unrecognized hardware penetration have been well publicized and documented over the past decade, and orthopaedists have become more aware of the need for accurate intraoperative imaging to prevent unrecognized complications.

This risk can also be reduced with other fluoroscopic techniques. Rooks et al[41] found that by internally and externally rotating the lower extremity under fluoroscopic control, accurate positioning of the fixation device could be achieved, with placement of the distal limb of the fixation device no closer than 8 mm from the subchondral bone and the articular surface (i.e., a distance of approximately one third of the radius of the femoral head). A similar finding was noted by Blanco et al.[42]

When cannulated screws are used, arthrography can be employed to document fixation position and to rule out articular invasion.[43]

A third approach is arthroscopy. Futami et al[44] used sonographically guided arthroscopy to examine five acute slips and showed a posterolateral acetabular labral injury and an anterosuperior acetabular erosive change in two. Bassett[45] reported the use of endoscopic visualization in 13 hips in 12 patients with SCFE (Fig. 3); he was able to document articular penetration in two hips, in one of which acute cartilage necrosis was present. Transient screw penetration of the joint was found in one case. Four of the slips were described as severe, but no specific comment was made concerning physeal stability or acuity of symptoms.

Treatment

In 1962, Watson-Jones[46] lamented that "the treatment of displacement of the upper femoral epiphysis is not a very happy chapter in the history of orthopaedic surgery." The litany of complications associated with this condition is long. In recent years, improvements in understanding of the stability status, imaging techniques, and fixation methods have led to significant changes in this outlook.

The immediate goals of treatment of an acute SCFE are threefold: (1) pain relief, (2) maintenance of an epiphyseal-femoral neck relationship that will avoid further slip progression, and (3) acceleration of epiphysiodesis so that risk of repeat slippage is eliminated. Long-term goals include avoidance of complications that could lead to significant premature secondary degenerative joint disease.

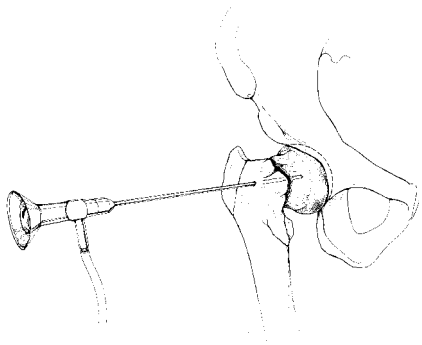


Fig. 3 Arthroscope positioned via guide pin and cannula after drilling to allow use of endoscope to determine potential fixation position and to rule out intra-articular transgression.

Preoperative Treatment

There are multiple opinions about the value and necessity of traction. Traction is usually used only for a brief period of time in the hope of reducing the potential for avascular necrosis.[1,8,32] Casey et al[32] had no cases of avascular necrosis in seven patients who had preoperative skin traction. This complication also was not seen in 11 patients who had preoperative traction and then underwent reduction under general anesthesia. However, avascular necrosis developed in 5 of 12 cases in which formal manipulation was done intraoperatively prior to fixation but preoperative traction had not been used; in several of these cases, overreduction occurred. The authors suggested that reduction without traction led to progressive compromise of the remaining posteroinferior medial vascular supply to the femoral head, especially if overreduction had occurred. This conclusion is supported by Green et al.[47]

In the operating room, reduction may be accomplished by formal manipulation. Sometimes reduction occurs incidentally while the patient is being placed on the fracture table. The frequency and magnitude with which this incidental reduction is obtained solely as the result of anesthetically induced muscle relaxation, pain relief, or positioning on the fracture table or operating table are not documented in the literature. In a personal review of seven cases of acute SCFE, I found the diminution in angle as the result of anesthetic and operative positioning to be approximately 50% (Fig. 4). Pre-

Fig. 4 Two-screw fixation of an acute SCFE. Incidental reduction was achieved at the time of anesthesia and positioning. No formal reduction maneuver was performed.

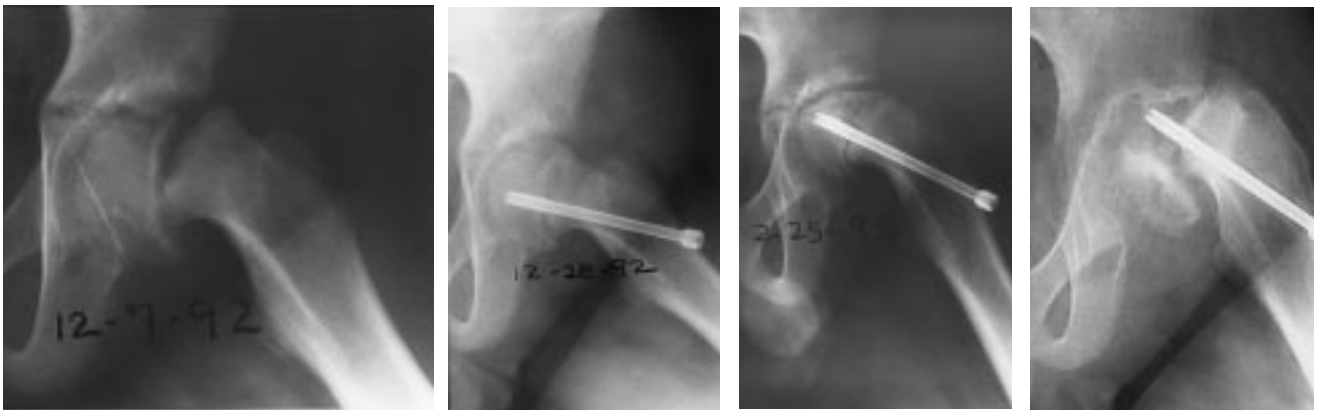
operative head-shaft angles averaged 75.3 degrees (range, 70 to 83 degrees). Postpositioning angles averaged 37.2 degrees (range, 35 to 40 degrees).

More formal reduction maneuvers that attempt to provide anatomic restoration of the head-neck relationship may produce undesired further epiphyseal displacement with an increased risk of avascular necrosis secondary to retinacular vessel compromise (Fig. 5). Carney et al[8] noted a 12% incidence of avascular necrosis and a 16% incidence of acute chondrolysis when formal intraoperative reduction was performed, followed by spica casting. Open reduction is infrequently used because of the high risk of avascular necrosis.

Spica Casting

Spica-cast treatment alone has been suggested because it eliminates the hazards of hardware insertion and removal,[1,13,35,48,49] and may eliminate the risk of avascular necrosis. There are only limited data on the efficacy of cast management of acute SCFE. As already mentioned, Carney et al[8] found a 12% incidence of aseptic necrosis and a 16% incidence of acute cartilage necrosis in patients treated with casting following manipulative reduction of acute slips.

Betz et al[48] treated 32 patients (37 hips) with acute-on-chronic or chronic SCFE with a regimen that included an average of 10 days of bed rest, longitudinal skin traction, and then spica casting for an average of 12 weeks. Eight patients (nine hips) had acute-on-chronic slips. No cases of avascular necrosis were seen in the 32 patients. One patient with chronic SCFE had progression of the slip while casted. Seven of the 37 hips (19%) had some narrowing of the cartilage space, but only 5 hips (14%) had definite chondrolysis. Two of the patients with chondrolysis were considered retrospectively to have had chondrolytic changes prior to casting.



A **B** **C** **D**

Fig. 5 Images of a patient with acute unstable SCFE. **A**, Before treatment. **B**, Immediately after formal reduction and fixation with a single screw. **C**, Onset of avascular necrosis was noted at follow-up 2 months after reduction and fixation. **D**, Progressive change occurred over the next year, with progression of deformity and intra-articular protrusion of the screw. Note lucent zone around screw shaft.

Meier et al[50] reported the data on 13 patients (17 hips) with stable SCFE treated with spica-cast immobilization for 3 months. Complications in 14 hips included pressure sores, progressive slip after cast removal (17%), and acute cartilage necrosis (53%). The chondrolysis was transient in four of the nine patients, but at 2 years all nine patients had radiographic evidence of degenerative joint changes. These dismal results led the authors to abandon this treatment technique.

Because of the cumbersomeness of the casting in obese patients and the potential of a high rate of acute cartilage necrosis, most orthopaedists have abandoned this technique for managing acute or chronic SCFE.

Internal Fixation

Sturrock[51] reported the first case of internal fixation of SCFE in 1894. The patient was a 13-year-old with an acute slip, which Sturrock fixed with a nail from the femoral neck into the epiphysis. The nail was removed 2 days later because of infection.

Changes in metallurgy design and materials have led to improved internal fixation devices and subsequent surgical techniques. There are currently a variety of devices, differing in terms of morphology, size, and number of implants necessary.[6,7,23,33,42,43,52-55] These developments have allowed diminution in the number of devices implanted, with consequent reduction of the potential joint transgression, vascular compromise, and loss of fixation that were associated with use of some of the earlier fixation devices.

The concomitant use of improved fluoroscopic imaging and cannulated techniques has improved the accuracy of positioning the implant, which has had a major impact on reduction of morbidity associated with internal fixation.

Bone-graft epiphysiodesis using an iliac-crest graft is advocated by some authors, in combination with either internal fixation or postoperative casting in patients with unstable acute slips.[1,13,49] The use of postoperative spica-cast immobilization, particularly in obese children, has been recommended by some authors as an adjunct to internal fixation with metal or bone-graft epiphysiodesis. The usual time for casting in obese children is between 12 and 14 weeks.

The use of percutaneous fixation techniques with one cannulated threaded device was first popularized by Morrissy in the 1980s (Fig. 6).[55,56] The advantages of diminished operative morbidity, improved visualization, and satisfactory fixation make these techniques attractive. The fixation device should be perpendicular to the epiphysis, not parallel to the femoral neck—a principle of internal fixation for femoral neck fractures (Fig. 7). A more anterior entry point allows central perpendicular fixation, which avoids misplacement of the device, especially into the supralateral corner of the epiphysis, with potential risk for avascular necrosis because of compromise of the artery of Brodetti.[57]

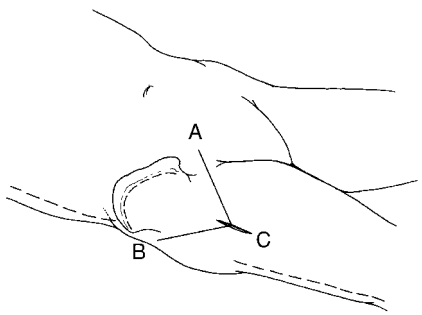


Fig. 6 Fluoroscopic imaging is used to determine lines on skin for percutaneous guide-pin placement. Lines overlying neck (bisecting femoral head, perpendicular to physis) in AP (A) and lateral (B) planes are used to determine femoral physeal center. C = skin incision.

Such central fixation was demonstrated by Ward et al[7] to enhance the rate of physeal closure. Ward et al, Aronson and Carlson,[6] Morrissy,[55] and Blanco et al[42] have all noted the diminished complications associated with the use of fewer implants, particularly when the fixation device is placed perpendicular to the epiphysis in the central zone at least 5 mm from the articular border.

Blanco et al[42] suggest that treatment of an unstable acute slip may require more than one screw, but their data do not substantiate this conclusion. Ward et al[7] found that single-pin fixation provided satisfactory stability in five of five hips with acute or acute-on-chronic slips. Aronson and Carlson[6] found loss of position after single-screw treatment in only one of eight patients with acute slips; a 6.5- or 7-mm-diameter screw seemed to provide adequate stability.

In canine[58,59] and bovine[60] models of experimentally produced SCFE, single-pin fixation provided 70% to 80% of the strength and stiffness of the intact physis in resistance to shear. Use of an additional pin provided some increase in shear resistance to acute failure. Whether this difference is clinically significant in the cyclically loaded human hip is unknown.

The usual operative technique for pin insertion is percutaneous, using 1- to 2-cm skin incisions. With this technique, the postoperative morbidity is low, and patients are commonly discharged within 24 hours of surgery. Crutch-protected ambulation with weight-bearing within the range of comfort is allowed. Although most authors suggest a period of protected weight-bearing of 6 to 12 weeks,[6,7,12,54,55] most surgeons find that patients are very comfortable and not compliant and often discontinue use of crutches after 1 week.

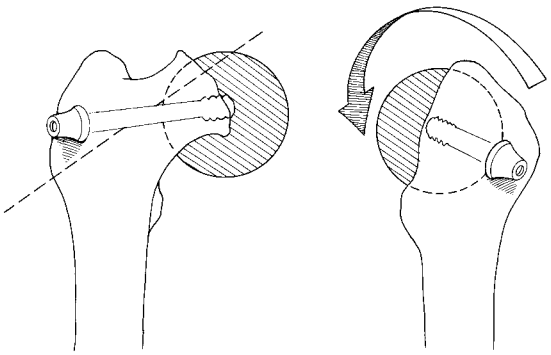


Fig. 7 Central screw position in thec femoral epiphysis is perpendicular to the physeal line, not parallel to the femoral neck.

Bone-Graft Epiphysiodesis

Advocates of the technique of bone-graft epiphysiodesis are a regional but adamant constituency.[1,13,49] These surgeons suggest that the advantages of the technique include accelerated physeal closure, avoidance of hardware hazards, and diminution of acute cartilage necrosis and avascular necrosis compared with other techniques (Fig. 8).

With acute SCFE, there is no immediate physeal stability with bone-graft epiphysiodesis; thus, the potential for graft failure with progression of the slip exists. For this reason, bone-graft epiphysiodesis in acute slips requires adjunctive immobilization by either internal fixation or postoperative casting. In 30 years' experience with 176 patients with 207 SCFEs, Weiner et al[49] treated 26 acute slips with bone-graft epiphysiodesis and spica casting for 6 weeks postoperatively. Acute cartilage necrosis developed in 7.7% of the treated hips, and avascular necrosis developed in 3.8%. In 1988 Weiner et al[61] published guidelines for an anterolateral surgical approach intended to reduce the problems associated with anterior approaches in obese patients.

Wolff et al[13] treated 7 acute and 17 acute-on-chronic cases of SCFE with either in situ pinning or bone grafting. They found a 14% incidence of avascular necrosis in the acute group and a 7% incidence of avascular necrosis in the acute-on-chronic group. No case of acute cartilage necrosis was seen. In the 12 patients treated with bone grafting alone, no evidence of avascular necrosis or acute cartilage necrosis was observed.

Contradictory data on results of bone-graft epiphysiodesis have been presented from other centers, although these reports have mainly focused on complications resulting from management of chronic slips.[53,62] All of these authors discuss an associated learning curve for performing this type of epiphysiodesis. The main problem in acute slips is the loss of epiphyseal position secondary to graft absorption or graft fracture. The authors comment on prolonged operative time, blood loss, and resultant thigh hypesthesia in patients treated in this manner. In a historical technical review of types of fixation for SCFE, Irani et al[53] noted one case of avascular necrosis and two failed epiphysiodeses in patients treated with bone-graft epiphysiodesis. Ward and Wood[62] reported on 17 hips in 17 patients with SCFE treated with bone-graft epiphysiodesis, four of whom had acute slips. Three of the latter four patients were treated in spica casts for 6 weeks after epiphysiodesis; two of the four patients had evidence of graft insufficiency with fracture and loss of position. The

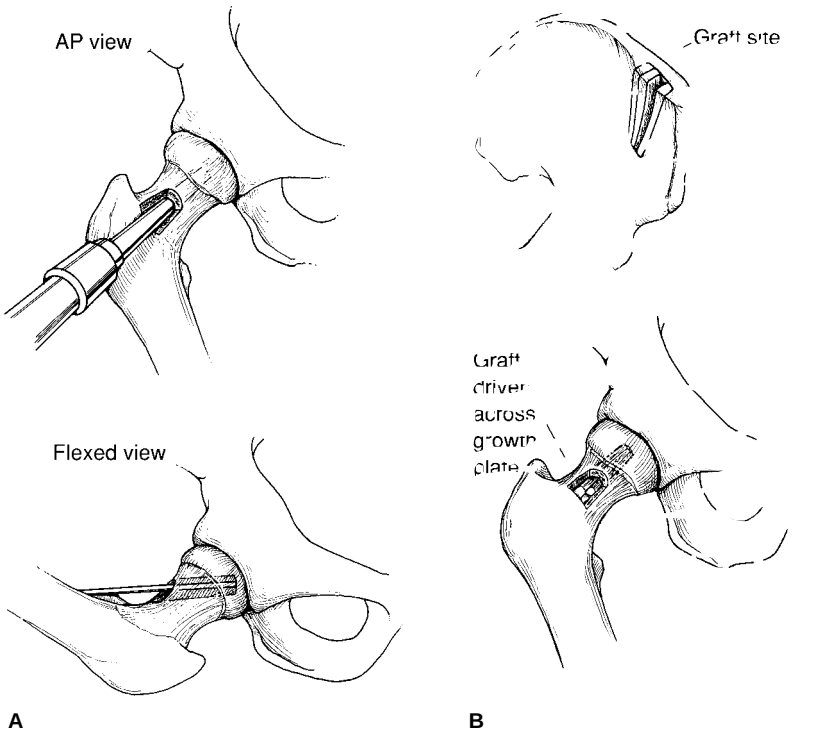


Fig. 8 **A,** Bone-graft epiphysiodesis approach and epiphyseal curettage. **B,** Bone grafting.

fourth patient had not been treated with a cast or internal fixation.

Because of the technical demands of the procedure, as well as the need for postoperative cast immobilization and its attendant complications, bone-graft epiphysiodesis may not be as appealing to surgeons who can provide immediate physeal stabilization and fixation with minimal operative morbidity by using percutaneous cannulated fixation techniques.

Intracapsular Osteotomy

Intracapsular osteotomy for management of acute SCFE must be considered an open reduction and internal fixation of an acute physeal fracture. Because of the unacceptably high rate of avascular necrosis (ranging from 20% to 30% in recent series),[63,64] it is not currently considered as primary treatment for the acute slip.

In a study of acute-on-chronic changes in seven patients, Fish[64] reported excellent results in five following fracture manipulation (without preoperative traction) and osteotomy of the supralateral neck with anatomic reduction and internal fixation of the epiphysis. The result was unsatisfactory in two patients (28.6%); one patient developed avascular necrosis, and another had significant progression of degenerative joint disease.

Broughton et al[63] reported a series of open reductions of 38 acute-on-chronic slips. Avascular necrosis developed in six patients, chondrolysis developed in one patient, and three patients had a combination of acute chondrolysis and avascular necrosis. Because of such dismal results, this procedure is not recommended for acute or acute-on-chronic slip management. I believe that primary femoral extracapsular osteotomy is not indicated at this time for treatment of acute or acute-on-chronic SCFE.

"Prophylactic" Treatment

"Prophylactic" treatment of the opposite asymptomatic hip has been reported in several series.[52,65,66] The rationale for such simultaneous treatment, usually with internal fixation, is based on the high incidence of eventual bilaterality in this condition. Bilateral involvement in chronic stable SCFE has been reported to occur in 40% to 70% of patients, especially if "silent slips" at the time of follow-up are included.[7] This prophylactic surgery is designed to prevent sequelae of an acute or chronic slip, such as proximal femoral deformity and secondary degenerative change, and to reduce the high risk of avascular necrosis with an acute slip. Treating both hips simultaneously also avoids the risk of later surgery should the slip occur on the opposite side.

O'Beirne et al[66] reported treatment of 15 asymptomatic hips with a single, noncannulated screw. No evidence of acute cartilage necrosis or avascular necrosis was seen, but one deep wound infection did occur on the prophylactically treated side.

Emery et al[65] reported the prophylactic use of three-pin fixation in 95 hips. Of the 285 pins inserted, four were placed intra-articularly, three were placed outside the head and neck, and three were bent. In 29% of the hips, the femoral epiphysis grew off the pin fixation. No episodes of avascular necrosis or acute chondrolysis were reported. There was a 15% complication rate in 64 patients who underwent pin removal in this series, the major complication being inability to remove the fixation devices.

Hansson[52] used a unique hook-nail device to pin 37 asymptomatic hips as part of simultaneous fixation in patients with unilateral slipped epiphyses pinned in situ. No case of avascular necrosis or other complication was reported.

Although current techniques of imaging and fixation have decreased operative morbidity, the potential complications from surgery on an asymptomatic uninvolved hip must be weighed against the advantages of a simultaneous procedure in someone who may not develop a slip on the opposite side. In patients in whom an acute slip is secondary to an unusual cause, such as a metabolic or an endocrine disorder, and who therefore have an extremely high likelihood of bilateral slip, simultaneous fixation seems justified.

In a 30-year review of 131 cases of SCFE (bilateral in 40) in patients with known endocrinopathies (panhypopituitarism, hypothyroidism, or hypogonadism), Wells et al[24] found a high potential for bilateral SCFE at initial presentation. There was a mean bone age delay of 4.6 years. Three of nine patients with acute-on-chronic slips had bilateral symptoms at initial presentation; in the remainder, bilateral disease developed within 28 months after the initial diagnosis. The authors suggested that surgeons should have a heightened awareness of possible endocrinopathies when children under the age of 10 years present with slips. Appropriate endocrine screening, particularly for underlying thyroid disease, appears prudent.

Rappaport and Fife[67] reviewed the data on patients with growth hormone deficiency who were undergoing treatment with human growth hormone. In their literature review, they found that 272 of 10,000 patients had evidence of SCFE. The acuity and magnitude of the slips and their treatment were not discussed. Patients with growth hormone deficiency and delayed physeal closure and patients treated with human growth hormone, with its attendant acceleration of growth, appear to be at higher risk than the

normal population for development of SCFE, which in most cases is bilateral.[27,67]

Segal et al[23] reviewed the data on 21 patients (33 hips) with juvenile SCFE that occurred at least 1 year earlier than the usual onset (13.5 years in boys and 11.5 in girls) and found that 10 of 33 slips were acute and 3 were acute-on-chronic—a very high combined incidence of 39.3%. Forty-seven percent of the patients had bilateral disease at presentation. In an additional nine patients, an acute slip developed in the opposite hip within an average of 13.6 months following the initial episode. Because of the eventual 81% bilaterality noted in this group of young patients, the authors recommended contralateral simultaneous fixation at the time of initial treatment, using a smooth-pin construct to prevent premature physeal closure if significant growth remains (Fig. 9). The authors also advocated a search for endocrine disorders, especially thyroid disease, in these young patients.

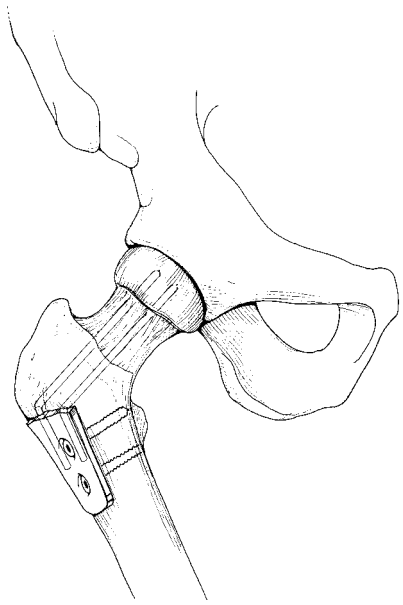


Fig. 9 Proposed construct composed of a plate and a smooth pin for use in very immature patients to allow continued physeal growth.

In younger patients, unique fixation designs have been developed to allow growth.[25,52,68] Hansson and colleagues[52,68] report use of a hook-nail device with smooth-pin fixation, which allows continued physeal growth in younger patients. In 38 cases (in which the asymptomatic, uninvolved opposite side was also pinned, for a total of 75 pinnings), they found no avascular necrosis in 74 hips fixed in situ. The 5- to 15-mm-long pin was set proportional to the growth expected. No evidence of premature closure was noted. Equal amounts of growth were seen on the asymptomatic uninvolved side and the slip side. As much as 15 mm of growth was reported. In 12 hips there was no growth on either side and no change in pin position. Hansson[52] made no specific comment about use of the hook-nail in acute slips; however, in 12 patients displacement by greater than half of the neck occurred, and four hips were considered spontaneously reduced under general anesthesia.

In a condition such as renal osteodystrophy, which is reversible by renal transplant and hence has the potential for resumption of normal physeal metabolism and growth, fixation with a smooth device provides a unique means of management.

Complications

A significant frequency of complications has been reported following acute SCFE. Some of these complications are inherent to the injury and reflect the magnitude of epiphyseal damage done at the time of the injury. The association of avascular necrosis with acute SCFE is high and is related to the vascular compromise that occurs at the time of the initial injury.[1,12,32,34] Green et al[47] believe that early reduction diminishes retinacular vessel obstruction, and they and others[69] speculate that increased intra-articular pressure and vascular tamponade are likely contributing factors in the development of avascular necrosis. However, Loder et al[12] have documented the lack of relationship between the time from injury to definitive treatment and the development of avascular necrosis, with or without preoperative traction. The abnormal head-neck relationship also is postulated to provide further mechanical vascular compromise, as are reduction and inaccurate epiphyseal fixation. To date, no imaging study has been proved to be a highly sensitive and specific way of identifying avascular change before treatment.

Acute cartilage necrosis is thought to occur irrespective of the mode of treatment. Although the relative association of chondrolysis with intra-articular violation by a variety of devices has been stressed, it must be remembered that acute cartilage necrosis occurs without any treatment and also is seen following casting with or without bone-graft epiphysiodeses.

Some investigators[70] have hypothesized that thermal injury secondary to use of the drill and power reamer at the time of internal fixation may predispose the femur to failure. In a small pilot study using human and synthetic polymer femoral head and neck models, temperature measurements were made during insertion of Knowles pins or cannulated screw reamers at 500 to 700 rpm. In nine trials of each device in each model, they found that the power reamer produced higher levels of heat than did simple insertion of the Knowles pin. The range of temperature produced while reaming was significant. Further experi-

mental and clinical validation is required before indictment of the cannulated screw reamer can be substantiated. Most surgeons use hand, not power, reaming prior to screw insertion.

Potential mechanical complications of treatment include hardware loosening,[71] neck fractures,[70] and slip progression. Progression of the slip after internal fixation and bone-graft epiphysiodesis has been reported to occur infrequently.[6,7,42,72]

With modern fixation devices, adverse reactions to implants are rare. In view of the difficulty and complications associated with hardware removal, many pediatric orthopaedists question the need for it under normal conditions.

In acute SCFE, the hardware provides stability until fusion occurs. A similar biologic concept is present in other musculoskeletal procedures, such as acute fracture treatment and spinal deformity instrumentation and fusion.

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