Slipped Capital Femoral Epiphysis and Its Variants

5

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Introduction

Slipped capital femoral epiphysis (SCFE) has been discussed in the orthopaedic literature since the late nineteenth century [1]. Classically, the goals of treatment have been to stabilize the physis and prevent the iatrogenic complications of osteonecrosis and chondrolysis [2, 3]. This schema is currently undergoing re-evaluation and considerable debate, due to the recognition that even mild stable SCFE can cause femoroacetabular impingement (FAI) [4–12]. Although the potential for impingement in SCFE has been recognized for some time [4, 5, 13–16], preventing impingement and the resultant damage to the cartilage and labrum is becoming a more important principle of SCFE treatment. This has occurred in part because the idea of FAI has gained acceptance in the orthopaedic community. In addition, improved knowledge of the vascular anatomy responsible for femoral head perfusion [17] has allowed the development of a safe technique for open reduction and internal fixation of the displaced epiphysis [5, 18].

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Background

Strictly defined, a SCFE is displacement of the capital femoral epiphysis from the metaphysis, through the physis. The epiphysis remains located in the acetabulum, tethered by the ligamentum teres, and the metaphysis moves relative to the epiphysis. The most common pattern is a varus slip, where the metaphysis moves superiorly and anteriorly. Valgus slips, where the metaphysis slips inferiorly and posteriorly, occur in about 4 % of cases [19, 20].

The natural history of SCFE is controversial. While it is generally accepted that more severe slips and unstable slips have a worse prognosis than a stable mild slip [3, 7, 21], a closer look at the long-term outcomes reveals a more complicated picture. Long-term follow-up of patients who underwent treatment of SCFE in the mid-twentieth century, reveals slow yet progressive decline, with about 10 % of patients undergoing an additional reconstructive procedure [21, 22]. Patients in their mid-40s with mild SCFE reported an average Iowa hip score of 87, consistent with good but not excellent function. This represented a clear shift from their average Iowa Hip Rating of 93, when the patients were in their 20s and 30s. For patients with moderate and severe slips, the average Iowa Hip Rating decreased to 80 and 70, respectively, when the patients were in their 40s. This is as compared to average scores in the mid-80s a decade previously. A score of 80 is still considered to be good function, while a score of 70 is considered borderline fair function [21]. Investigation of the Hamann-Todd osteological collection revealed a greater prevalence of grade 2 or 3 osteoarthrosis in femurs with mild post-slip morphology as compared to age and gender-matched controls [23]. In the specimens with mild arthrosis, the authors observed flattening and the first arthritic changes in the anterosuperior region of the acetabulum, consistent with an impingement mechanism of cartilage damage. Arguably, this paper was published prior to the description of FAI, such that some of the femurs that were considered to have post-slip morphology may have actually had idiopathic cam deformities.

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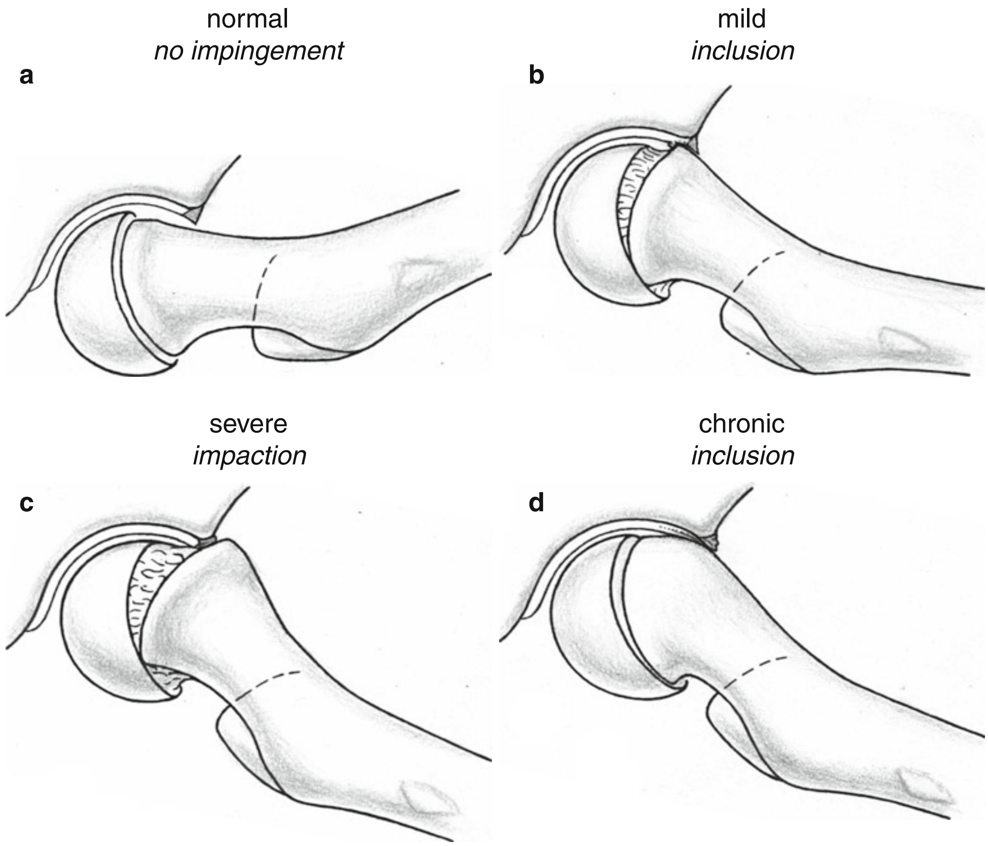

Fig. 5.1 Inclusion and impaction-type impingement in SCFE. (**a**) Normal hip. (**b**) Inclusion occurs with mild to moderate SCFE, where the metaphyseal deformity is still small enough to be included in the acetabulum. The prominent metaphysis causes cartilage and labral damage when the hip is flexed, analogous to cam FAI. (**c**) Impaction occurs in moderate to severe SCFE when the metaphyseal deformity is too large to enter the acetabulum. The deformity limits range of motion, and the metaphysis impacts the acetabular rim causing labral crushing analogous to pincer FAI. With forced flexion, the femur levers on the acetabulum, which also occurs in pincer-type FAI. (**d**) With metaphyseal remodeling in chronic SCFE, the deformity is reduced enough that inclusion impingement can occur again (Reprinted with permission, Leunig [5])

Although the terms cam and pincer impingement are used to describe FAI, slightly different terminology has been used to describe the impingement that occurs as a result of SCFE (Fig. 5.1) [4, 5]. Inclusion describes the impingement that occurs when the deformity is small enough to be included in the acetabulum when the hip is flexed. This happens with mild slips and after femoral neck remodeling in severe slips. With inclusion, the prominent anterior metaphysis abrades the cartilage and the labrum, analogous to cam impingement [4, 5]. Impaction describes impingement that occurs when the metaphysis impacts the acetabular rim because the deformity is too large to enter the acetabulum. Chronic impaction can cause erosion of the acetabular rim, and forced motion can cause the femoral head to lever on the acetabular rim [4, 5]. This is analogous to pincer impingement. The concepts have been somewhat validated by three-dimensional computer modeling of range of motion in mild, moderate, and severe slips demonstrating limited range of motion and alterations of the gait cycle to accommodate the impingement [4, 8].

The development of a safe surgical hip dislocation [24] allowed intraoperative observations of cartilage and labral damage in SCFE [5], providing further insight and confirmation of these ideas. The metaphysis is rough and at least level, if not more prominent than the femoral head, creating a cam deformity (Fig. 5.2a). In these cases, hip flexion causes impingement of the metaphysis on the anterosuperior acetabulum and labrum (Fig. 5.2b) [5, 10]. The degree of the slip determines whether the metaphyseal prominence is able to enter the acetabulum. In severe SCFE, the metaphysis is so prominent that it cannot enter the joint [5] and, consequently, damage is limited to the labrum and rim. Metaphyseal remodeling, which previously was interpreted as a positive adaptation, enables the metaphysis to once again enter the acetabulum. This changes the severe SCFE from pincer-type impingement into cam-type impingement, which is more destructive to the acetabular cartilage. In this setting severe labral and cartilage damage occurs at the zone of impingement, and full-thickness acetabular cartilage lesions are often observed (Fig. 5.2c) [5, 10, 25, 26]. This degree of FAI is also the likely mechanism for radiographic chondrolysis occurring after a severe SCFE, analogous to mechanical chondrolysis occurring when an implant is prominent within a joint.

Classification

Traditionally, SCFE was classified as pre-slip, acute, chronic, or acute-on-chronic, depending on whether symptoms were present for more or less than 3 weeks. This has been replaced by a different system; slips are now more often described as

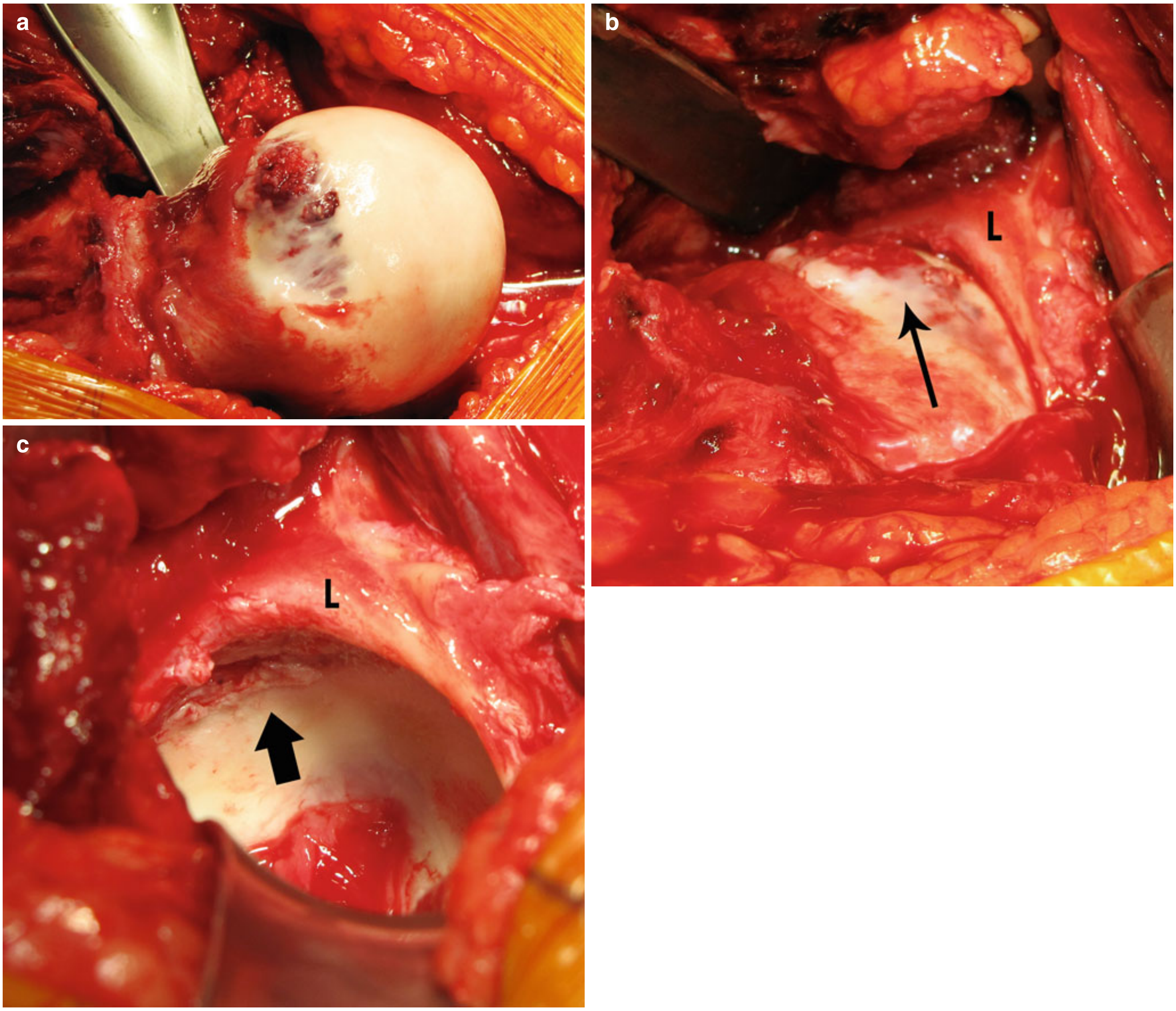

Fig. 5.2 The appearance of the femoral head (**a**, **b**) and acetabulum (**c**) in a moderate SCFE. The periosteum over the metaphysis is partially torn (**a**) and the rough surface of the metaphysis (*thin arrow*) protrudes above the femoral head cartilage. (**b**). With the hip flexed, the rough metaphysis abraded the acetabulum and caused a full-thickness cartilage lesion (*thick arrow*) (**c**), *L* labrum

either stable or unstable, regardless of symptom duration. Classification by physeal stability also has prognostic value [27, 28]. A slip is considered stable if the patient can walk or weight bear, with or without crutches. Patients with unstable slips are unable to walk, and are more likely to develop avascular necrosis [27, 28].

Interestingly, the clinical assessment of physeal stability does not always correlate with the intraoperative physeal stability [29]. The stability of the physis has been assessed in series of patients undergoing open reduction for SCFE [26, 29]. Stability was categorized as grossly unstable, easily separable, or stable. In grossly unstable physes, the anterior periosteum was visibly torn and the physis separated easily from the metaphysis. In easily separable physes the periosteum was intact, but once the periosteum was freed the physis separated easily from the metaphysis. Patients with a stable physis had an intact periosteum requiring dissection and separation of the physis for reduction on the metaphysis [26]. Comparison of physeal stability at the time of surgery with the clinical classifications reveals the limitations of this system [29]. In this series, 61 % of patients with clinically classified stable slips were found to have mechanical disruption of the physis, while 24 % of patients were classified clinically as unstable but had stable physes intraoperatively [29]. These patients with stable physes may be unable to weight-bear because of painful impingement-related chondrolabral damage.

Open reduction of SCFE has also provided some explanation about the potential etiology of avascular necrosis. It is commonly thought that the separation between epi- and metaphysis is the main cause of necrosis. However, intraoperatively all but two unstable epiphyses were perfused, regardless of the time between the onset of symptoms and surgery [29]. This means other factors, like the type of treatment (e.g. a "gentle" reduction), must play a role in causing avascular necrosis.

Clinical and Radiographic Evaluation

In an unstable SCFE, the patient may report a history of prodromal or "pre-slip" symptoms. These consist of leg weakness, limping, and groin or knee pain, all of which may be exacerbated by standing or walking. An unstable slip is characterized, however, by extreme pain such that the patient resists any attempt at weight bearing or movement of the leg, with or without crutches. There may also be an external rotation deformity or shortening of the leg [3, 7]. Patients with stable SCFE may describe groin, thigh, or knee pain and often walk with a limp. Not infrequently, the initial symptom is knee pain, and some SCFE patients do not develop groin pain. Symptoms may be present for months or years and may have a waxing and waning course. Up to 50 % of patients have bilateral SCFE, so the presence of symptoms in the other hip is also important to note [30, 31]. Physical exam reveals a loss of flexion and internal rotation, and hip flexion may cause spontaneous abduction and external rotation [3, 7], known as the Drehmann's sign. These patients may also have a leg length discrepancy and demonstrate an antalgic gait with loss of internal rotation, abduction, and flexion.

Patients with suspected SCFE should have both AP and lateral pelvic radiographs (Fig. 5.3). Obtaining a frog-lateral radiograph may be difficult or impossible for a patient with an unstable slip, but a Dunn or true cross-table lateral x-ray of the affected hip is also appropriate. The symptomatic side should be compared to the contralateral side. If the SCFE is early or mild, it may only be visible on the lateral radiograph or relative to Klein's line. Normally, a line drawn tangent to the lateral femoral neck (Klein's line) bisects some portion of the femoral head, however in SCFE the line is lateral to the head (Fig. 5.3) [32]. Steel's sign is also occasionally visible in early or mild SCFE, with increased density adjacent to the physis. This occurs when the epiphysis has displaced posteriorly but not medially, causing the epiphysis and metaphysis to overlap radiographically (Fig. 5.3) [33]. The severity of the SCFE can be evaluated by the Southwick angle which is measured on a lateral radiograph and represents the difference between the head-shaft angle of the affected and normal side. Mild slips measure less than 30°, moderate slips are between 30° and 50°, and severe slips are greater than 50°. Alternatively, the slip severity can be evaluated by the amount of relative displacement between the epiphysis and metaphysis [34]. In this system, mild SCFE have less than 33 % displacement, moderate slips have 33–50 % displacement, and severe slips have greater than 50 % displacement. In chronic slips, a periosteal reaction, remodeling, or new bone formation may be visible.

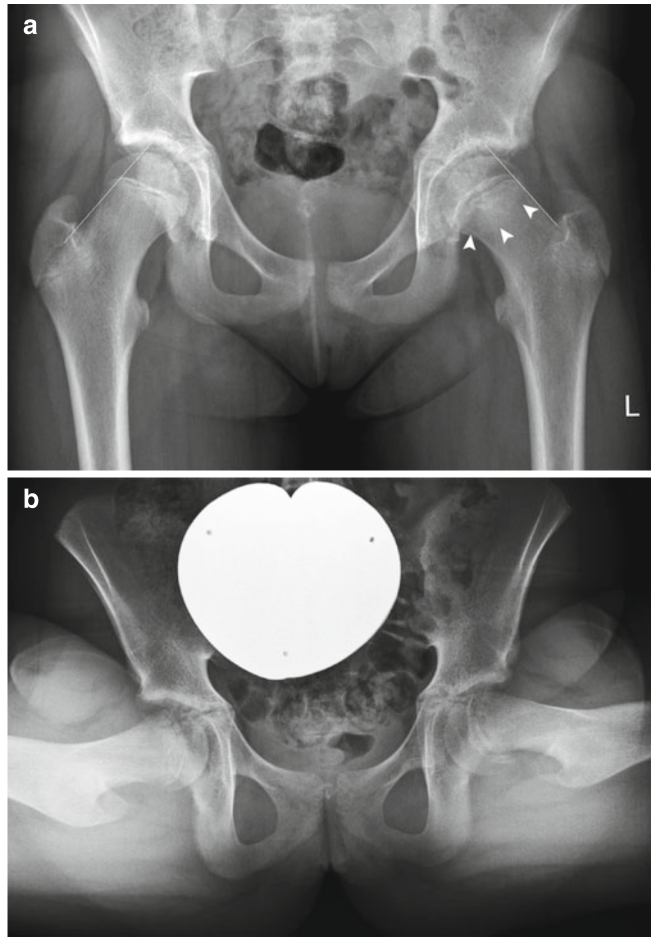

Fig. 5.3 (**a**) AP pelvis radiograph of a mild slip. The physis is widened and more of the femoral head is medial to Klein's line when compared to the contralateral side. Steel's sign, increased metaphyseal density (*arrow heads*) is also visible. (**b**) The slip is clearly visible on the frog lateral radiograph

In the pre-slip stage, an MRI will reveal bone marrow edema around the physis [35], but no physeal displacement. MRIs obtained in patients with "acute" slips demonstrated some evidence of callus in all patients, even for those with SCFE associated with a fall (Fig. 5.4) [36]. Patients whose SCFE was associated with a fall also had visible disruption of the physis and periosteal sleeve on the MRI, indicative of an unstable slip [36]. MRI can also provide early diagnosis of osteonecrosis in chronic slips and radial MRI slices are useful for evaluating the head-neck offset and impingement in chronic SCFE [37, 38].

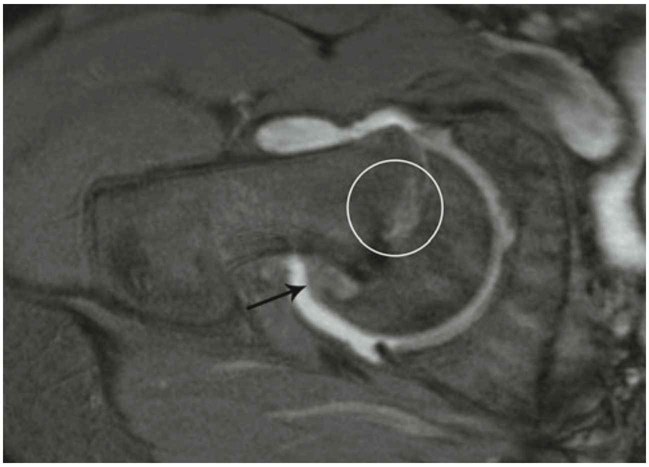

Fig. 5.4 Radial T2 MRI of an acutely unstable slip. Callus is visible posteriorly (*arrow*) and bone marrow edema is present around the physis (*circle*). A closed reduction of the epiphysis would stretch the retinacular vessels over the posterior callus, endangering the blood supply to the femoral head

Treatment

The ultimate goal of treatment is to obtain the best possible hip function. For SCFE this involves stabilizing the physis, correcting the deformity, and avoiding iatrogenic complications of osteonecrosis and chondrolysis. Thus, important factors to consider when deciding on treatment include whether or not the physis is open or closed, the stability of the physis, the degree of the deformity and the potential for impingement, and the treating surgeon's ability and experience with complex hip surgery.

For acute or unstable SCFE, one goal of treatment is to stabilize the physis and prevent progression of the slip. Pinning in situ has long been the standard of care [2, 3, 7], with reasonable results after long-term follow-up [21, 22]. Closed reduction is not recommended due to the risk of osteonecrosis. It is now understood that most SCFE have some amount of posterior callus, regardless of the duration of symptoms [18, 36, 39]. Reducing the epiphysis without removing the posterior callus stretches the retinacular blood vessels and places the blood supply of the femoral head at risk, regardless of how "gentle" the reduction maneuver is. The disadvantage of pinning in situ is that it does not correct the anatomic deformity caused by the SCFE, meaning that the patient is likely to have FAI.

Contemporary treatment of SCFE should, then, also correct the anatomic deformity to prevent impingement, continued cartilage damage, and subsequent arthrosis. For mild SCFE with slip angles <30° and no translation of the epiphysis on the metaphysis, the slip may be pinned in situ and the anterior metaphysis can be decompressed either arthroscopically or via a mini-open anterior approach, similar to standard treatment for FAI [25]. These approaches are discussed extensively in other chapters of this book, and the reader is directed to these for further details regarding the technique.

Authors' Preferred Technique

If the surgeon is technically capable, open reduction and internal fixation of unstable or moderate to severe SCFEs via a surgical hip dislocation and a modified Dunn approach is the ideal treatment method as it enables safe correction of the deformity as well as stabilization of the physis [5, 18, 24, 26, 40]. The procedure is complex and should not be attempted by those inexperienced with the technique. Thus, for patients with moderate to severe deformity, we recommend that patients be referred urgently to a tertiary-care center with this capability. Depending on the clinical circumstances and the proximity to a tertiary care center, the surgeon unfamiliar with the modified Dunn procedure may consider temporary stabilization of the epiphysis prior to transfer of care.

The patient is placed in the lateral decubitus position and the leg is draped freely. A sterile bag is placed at the anterior portion of the table to maintain sterility of the leg when the hip is dislocated. The incision is centered over the anterior third of the greater trochanter, and is generally about 20 cm long. Proximally, the fascia is split between the gluteus maximus and medius, distally the iliotibial band is divided in line with the femur. Patients with SCFE frequently have an external rotation contracture, which can narrow the normal distance between the posterior border of the greater trochanter and the posterior acetabulum and may render the execution of the trochanteric osteotomy more difficult. Internal rotation of the leg and dissection of the overlying bursa and adipose tissue facilitates identification of the posterior border of the gluteus medius. The trochanteric osteotomy should be performed so that the gluteus medius, gluteus minimus tendon, and vastus lateralis, are attached to the trochanteric fragment, but that the external rotators and piriformis remain attached to the femur. The osteotomy itself is made from the postero-superior edge of the trochanter to the posterior border of the vastus lateralis, anterior to the trochanteric crest. This creates a fragment that is usually 1–1.5 cm thick, depending on the size of the patient.

The trochanteric fragment is then mobilized with careful dissection between the piriformis tendon and gluteus medius and elevation of the vastus lateralis along its posterior border to the level of the gluteus maximus tendon insertion. Any remaining gluteus medius fibers on the femur are also released so that the fragment can be taken anteriorly. With the leg in flexion and external rotation, the gap between the piriformis and gluteus minimus is easier to identify. The capsular insertion of the gluteus minimus is carefully released, further exposing the superior and anterior capsule. It is important that

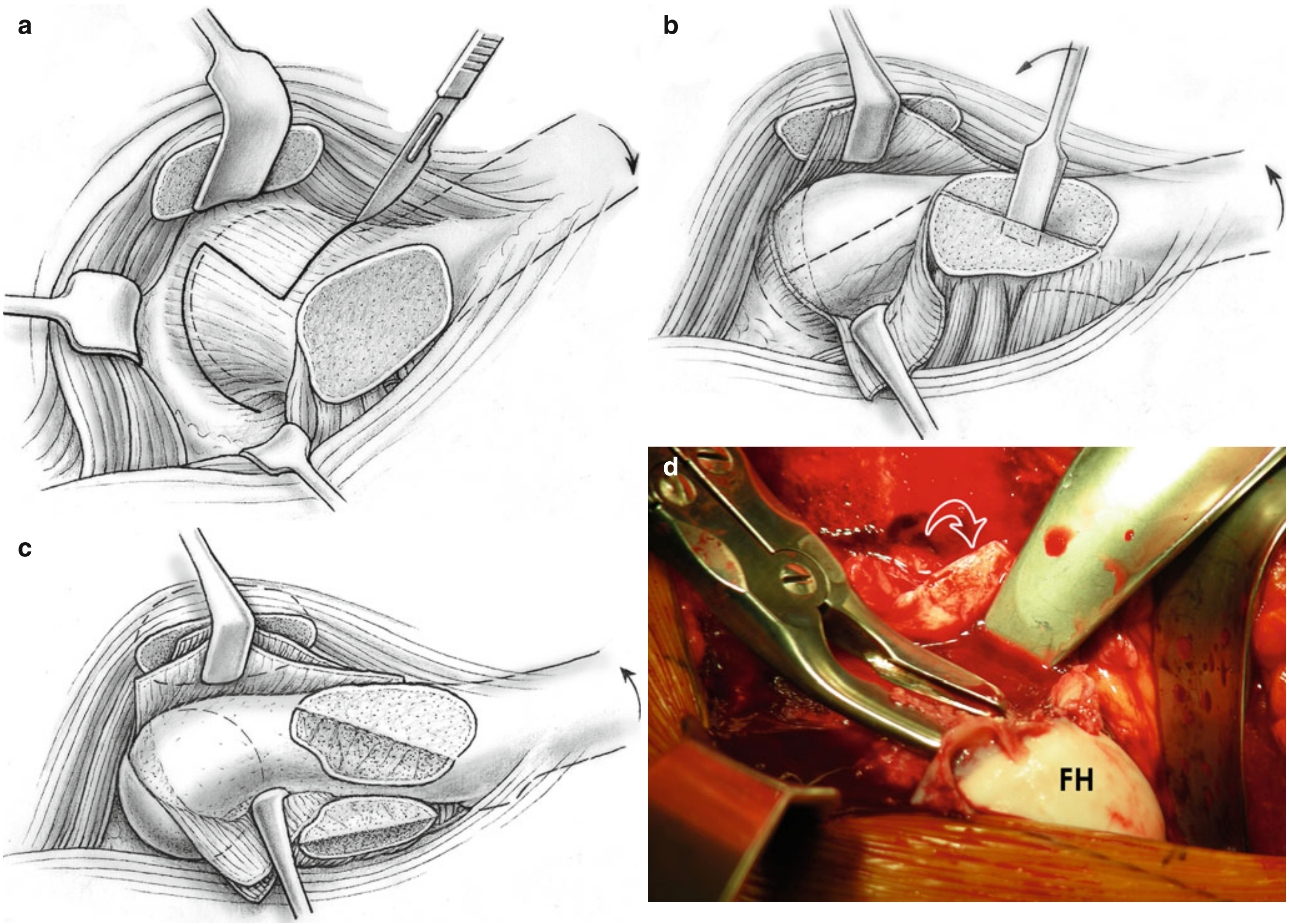

Fig. 5.5 Capsulotomy and creation of the extended soft tissue flap. (**a**) The first cut of the capsulotomy is made along the axis of the femoral neck, beginning at the anterior edge of the stable trochanter. The proximal and distal limbs are made in an inside-out manner to protect the cartilage and the labrum. Proximally, the cut can be made to the piriformis tendon but should not extend beyond the tendon (Reprinted with permission, Ganz [40]). (**b**) An extended soft tissue flap must be created to mobilize the retinacular vessels perfusing the femoral head. This allows the epiphysis to be safely separated from the metaphysis. The external rotator muscles are first mobilized through the apophysis of the greater trochanter (Reprinted with permission, Leunig [18]). (**c**) The remainder of the soft tissue flap is carefully mobilized via subperiosteal dissection (Reprinted with permission, Ganz [40]). (**d**) Intraoperative photo of the soft tissue flaps (*open arrow*) following mobilization

the dissection remains anterior to the piriformis tendon so that the deep branch of the medial femoral circumflex artery as well as the anastomosis between the inferior gluteal artery and medial femoral circumflex arteries are undisturbed.

The first cut of the capsulotomy is made in line with the femoral neck axis, beginning at the anterior superior edge of the stable trochanter (Fig. 5.5a). The capsulotomy is then extended perpendicularly along the capsular insertion at the anterior femoral neck, allowing creation of a capsular flap. The rest of the capsulotomy can be performed in an inside-out manner, which helps to protect the cartilage and labrum. The proximal portion of the capsulotomy is extended along the postero-superior rim of the acetabulum to the piriformis tendon. Retraction of the capsular flaps with two Langenbeck retractors and a narrow spiked Hohmann retractor placed just lateral to the anterior inferior iliac spine facilitates examination of the joint.

If the epiphysis is frankly unstable or its stability is uncertain, it should be prophylactically pinned with two 2 mm Kirschner wire prior to dislocation. No attempt should be made to reduce the epiphysis at this time, because of the risk of stretching the posterior retinacular blood vessels over the posterior callus. The hip is then gently flexed and externally rotated and the leg placed into the sterile bag at the anterior aspect of the table. The femoral head subluxes but will not frankly dislocated until the ligamentum teres is divided. After dividing the ligamentum teres, the head can be dislocated and the degree of acetabular damage fully assessed. In severe slips, dislocation may be difficult or impossible at this stage. If the epiphysis spontaneously falls into the acetabulum after mobilization, it is difficult to retrieve, thus a sponge should be placed into the acetabulum to prevent this.

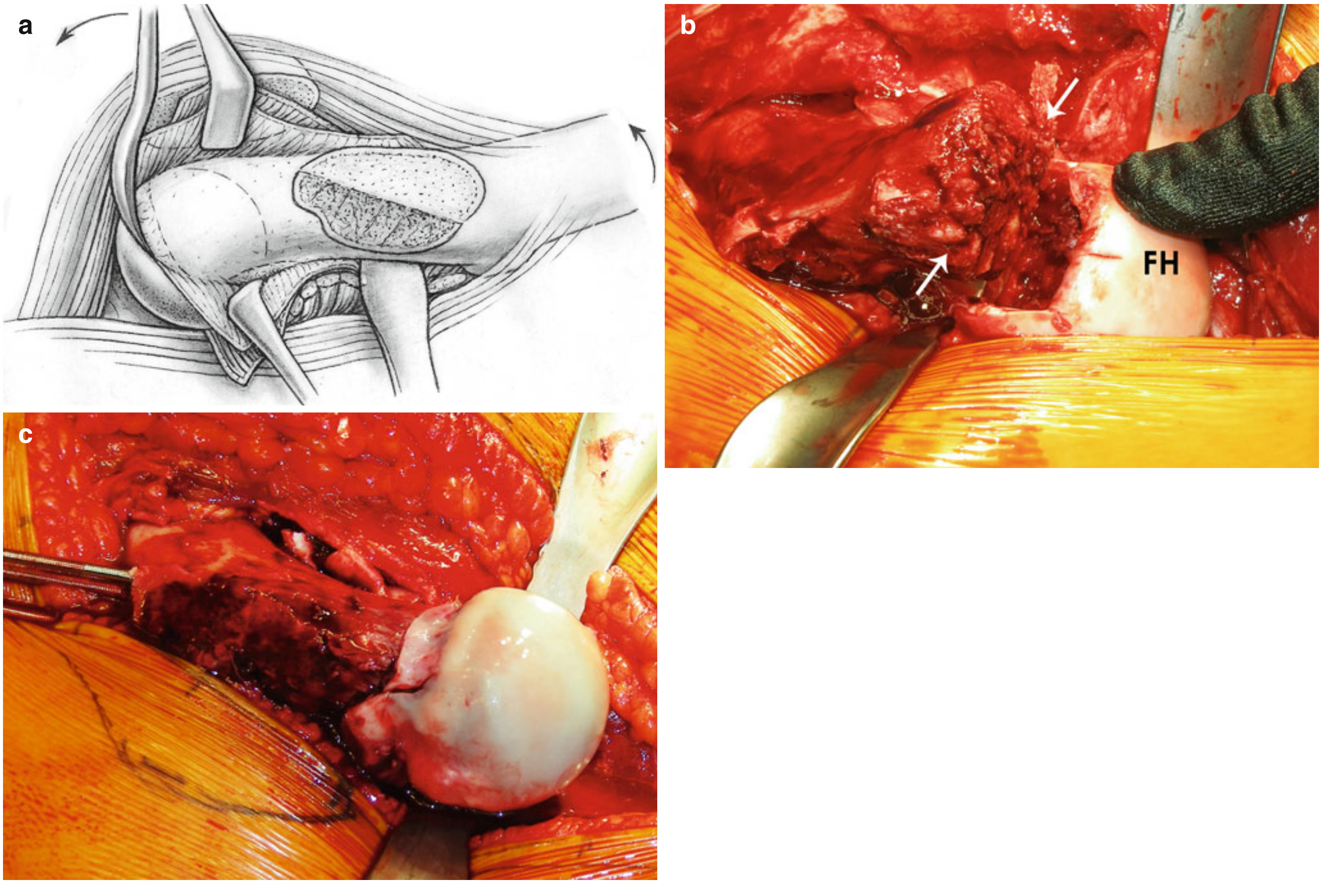

Fig. 5.6 Reduction of the epiphysis. (**a**) Using a chisel, the epiphysis is carefully mobilized through the physis (Reprinted with permission, Leunig [18]). (**b**) Intraoperative photo of the femur, following epiphyseal mobilization. The posterior callus can now be removed from the metaphysis (*arrows*) and the remainder of the physis is curettaged from the epiphysis. (*FH* femoral head) (**c**) The epiphysis is then reduced and pinned with a K-wire from the fovea to the lateral cortex. Note the significant improvement in the head-neck offset

The retinaculum containing the blood vessels is a slightly mobile layer of connective tissue located on the posterior superior aspect of the femoral neck. To more effectively protect the blood vessels from tension or tearing during the manipulation and reduction of the femoral epiphysis than with the original Dunn technique [41], a larger soft tissue flap must be created. The head is reduced back into the acetabulum during this step. The posterior aspect of the stable trochanter proximal to the visible apophysis is mobilized with an osteotome. The cancellous bone is carefully removed in an inside-out manner from the periosteum down to the level of the neck surface. Simultaneously, the periosteum along the antero-lateral femoral neck is incised along the neck axis, beginning at the greater trochanter, and is carefully elevated using an elevator and scalpel. Care is taken to preserve the attachment of the periosteum and retinaculum at the femoral head. The periosteal release is carried out distally and posteriorly to the base of the lesser trochanter. To release the periosteum anteriorly, the femoral head is gently re-dislocated and the periosteum is elevated to the level of the lesser trochanter. Care must be taken to keep Weitbrecht's ligament as part of this medial flap. Following the full release, there should be a periosteal tube around the femoral neck that remains attached to the epiphysis. If there are concerns about the perfusion of the head, it can be reduced and the perfusion re-evaluated with a drill hole or with laser-Doppler flowmetry [42].

With the femoral head dislocated, the epiphysis can be mobilized from the metaphysis (Fig. 5.6). K-wires that were used to stabilize the epiphysis can be removed. A curved 10 mm chisel is used to carefully mobilize the physis. In unstable slips, it may take little to no effort to mobilize the physis whereas in more chronic slips division of bridging callus in the postero-medial recess between epiphysis and metaphysis may be necessary or helpful for mobilizing the physis.

Once the epiphysis has been mobilized, it is manually tilted behind the metaphysis and the working space is increased with adduction and slight external rotation of the femur. This maneuver is executed slowly, with constant visualization of the soft tissue flap to ensure that it remains relaxed. The callus on the posterior aspect of the neck is then palpable and can be removed in a proximal to distal direction with a straight chisel.

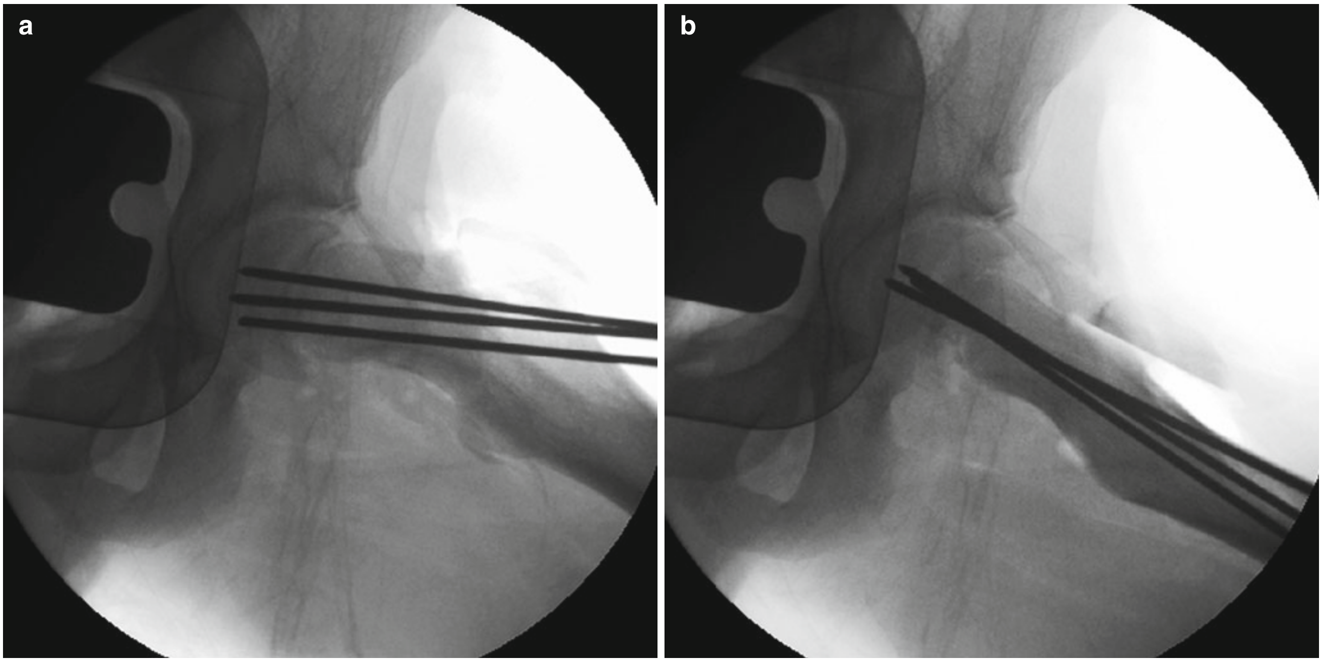

Fig. 5.7 Intraoperative fluoroscopic images following femoral head reduction. The epiphysis is centered on the metaphysis in both the AP (**a**) and lateral (**b**) views

Rounding of the upper surface of the metaphysis can also be performed to create a larger area of contact with the epiphysis. The remaining physis is curettaged from the epiphysis under manual stabilization. Usually, intact femoral head perfusion can be observed with bleeding of the newly exposed epiphyseal bone. However, sometimes bleeding becomes demonstrable only after anatomic reduction of the epiphysis or after the head has been reduced back into the acetabulum, allowing complete unfolding of the retinacular flap.

The epiphysis can now be reduced onto the metaphysis. If there is any tension on the retinaculum, the reduction maneuver is stopped and the cause of the tension is addressed. The epiphysis should be centered on the neck, with an equal distance between the border of the epiphysis and the metaphysis in all planes. The rotation of the epiphysis is evaluated with respect to the location of the retinaculum and the fovea. The epiphysis is provisionally fixed with a fully threaded K-wire inserted retrograde, from the fovea to the lateral cortex of the femur. The wire is cut and withdrawn from the lateral cortex so that the tip is level or just slightly below the femoral head cartilage. The head is reduced and the reduction evaluated. Intraoperative fluoroscopy is used to evaluate the angle of the head on the neck—the relative varus or valgus of the head (Fig. 5.7). Once the optimal alignment of the femoral head is achieved, one or two additional fully threaded K-wires are placed from lateral to medial to definitively fix the femoral head (Fig. 5.6d). No bone grafting is necessary as any existing gaps heal spontaneously (Fig. 5.8).

The periosteum is loosely readapted with a few interrupted stitches, taking care to avoid any tension on the repair or vessels. The capsule is also closed in a tension-free manner. Occasionally, the piriformis tendon can create capsular tension; if this occurs, the tendon should be released. If the trochanter fragment is reduced slightly more distally, care must be taken that it does not compress the capsular tissue at the level of the distal neck. The trochanteric fragment is fixed with two cortical screws and the soft tissue is closed in a layered fashion. In general, a layered closure eliminates any dead space, such that a drain is not necessary.

Postoperatively patients remain toe-touch weight-bearing for 6–8 weeks. Patients use continuous passive motion for 3 weeks postoperatively. The initial postoperative physical therapy is quite limited to allow the trochanter and epiphysis to heal. While inpatient, patients are taught how to safely use crutches, lift their leg, and navigate the stairs. An x-ray is obtained 4–6 weeks postoperatively to assess healing and whether the patient should continue toe-touch weight bearing or may gradually advance weight-bearing. Patients may fully weight-bear once there is radiographic evidence of both femoral neck and trochanter healing which normally occurs 8–10 weeks postoperatively. Exercises for abductor strengthening and gentle range of motion are started 6–8 weeks postoperatively and the patient is re-evaluated 12–16 weeks after surgery. Implant removal may be scheduled 1 year post-operatively.

The treatment of healed SCFE depends on the degree of the slip and the associated deformity. In cases with a mild to moderate head tilt, treatment can address the resultant FAI. This can be achieved arthroscopically (Fig. 5.9), open, or via a mini-open approach, depending on the degree of

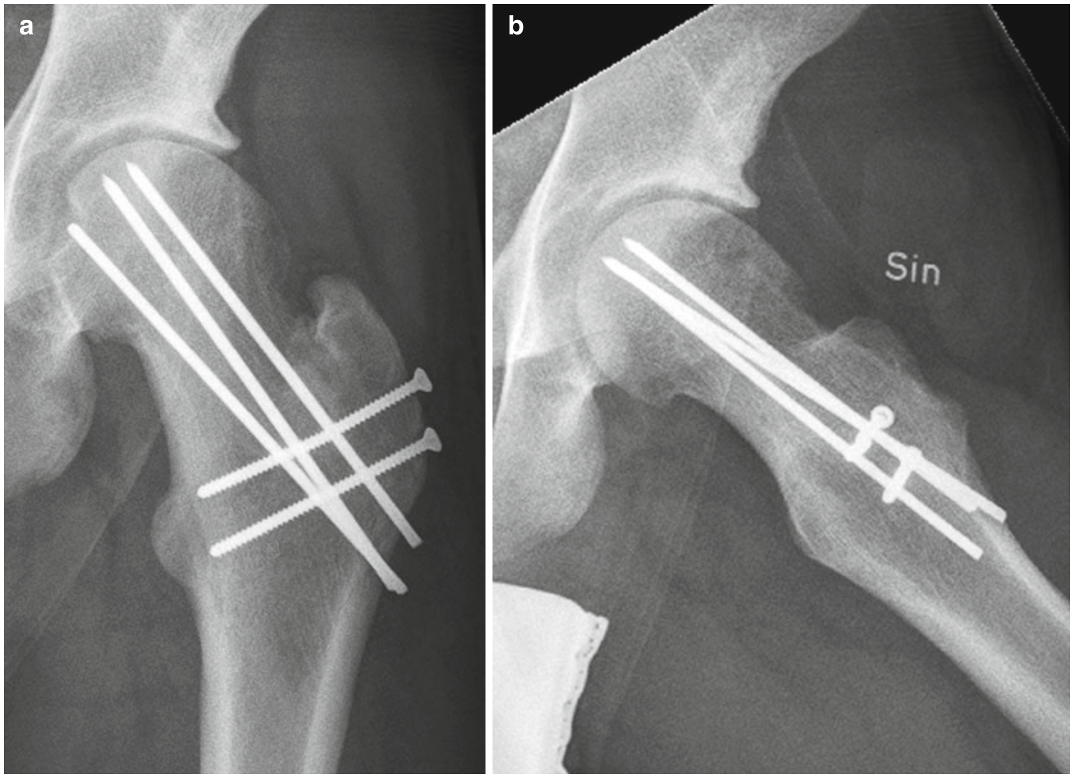

Fig. 5.8 AP (**a**) and lateral (**b**) hip x-rays of a healed SCFE after open reduction and internal fixation

the deformity and the resultant cartilage or labral pathology. Patients with SCFE are more likely to have associated acetabular retroversion or overcoverage [43], thus acetabular rim trimming may be necessary to fully address the impingement. Rarely, patients with acetabular overcoverage or deep sockets may need an accentuated femoral neck osteochondroplasty. Because SCFE patients can have large cam deformities, the surgeon should be aware that resecting more than 30 % of the femoral neck places the patient at risk of femoral neck fracture [44]. Larger retrotilt of the epiphysis also shifts the load distribution towards the postero-superior aspect of the joint while the anterosuperior acetabular roof remains unloaded. To correct these biomechanics, patients with chronic remodeled SCFE, severe gait dysfunction, and functional femoral retrotorsion may require a femoral neck osteotomy or derotational femoral shaft osteotomy. Because patients with large or severe SCFE often require complex osteotomies for deformity correction, they should be referred to tertiary care centers with experience treating complex hip pathology.

Results

Published results of in situ pinning and arthroscopic femoral head-neck osteoplasty are limited [25, 45] and consist of the short-term outcomes of two small case series. Nonetheless, the patients improved by all outcomes measures. In one series, UCLA activity scores were 9, 9, and 8 with all patients reporting pain-free activity and full return to sport [25] at a minimum of 6 months of follow up, while in the second series, the average WOMAC score improved by 9.6 points [45]. Range of motion improved to at least 90° of flexion and neutral internal rotation for all patients [25, 45] and post-operative alpha angles measured on lateral radiographs were reduced to near-normal values (<55°) [25, 45]. This method for addressing mild SCFE appears promising, but mid-term and long-term results are necessary to determine if this approach will also prevent arthrosis.

Short to mid-term results are available for patients undergoing open reduction of the epiphysis via the surgical dislocation approach. When assessed by validated outcomes measures, most patients report good, if not excellent, hip function [26, 39, 46, 47].

Clinically, patients demonstrate restoration of normal range of motion and radiographically, normal femoral head-neck anatomy is restored and maintained [26, 39, 46]. Reported complications after this procedure include reoperation for prominent, bent, or broken hardware [26, 39, 46] and heterotopic ossification [26]. Two cases of avascular necrosis have been reported, in patients who had no femoral head perfusion at the time of capsulotomy in the index operation [39, 46]. No patient who was observed to have intact femoral head perfusion developed subsequent avascular necrosis [26, 39, 46]. Long term results are not yet available but it is to be expected that open reduction ultimately produces better outcomes than in situ fixation.

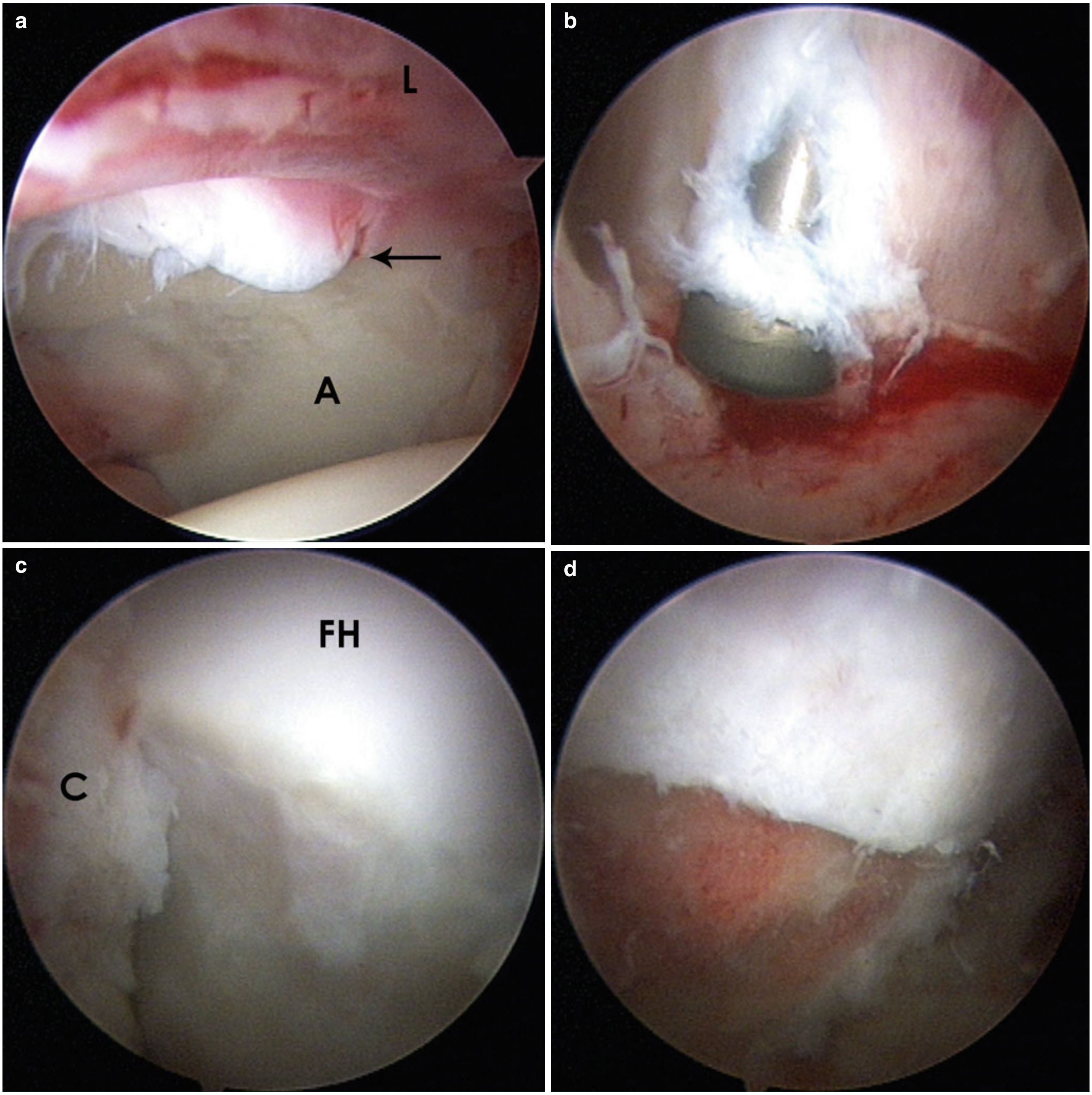

Fig. 5.9 Arthroscopic images demonstrating FAI after in situ pinning of a mild SCFE. (**a**) The labrum is abraded and inflamed. There is a large cartilage flap (*arrow*) in the same region as the labral tear. (*L* labrum, *A* acetabulum) (**b**) The screw at the base of the femoral neck from the in situ pinning. (**c**) Decreased head-neck offset due to the slip. (*C* capsule, *FH* femoral head) (**d**) Improvement in the head-neck offset after femoral neck osteoplasty

Traditionally, SCFE has been associated with both osteonecrosis and chondrolysis. The incidence of osteonecrosis is clearly higher in patients with unstable SCFE [27, 28]. As discussed previously, one speculated cause of osteonecrosis is closed reduction of the epiphysis over posterior callus with subsequent stretching or tearing of the retinacular vessels perfusing the femoral head [18]. Correspondingly, overreduction of an unstable SCFE and attempted reduction of a stable SCFE are both associated with an increased risk of osteonecrosis [7, 21, 28]. Chondrolysis, or rapid destruction of the articular cartilage, was first described for patients with SCFE. It is thought to be the result of unrecognized intra-articular hardware following in situ pinning [3, 7]. However, intraoperative observations of full-thickness cartilage damage, particularly in severe SCFE, indicate that the associated impingement may also be responsible for the rapid progression of arthrosis [5, 39].

Summary

Although SCFE has been recognized and treated by orthopaedists for over a century, significant advances in the understanding and management have occurred in the past decade. In addition to stabilizing the physis, addressing the anatomic deformity to prevent impingement and arthrosis has become an important treatment priority. Although the surgical dislocation and open reduction are technically demanding, safe correction of the physis is now possible and the short to mid-term results are good. Long term results should be similar, but may be influenced by the amount of cartilage and labral damage at the time of surgery.

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