Fractures of the Femoral Head

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Introduction

Femoral head fractures represent a unique injury entity as they are regularly associated with other injuries to the femoral neck and acetabulum. The hip joint is inherently stable and resists significant forces up to 400 N. Thus, femoral head fractures typically result from high-energy trauma and are often observed in patients with multiple injuries [1, 2]. Six to 16% of posterior hip dislocations are associated with a femoral head fracture [3].

Femoral head fractures occur predominantly in young and middle-aged patients. In the elderly, the area of least resistance is the femoral neck, which will usually fracture before any injury of the acetabulum or the femoral head occurs.

The prognosis for patients with femoral head fractures depends on many variables. Some are inevitable, such as cartilage damage at impact and compromised femoral head vascularity. Modifiable management factors are early diagnosis and surgery, removal of intra-articular fragments, and, of course, accuracy of the reduction. Even if short-term complications such as avascular necrosis (AVN) and heterotopic ossification can be avoided, long-term outcomes of hip dislocation and femoral head fractures are difficult to predict. The incidence of unsatisfactory results, primarily as a consequence of post-traumatic arthritis, may exceed 50% [4, 5].

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Surgical and Applied Anatomy Relevant to Femoral Head Fractures

The hip joint is a constrained ball-and-socket joint. We emphasize the role of the fibrous cartilage labrum that covers more than 10% of the femoral head and protects it by more than 50% during motion.

The capsule of the hip joint is reinforced by strong ligaments:

1. The *iliofemoral* (or Y) ligament originates from the superior aspect of the joint at the ilium and anterior inferior iliac spine. It runs in two bands inserting along the intertrochanteric line superiorly, and just superior to the lesser trochanter inferiorly.
2. The *pubofemoral* ligament inserts on the intertrochanteric line deep to the Y ligament.
3. The *ischiofemoral* ligament within the capsule originates at the junction of the inferior posterior wall with the ischium and runs obliquely lateral and superior to insert on the femoral neck.

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The large muscles surrounding the hip tend to force the femoral head into the acetabulum, taking advantage of its depth. All nerves to the lower extremity pass close to the hip joint. The sciatic nerve is at great risk during posterior hip dislocations and surgical procedures. The femoral nerve lies medial to the psoas muscle in the same sheath and can be injured with anterior dislocations.

In adults, the primary blood supply to the femoral head derives from the cervical arteries. These arteries originate from the extracapsular arterial ring at the base of the femoral neck.

In contrast to common belief, the foveal artery, a branch of the obturator artery within the ligamentum teres, contributes little to the nutrition of the femoral head in adults.

Hip Dislocations

For the hip to dislocate, the ligamentum teres, and at least a portion of the capsule, must be disrupted. Labral tears or avulsions, as well as muscular injuries, are common in this setting. Pringle and Edwards [5] examined accompanying soft-tissue injuries in cadavers with experimental hip dislocations. They found that the capsule may be stripped as a cuff from either the acetabulum or femur by rotational forces, or be split by direct pressure (OTA Classification A1). A combination of these capsular injuries may occur, resulting in an L-shaped lesion [5].

In *posterior dislocations*, the capsule is torn either directly posteriorly or inferior-posteriorly, depending on the degree of flexion at the time of injury. The Y ligament remains generally intact, with the capsule stripped from its posterior acetabular attachment. In some cases, however, the Y ligament may be avulsed with a fragment of bone.

In *anterior dislocations*, the psoas muscle acts as the fulcrum of the hip, and the capsule is disrupted anteriorly and inferiorly. Although rare, in extremely high-energy injuries, the femoral vessels can be injured or an open hip dislocation can occur.

Associated femoral head injuries are common and may result from shearing, impaction, and, most frequently, avulsion. When the hip dislocates, a small fragment remains attached to the ligamentum teres (OTA B 31C1.1), avulsing from the head. These fragments, if small and within the fovea, are of minimal concern. More severe injuries to the head involve a shearing mechanism or an impaction force. Impaction is more common after anterior dislocation and may be quite large, similar to a Hill-Sachs lesion of the humeral head. Anterior dislocations with this pattern are at higher risk of AVN because the impaction occurs at the posterior-superior portion of the head-neck junction where the medial circumflex femoral artery (MCFA) vessels insert into the head. Shear injuries are usually the result of a posterior dislocation that occurs with less adduction and internal rotation, forcing the head against the rim of the posterior wall.

Hip dislocations and their accompanying injuries ultimately depend on the vector of the force and its magnitude. For example, minimal anteversion and internal rotation at impact tend to result in pure dislocations rather than fracture dislocation (Table 4.1).

Injury Mechanisms Causing Fractures of the Femoral Head

Damaging the femoral head mandates destruction of its protective soft-tissue envelope first, which is most often accomplished through forceful dislocation of the hip joint. The vast majority

Table 4.1 Position of the hip and leg during impact determines injury type

Position of the proximal femur	Dislocation
Full flexion, adduction, internal rotation	Pure posterior dislocation
Partial flexion, medium abduction, internal rotation	Posterior fracture dislocation
Hyperabduction, extension, external rotation	Anterior dislocation

of hip dislocations occur from high-energy motor vehicle accidents. Other mechanisms include falls, pedestrians struck by motor vehicles, industrial accidents, and athletic injuries [2].

Posterior dislocations outnumber anterior dislocations by approximately 9 to 1 [4, 6]. The typical mechanism for a posterior dislocation is a deceleration accident in which the patient's knee strikes the dashboard with both the knee and hip flexed. By vector analysis, Letournel demonstrated that more flexion and adduction of the hip during application of a longitudinal force through the femur increases the likelihood of pure dislocation [7].

Minimal adduction or internal rotation predisposes to fracture dislocation, which may occur together with a posterior wall fracture or a shearing injury of the femoral head. As the head impacts against the posterior wall, a fragment of the femoral head remains in the acetabulum, and the intact portion of the head connected to the femoral neck dislocates posteriorly.

The concept that the position of the femoral head at impact plays a large role in the type of injury was supported by Upadhyay and colleagues, who studied the effect of femoral anteversion in patients with hip dislocations and fracture dislocations [8, 9]. They saw that decreased anteversion of the femoral neck results in a more posterior position of the femoral head, similar to internal rotation, both tending to produce pure dislocation. In contrast, increased femoral neck anteversion and less internal rotation led to fracture dislocation.

The less common anterior dislocations are a result of hyperabduction and extension. This mechanism may be present in deceleration injuries in which the occupant is in a relaxed position during impact with the legs flexed, abducted, and externally rotated. This is a typical leg position in motorcycle accidents where the legs are frequently hyperabducted. Using cadavers, Pringle et al were able to cause anterior hip dislocations by hyperabduction and external rotation [5]. The degree of hip flexion determined the type of anterior dislocation, with extension leading to a superior pubic dislocation and flexion resulting in inferior obturator dislocation.

Femoro-acetabular impingement, either from decreased femoral head-neck offset (cam- type), or a deep acetabulum (pincer type), may be a risk factor of hip dislocation [10]. Insufficiency and stress fractures of the femoral head may occur, and their mechanism is often less comprehensible than high-energy trauma. They usually occur in patients with osteopenia, but also in healthy adults starting or intensifying exercise (e.g., in military recruits). They are reported as "subchondral impaction" or "insufficiency" fractures, but represent a significant injury to the femoral head [7, 11, 12].

Associated Injuries

Patients with a hip dislocation and/or femoral head fracture typically sustain multiple injuries (including intra-abdominal, head, and chest trauma) that require inpatient management. Marymont et al showed that posterior hip dislocations may even signal thoracic aortic injuries because of abrupt deceleration [13]. Despite typical clinical findings, such as extremity deformation, the diagnosis of hip dislocation may be delayed due to life-threatening injuries.

Common accompanying skeletal injuries comprise femoral head, neck, or shaft fractures, acetabular fractures, pelvic fractures, and knee, ankle, and foot injuries. Knee injuries, including posterior dislocation, cruciate ligament injuries, and patellar fractures, are associated with posterior hip dislocations due to direct dashboard impact (Fig. 4.1).

Tabuenca et al identified major knee injuries in 46 out of 187 (25%) patients with hip dislocations and femoral head fractures [14]. Seven of these injuries were not diagnosed during the initial hospital stay. Associated injuries dictate treatment in most cases of hip dislocation. Among them, undisplaced femoral neck fractures represent a major diagnostic pitfall. High-resolution computed

Fig. 4.1 Knee injury associated with posterior hip dislocation and femoral head fracture

tomography (HRCT) with fine cuts (2 mm) is needed to rule out occult femoral neck fractures before attempting closed reduction. In case of fracture lines at the level of the femoral neck, initial internal fixation must be considered.

Similarly, associated pelvic ring fractures may prohibit counter-traction, necessitating open reduction of the dislocation. Injuries to the knee are likely to be detected by careful clinical examination and conventional radiography.

Associated fractures of the hip itself, such as acetabular wall fractures and femoral head fractures, may require surgical intervention even if the hip dislocation can be reduced in a closed fashion. Femoral head fractures or intra-articular fragments may hinder closed reduction of the hip. Acetabular wall fractures may lead to instability – even after sufficient reduction – and then require fixation. Determining hip stability in the presence of a posterior wall fracture is important.

Clinical Signs and Symptoms of Hip Dislocations and Fractures of the Femoral Head

In the scenario of interest, hip dislocations may be easily missed simply because other, potentially life-threatening injuries demand attention by the trauma surgeon in charge. Thus, no caregiver can be blamed for overseeing a hip dislocation and/or femoral head fracture in patients with multiple trauma. Whole-body MDCT has emerged as the imaging standard in most industrial countries and is likely to reveal unsuspected hip dislocations and femoral head fractures.

Still, clinical examination is valuable, and hip dislocations may occasionally be detected simply by the position of the patient's legs. Typically, the involved leg appears shortened and excessively rotated, either externally rotated in case of anterior dislocation, or internally rotated in case of posterior dislocation. If hip dislocation is suspected, palpation of all long bones and joints (specifically the knee) of the affected extremity and the pelvis (stability testing), along with a meticulous neurologic and vascular examination, are key. Documenting pre-reduction function of the sciatic nerve is important in posterior dislocations, as the nerve can be injured by reduction. Careful testing of all branches is required. For example, impaired foot eversion may indicate peroneal branch lesions. Posterior dislocations are associated with posterior knee dislocations (posterior cruciate ligament rupture). Anterior dislocations may injure the femoral vessels, necessitating a careful assessment of distal pulses and duplex ultrasound.

Imaging and Other Diagnostic Studies for Hip Dislocations and Fractures of the Femoral Head

The first imaging available is usually the anteroposterior (AP) pelvis radiograph. This is usually taken as part of the initial trauma workup and helps direct treatment. The diagnosis of hip dislocation should be apparent on this single radiographic view (Fig. 4.2).

The key to the diagnosis on the plain AP pelvis is the loss of congruence of the femoral head with the roof of the acetabulum. On a true AP view, the head will appear larger than the contralateral head if the dislocation is anterior, and smaller if posterior. The most common finding, in the case of a

Fig. 4.2 AP pelvis radiograph shows a posterior dislocation with a femoral head fragment left in the acetabulum

posterior dislocation, is a small head that is overlapping the roof of the acetabulum. In an anterior dislocation, the head may appear medial to or inferior to the acetabulum.

It is critical that the initial radiograph be of good quality and carefully inspected for associated injuries before a reduction is attempted. In particular, associated femoral neck fractures, which may be nondisplaced, must not be overlooked. Likewise, associated femoral head fractures are usually visible as a retained fragment in the joint (Fig. 4.3). Acetabular fractures and pelvic ring injuries are also visible on the plain AP radiograph. Additional radiographic assessment is not usually indicated before attempts at reduction unless a femoral neck fracture cannot be ruled out or there is a clinical suspicion of a femur, knee, or tibial injury that will affect the ability to use the extremity to manipulate the hip. In such cases, bi-planar radiographs of all questionable areas must be obtained.

The patient with a hip dislocation (including those with a femoral head fracture) has, in most of the cases, sustained a major trauma and will be subject to modern trauma management, which consists of an initial pan-CT-scan including angiography as a keystone of diagnostics (Fig. 4.3) [15]. Here, all relevant injuries

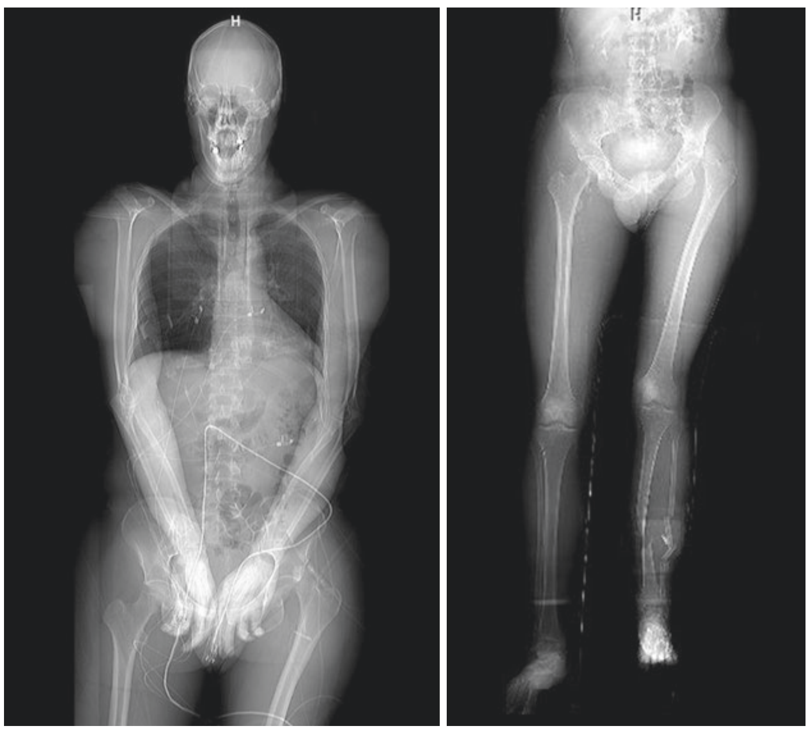

Fig. 4.3 (**a**,**b**) Pan-CT as initial screening diagnostics in polytraumatized patient with posterior hip dislocation and femoral head fracture

can be detected within the first minutes of the patient's arrival at the trauma center.

A concomitant non-displaced femoral neck fracture and other adjacent injuries can be identified and have to direct the treatment. In the case of an unreducible hip, the CT scan has to be analyzed to identify the obstacle that prevents the femoral head from moving back into the acetabulum.

After reduction, five standard views of the pelvis should be obtained. These include the ap pelvis both Judet (45° oblique) views, and an inlet and outlet of the pelvis. Evaluation of the X-rays should focus on the concentric reduction of the hip. The use of the contralateral hip is necessary to answer this question. Using the relationship of the femoral head to the acetabular roof on each view, the congruency of the hip is evaluated by comparing it to the contralateral side. Any incongruency or widening of the joint space may indicate a loose body inbetween femoral head and the acetabulum.

After reduction of the hip, a CT scan with a minimum of 2 mm cuts through the hip is the diagnostic standard. The scan is more sensitive in detecting small, intra-articular fragments, femoral head fractures, femoral head impaction injuries, acetabular fractures, and joint incongruity. Hougaard et al reported six cases of minor acetabular fractures, and six cases of retained intra-articular fragments visualized on CT and not visible on plain radiographs after closed reduction of posterior hip dislocations [16]. The congruence of the hip is also easily evaluated using CT. The head should be in the center of the subchondral ring of the acetabulum as it becomes visible, appearing as a bulls eye. Impaction injuries and femoral head fractures are much more easily seen on the post-reduction CT. The quality of the reduction of femoral head fractures is also apparent and determines treatment. Besides the importance of meticulous diagnostics, the CT scan plays a major role in planning the operative intervention, when necessary, in cases of concomitant fracture, irreducible dislocation, or incongruent reduction. The location, size, and number of free intra-articular fragments and the location, The location and size of an acetabular fracture as well as the size and location of a femoral head fragment must be identified and will affect the treatment plan.

MRI is helpful in the evaluation of a traumatic osteonecrosis of the hip. MRI changes of AVN may not be present before 6 to 8 weeks. MRI studies can also help define soft tissue injuries following hip dislocations. Apart from its predictive values of AVN in the acute setting, MRI is the optimal study for evaluation of the soft tissues such as the external rotator tendons, the labrum, and cartilage. The traumatized hip from a dislocation will likely have an effusion, which will help identify any abnormalities of the labrum or capsule.

Injury Classification Schemes

Classification of Hip Dislocations and Fractures of the Femoral Head

Several classification schemes have been described for hip dislocations. All of these schemes include subtypes for important associated injuries. The first distinction is whether the hip dislocation is anterior or posterior.

Posterior dislocations are much more common than anterior dislocations. Two original classification schemes have been described for posterior dislocations. Thompson and Epstein and, subsequently, Stewart and Milford, both described systems incorporating associated fractures.

The Stewart and Milford scheme specifically addresses post-reduction stability in the case of acetabular fracture, which has prognostic implications. Epstein's type 5 dislocation includes a femoral head fracture. This type has been subdivided by Pipkin into four types (Table 4.2 and Fig. 4.4).

The Pipkin classification is commonly used and is important in decision-making.

A combined descriptive scheme has been suggested by Brumback et al and can be used for anterior or posterior dislocations with femoral head fractures (Table 4.3). Brumback's classification takes into account the size of the head fragment, the direction of the dislocation, and the resulting instability [18].

Finally, the Orthopaedic Trauma Association's comprehensive fracture classification scheme includes hip dislocations (Fig. 4.5).

The most important factors are whether there is an anterior or posterior dislocation, an associated fracture in the vicinity (acetabulum, femoral neck), and the stability of the hip after reduction (only the Brumback Classification [Fig. 4.6 and Table 4.3] takes all these relevant factors into account). In each scheme, the presence of an acetabular fracture requiring reduction and fixation is noted.

Table 4.2 Pipkin classification

Type I	Posterior dislocation with femoral head fracture caudad to the fovea
Type II	Posterior dislocation with femoral head fracture cephalad to the fovea
Type III	Femoral head fracture with associated femoral neck fracture
Type IV	Type I, II, or III with associated acetabular fracture

Treatment Options for Hip Dislocations and Fractures of the Femoral Head

Non-operative Treatment of Hip Dislocations and Fractures of the Femoral Head

The initial management for almost all hip dislocations is an attempt at a closed reduction (Table 4.4). The reduction should be considered an emergent procedure and includes patients with

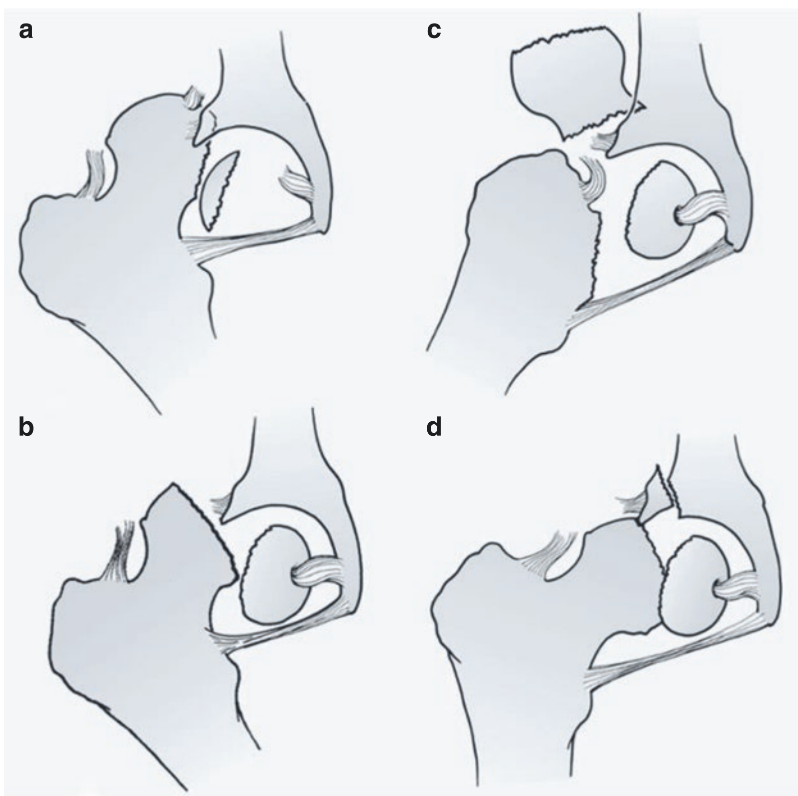

Fig. 4.4 Pipkin classification. (**a**) Fracture inferior to fovea (**b**) Fracture superior to fovea(**c**) Fracture of femoral head and neck (**d**) Fracture of femoral head and acetabular fracture [17]

Table 4.3 Brumback classification of femoral head fractures

Type	Description
Type 1	Posterior hip dislocation with fracture of the femoral head involving the inferomedial portion of the femoral head
Type 1A	With minimum or no fracture of the acetabular rim and stable hip point after reduction
Type 1B	With significant acetabular rim and stable joint after reconstruction
Type 2	Posterior hip dislocation with fracture of the femoral head involving the supermedial portion of the femoral head
Type 2A	With minimal or no fracture of the acetabular rim and stable joint after reduction
Type 2B	With significant acetabular fracture and hip point instability
Type 3	Dislocation of the hip (unspecified direction) with femoral neck fracture
Type 3A	Without fracture of the femoral head
Type 3B	With fracture of the femoral head
Type 4	Anterior dislocation of the femoral head
Type 4A	Indentation type, depression of the superolateral surface of the femoral head
Type 4B	Transchondral type, osteocartilaginous shear fracture of the weight-bearing surface of the femoral head
Type 5	Central fracture-dislocation of the hip with femoral head fracture

From Stannard et al. [20]

concomitant femoral head fractures or acetabular fractures.

Contraindications to standard closed reduction are non-displaced femoral neck fractures and other associated injuries that exclude using the lower extremity to manipulate the hip.

A reduction is typically performed in the operating room, but can be performed in the emergency department if the patient is already intubated. Regardless of the direction of the dislocation, the reduction is attempted by traction in line with the femur and gentle rotation.

An Allis maneuver is next if the dislocation is posterior.

The patient must be under a full muscular relaxation, regardless of the technique used in order to achieve a closed reduction of the hip joint. The use of real-time fluoroscopy to aid the reduction is recommended. The position of the head with respect to the acetabulum can be easily visualized if there is difficulty reducing the hip, and adjustments based on the position can be made. It also allows for a thorough evaluation of hip stability or, if warranted, a stress exam following reduction.

The Walker modification of the Allis technique is performed if the dislocation is anterior (Fig. 4.7).

Anterior dislocations are also reduced using traction and counter-traction. For inferior dislocations, Walker described a modification of the Allis technique. Traction is continuously applied in line with the femur with gentle flexion. Along with a lateral push on the inner thigh, internal rotation and adduction are used to reduce the hip (Fig. 4.8). If the dislocation is superior, then distal traction is applied until the head is at the level of the acetabulum and gentle internal rotation is applied. Extension may be necessary when reducing anterior dislocations.

For all types of reduction, the surgeon should use steady traction. By using continuous distraction and gentle manipulation, the reduction is achieved while minimizing additional trauma. Sudden forceful movements can cause fractures of the neck and damage the articular surface of the femoral head. If the closed reduction is successful, then post-reduction diagnostics include AP and Judet views of the hip, and a CT with 2-mm cuts are obtained to determine the congruence of the reduction and the post-reduction position of any associated fractures or loose bodies. If there is no associated fracture and the hip is congruent with symmetric joint space to the contralateral hip on all plain films and the CT scan, then non-operative management is recommended. Sometimes a small fragment attached to the ligamentum teres is visible within the joint, but

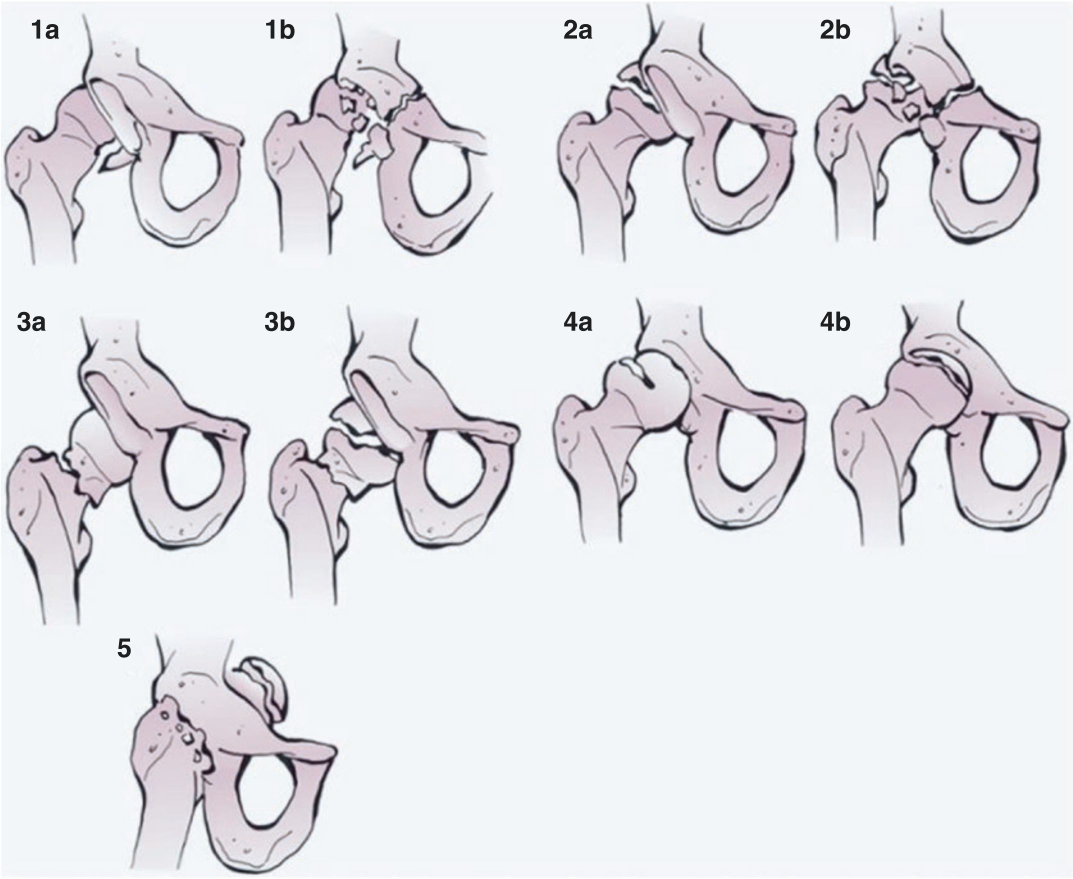

Fig. 4.5 Brumback classification of hip dislocations and femoral head fractures

if positioned within the fovea, then it may be treated non-operatively, since it will not move due to its tether to the ligamentum teres.

In the early post-operative period, patients may experience groin pain or mechanical symptoms. These should be worked up with MRI and may be considered for operative management with hip arthroscopy.

Fluoroscopic Evaluation of the Hip Following Closed Reduction

Definitive non-operative management is also indicated if there are fractures that do not require fixation or cause instability of the hip. Two types of injury fall into this category: Pipkin type I femoral head fractures, which do not create incongruity, and small posterior wall fractures that do not allow for instability. In cases of inferior femoral head fractures, the fragment does not affect the weight-bearing surface. These fracture fragments are not loaded during normal gait and therefore may be treated as loose bodies. If the fragments are well reduced or in a position that does not create an incongruent reduction of the hip, they can be left in place. Thus, fixation or excision is not necessary if the reduction of the hip is congruent. These injuries may be treated with the same non-operative protocol as a pure hip dislocation.

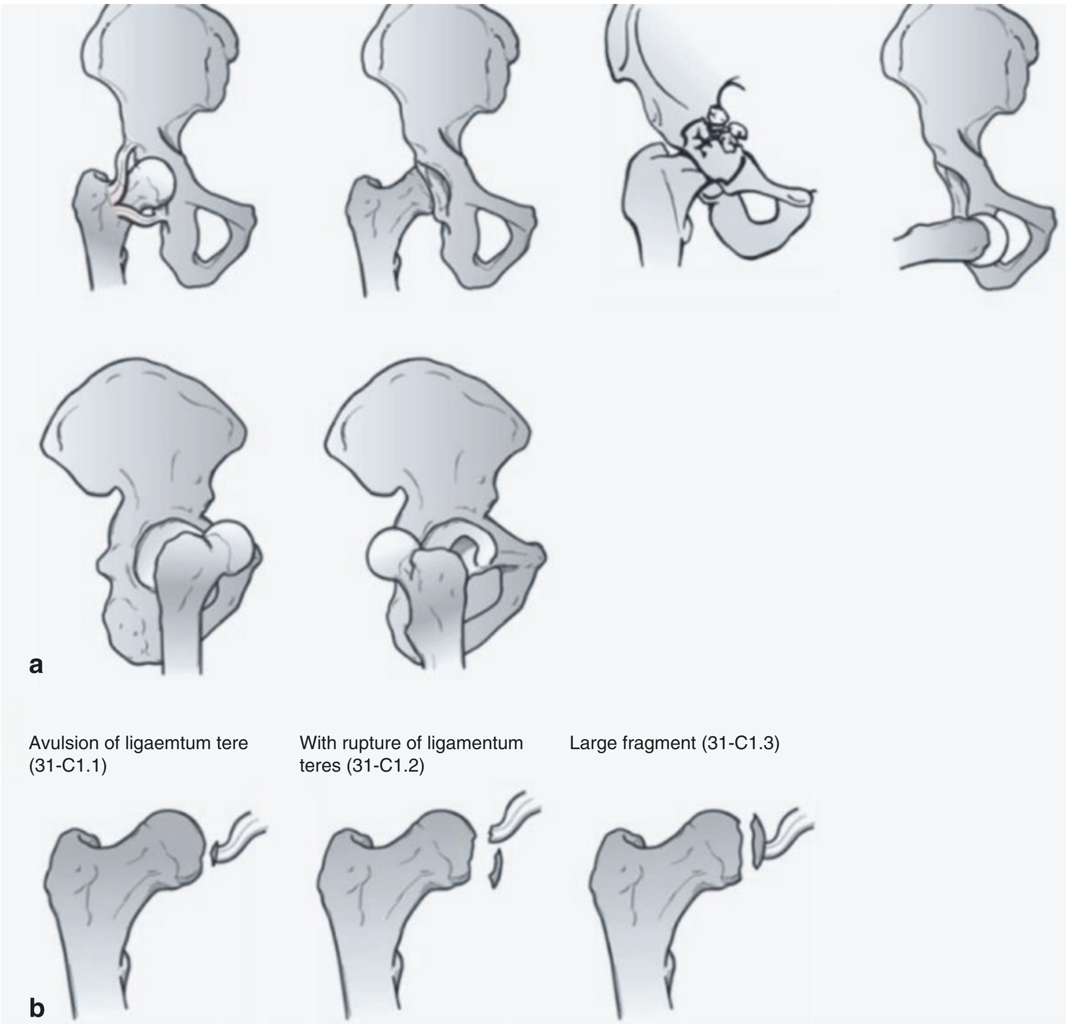

Fig. 4.6 OTA classification classification of femoral head fractures with hip dislocation

Table 4.4 Indications for non-operative treatment in hip dislocations with femoral head fractures

Non-operative treatment after successful hip reduction	
Indication	Relative contraindication
Pipkin I	Pipkin III and IV
Pipkin II	Incongruent reduction of the head fragment
Congruent joint post reduction	Unstable joint
Small ligament teres fragment in the fossa	Loose bodies interfere with the joint surface

The amount of posterior wall that can be affected without causing instability is debated. If greater than 35% of the posterior wall is affected, the loading pattern of the hip is altered and may lead to post-traumatic arthritis. On the basis of cadaveric studies, most authors would recommend ORIF of these fractures. If the posterior wall fragment is small enough that fixation may not be required, stability testing can be performed to ensure that the hip is stable.

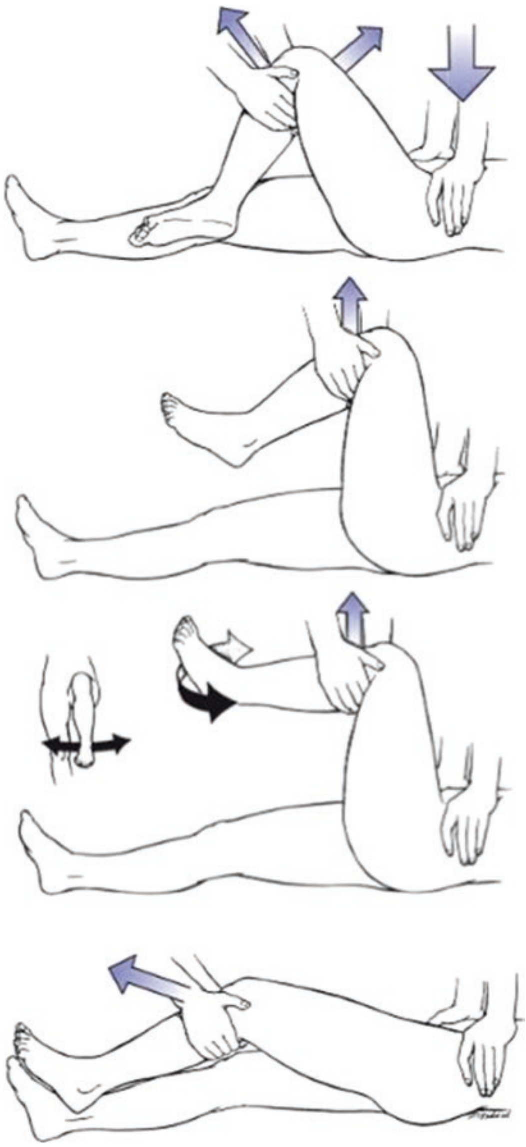

Fig. 4.7 Allis maneuver for posterior hip reduction

In the face of an associated posterior wall fracture, if the hip reduction is incongruent, then an open reduction of the hip is necessary with removal of debris as described above. The posterior wall is fixed at the same time through the same incision.

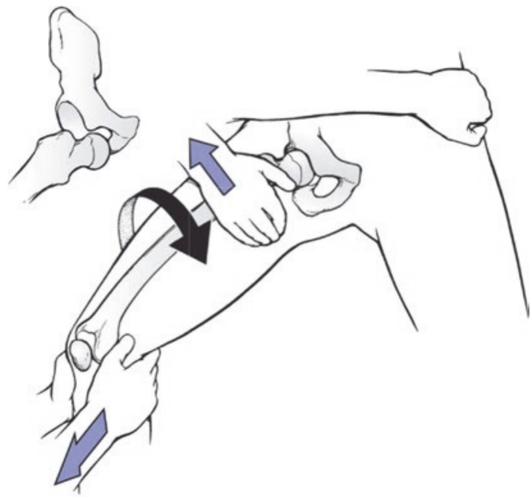

Fig. 4.8 Walker maneuver for anterior hip reduction

Operative Treatment of Hip Dislocations with Fractures of the Femoral Head

Indications/Contraindications

Operative management is required if the hip joint is irreducible, or if there is an incongruent reduction; there is also a relative indication for operative management with sciatic nerve damage following an attempted reduction, and in some cases of fracture-dislocation. A secondary nerve lesion (after reduction) should lead to immediate, specific diagnostics to rule out a fragment or an interposition that is mechanically impinging. If mild traction during reduction has caused the nerve lesion in most cases, spontaneous recovery is to be expected.

Indications for operative treatment can be broken down into two treatment groups:

(1) Open reduction with or without debridement, and
(2) Open reduction and internal fixation.

If an open reduction is necessary to restore an articulating hip joint, then joint debridement and treatment of all associated fractures can be performed simultaneously. For example, a posterior wall fracture or Pipkin II fracture can be reduced and stabilized in the same session as loose bodies are removed from the joint.

In cases of a posterior wall and intra-articular debris, a surgical hip dislocation may be the best choice, as it allows 360° views of the head and acetabulum while preserving the blood supply to the head.

If the hip is reduced, but incongruent, then the offending structures need to be removed, which can be done arthroscopically or in an open fashion. For small intra-articular fragments, an arthroscopic approach is preferred. Large fragments can be extracted by surgical hip dislocation.

During the debridement of loose bodies, it is difficult to determine whether the joint is completely free of fragments; therefore, knowing the number, location, and sizes of bony fragments is imperative. If the labrum is avulsed from the acetabular rim, repair via suture anchors to a freshened cancellous surface may provide improved stability.

Post-op protocol for patients with hip dislocations and femoral head fractures include HO prophylaxis with NSARs (indomethacin) for 6 weeks; radiation is in most cases not favored due to the young population. In dislocations with fractures of the femoral head and open reduction with internal fixation, we allow immediate mobilization with movement of the hip joint and touch-down partial weight bearing, progressing to full weight bearing after 10-12 weeks.

Open Reduction with or without Debridement and with or without ORIF

Irreducible dislocations require emergent open reduction. Approximately 2-15% of dislocated hips are irreducible via closed means. The offending structure may be a bony impingement or soft tissue interposition. Anterior dislocations are associated with interposition of the M. rectus femoris, the iliopsoas, the anterior hip capsule, or the labrum. Buttonholing through the capsule, and bony impingement in the obturator foramen, have also been reported. In posterior dislocations, the causes of irreducibility are buttonholing though the posterior capsule, and interposition of the piriformis, gluteus maximus, ligamentum teres, labrum, or large bone fragments.

Incongruent reductions occur if there are bony fragments or soft tissue interposed in the acetabulum. Free fragments located between the femoral head and acetabular articular cartilage must be removed. This may be an indication for arthroscopic debridement and evaluation of the hip joint, depending on the size of the fragment(s).

The post-reduction CT will show the location, size, and number of offending bony fragments, thereby allowing better planning of the procedure (Fig. 4.9). Fragments treated by debridement include avulsions from the femoral head, inferior femoral head fractures (Pipkin type I), loose fragments from the posterior wall, and cartilage fragments sheared from the femoral head.

In many cases, Pipkin type II fractures align well with reduction of the hip as the femoral head fragment is held in place by the ligamentum teres. A post-reduction CT of the hip joint, in conjunction with an AP and Judet views, will show any displacement. If the fragment is not anatomically reduced (step off >2 mm, gap >4 mm), then ORIF has to be considered. Fixation

Fig. 4.9 Post-reduction CT scan with displaced head fragment

of these fractures can be challenging, as the fragment is frequently thin.

Many surgical approaches have been advocated for open reduction and internal fixation of femoral head fractures. Due to the most common mechanism of a posterior hip dislocation, the fracture fragment is often located anteromedially, as it was sheared off by the posterior wall. Although Epstein had recommended debridement of the joint via a posterior approach to utilize the already damaged capsule, this may not be the best approach for the treatment of femoral head fractures. To reduce and fix an anteromedial fracture of the femoral head from a posterior approach, the hip may require re-dislocation. Even with the femoral head out of the acetabulum, anatomic reduction may be difficult without disrupting the ligamentum from the femoral head fragment, potentially devascularizing it. Positioning the intact posterolateral head against the anteromedial fragment – without disrupting its soft tissue – is extremely difficult, and, at best, visualization of only a portion of the fracture is possible. In addition, the posterior approach may further compromise the medial femoral circumflex artery, the blood supply to the femoral head, making other surgical approaches more appealing.

An anterior approach (modified Smith-Peterson) allows for direct visualization of the femoral head fragment without re-dislocating the hip. External rotation of the hip allows for cleaning of the fracture bed and accurate reduction of the fragment. Since the major blood supply to the femoral head arises from the posterior cervical branches (MFCA), which may be damaged, there is a consideration for an anterior surgical dissection. Swiontkowski et al compared the anterior and posterior approaches in the management of femoral head fractures meeting operative criteria. The incidence of AVN was not increased in hips treated via the anterior approach vs. the posterior approach [19]; the anterior approach allowed for an easier reduction and better visualization. Stannard et al also found a higher rate of AVN after posterior than anterior approach for treatment of femoral head fractures. Four of five patients treated via a posterior approach developed AVN to some degree [20].

A trochanteric osteotomy with a surgical dislocation of the hip, described by Ganz et al, has also been described to treat these fractures. Massè et al reported on a series of 12 patients with femoral head fractures treated with surgical dislocation [21, 22]. In this group, 83% had good-to-excellent outcomes, compared to 56% of patients treated using other approaches (Watson-Jones, Smith-Petersen, and Kocher-Langenbeck). Other authors have also described this technique for femoral head fractures – in particular, those with combined posterior wall lesions. While this is a logical approach for the treatment of femoral head fractures, thus far only small numbers of patients have been reported on.

Fixation of the fragments is often difficult, due to the shallow nature of the fragment. Techniques that allow for subarticular fixation are necessary. These include the use of headless screws, countersunk screws, resorbable pin fixation, and suture repair. Regardless of the chosen technique, it is imperative that the fixation be within the subchondral bone and not protrude into the joint.

Lastly, large femoral head impaction may require operative fixation and restoration of joint congruity. Recent biomechanical studies have shown that a 2 cm^2 area must be present to significantly affect the contact force distribution in the hip. If such an injury exists, the impacted area can be elevated and grafted. This should be considered if there is an impacted area of 2 cm^2 and more in the weight-bearing portion of the head.

Arthroscopic Technique in the Management of Hip Dislocations

The use of hip arthroscopy has increased substantially in the last decade. During this time, the instrumentation and techniques have improved, and therefore its use for the treatment of the injured hip has significantly increased. Several authors have now demonstrated that loose bodies, chondral injuries, and labral tears occur as a result of simple hip dislocation and are not detected by initial plain radiographs or fine-cut CT scans. Hip arthroscopy can be used for fracture-dislocations of the hip in which only a debridement of chondral damage or small loose bodies is necessary. There have been case reports of fracture fixation using arthroscopic methods, but this is not yet advocated as standard practice. Hip arthroscopy is contraindicated if there are fractures of the acetabulum that would allow fluid extravasation into the pelvis. The tear of the capsule after hip dislocation creates no obstacle if a modern fluid management system is used in arthroscopy.

Complications

Avascular Necrosis (AVN)

AVN is a common sequela of posterior hip dislocations and correlates with the time to reduction. AVN occurs in 1.7-40% of hip dislocations. If the hip is reduced within 6 h of the dislocation, the literature shows significantly lower AVN rates – between 0 and 10% [23].

The cause of AVN is thought to be multifactorial. In part, the cervical vessels to the head and the contributions from the ligamentum teres are damaged at the time of injury. Secondarily, an ischemic injury to the femoral head while it is dislocated affects the outcome.

Radiographic findings of an AVN are usually present within 2 years of the injury (Figs. 4.10, 4.11, and 4.12).

Diagnosis may be delayed until collapse is present. MRI is the most sensitive and specific imaging modality for AVN and is recommended if there are signs and symptoms. Treatment should involve initial weight-bearing restriction to prevent subchondral collapse.

Arthritis

The most common complication after hip dislocation with femoral head fracture is post-

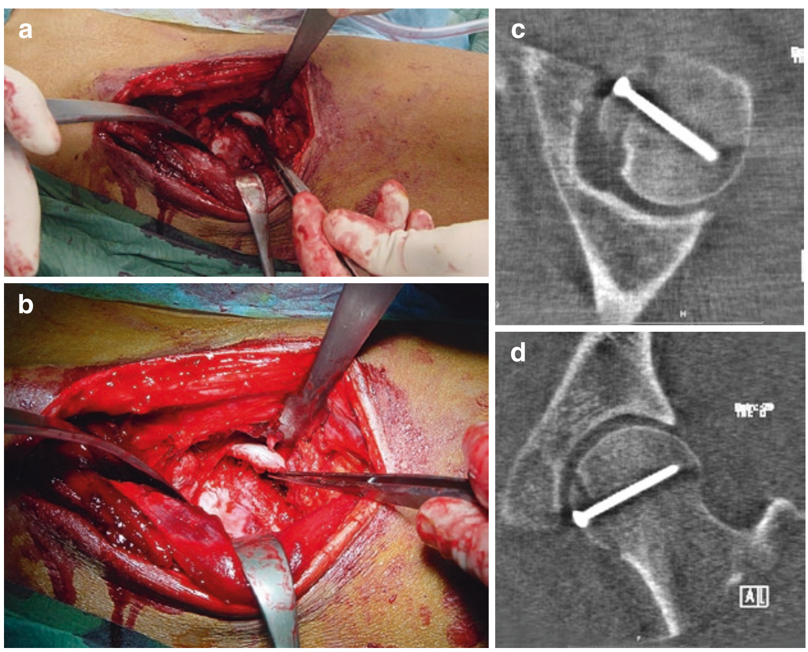

Fig. 4.10 (**a**) Anterior approach to the hip joint showing a displaced femoral head fragment, after posterior fracture dislocation and initial closed reduction. (**b**) Mobilizing the fragment and performing the reduction. (**c**, **d**) Intraop 3-D imaging with C-Arm for control of fracture reduction and congruity of the hip joint

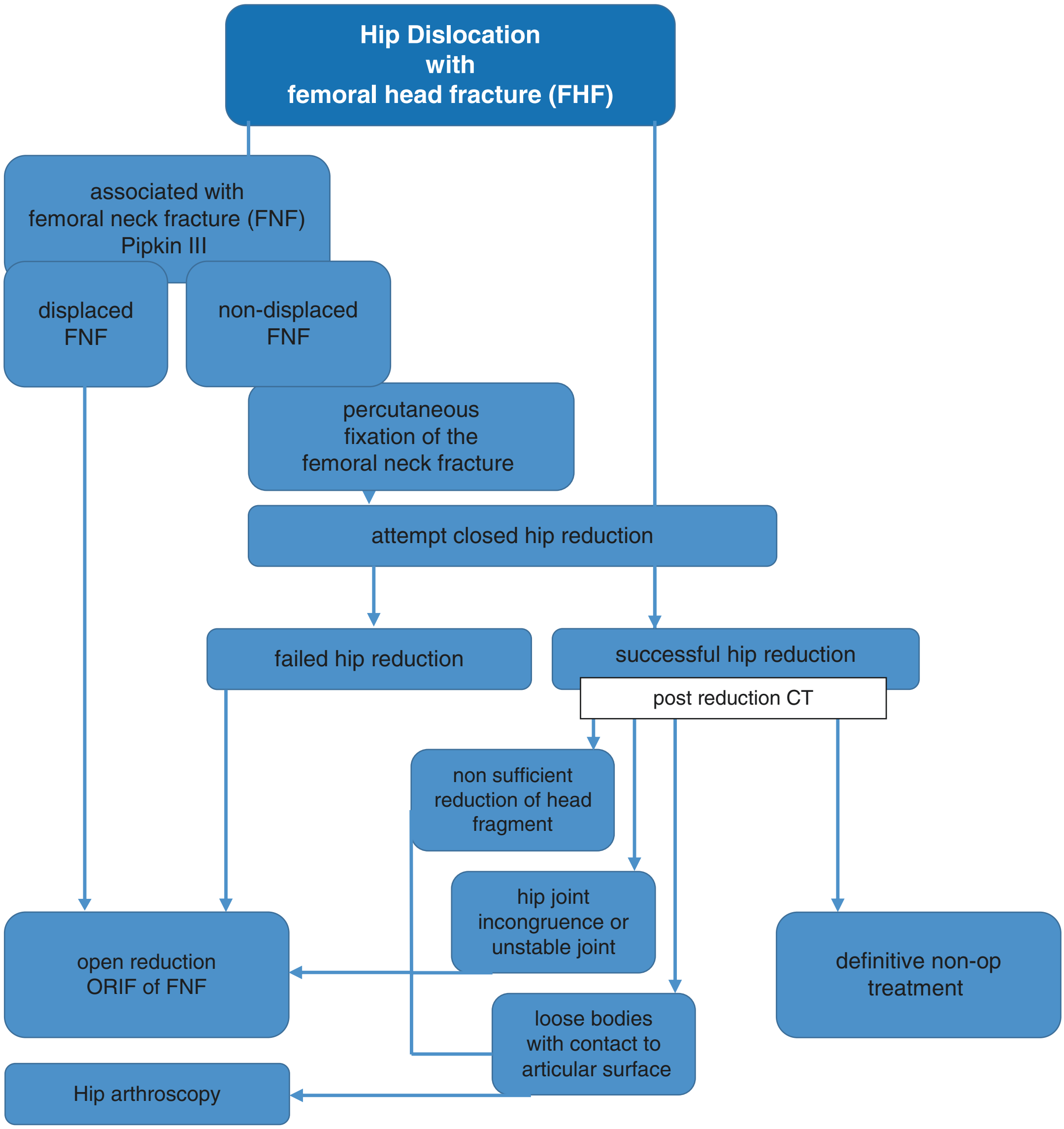

Fig. 4.11 Treatment algorithm for dislocations of the hip with femoral head fragments

traumatic arthritis. Posterior dislocations have a higher rate of post-traumatic arthritis than anterior dislocations. Dislocations with associated femoral head fractures may develop arthritis in 50% of patients. The higher rates of arthritis in fracture dislocations may be in part due to chondrocyte damage, as marginal cartilage injury is common in cases of fracture dislocation. Repo and Finely were able to induce chondrocyte death by applying a 20-30% strain.

In addition, AVN does lead to arthritis. The incidence of primary arthritis is highest in severely injured patients. The effect of open reduction on later degeneration is not clear.

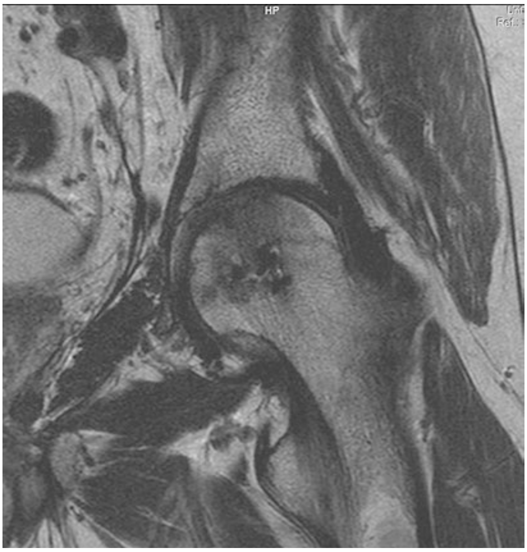

Fig. 4.12 MRI 9 months after posterior hip dislocation with femoral head fracture and AVN of the femoral head

Heterotopic Ossification (HO)

Heterotopic ossification is very common after posterior fracture dislocation (Fig. 4.12). It is most common after open reduction of a posterior dislocation. This complication is also commonly reported after posterior wall fractures. It is likely due to posterior muscle injury from the dislocation in combination with surgical trauma. In cases of femoral head fracture, Swiontkowski et al reported on a higher incidence of HO after ORIF via an anterior approach than a posterior approach [19]. In cases of posterior dislocation, the use of indomethacin may diminish the rate of clinically significant HO. Radiation therapy, usually a single dose with 700 Gy may be administered 24 h before, or within 48 h post-operatively. Data on the effectiveness of NSAIDs vs. radiation are inconsistent at best, and future large RTCs will need to identify the optimal prophylaxis [24]. HO development seems to be related to initial trauma impact. Pape et al reported a rate of 60% in cases that did not undergo surgical fixation [25].

Malunion

Yoon et al reported on three patients who required late excision of an inferior femoral head fracture due to pain and limitation of motion. These patients were initially treated with non-weight bearing and then gradual ambulation. In each case, the inferior fragment was excised, thereby restoring motion.

Sciatic Nerve Dysfunction

Late sciatic nerve dysfunction has been reported by several authors. It is usually from HO, either compressing the nerve or causing it to be stretched. It is important to continue to examine the nerve function at each post-injury visit, as early decompression may favor neurologic return.

Outcomes After Femoral Head Fractures

Outcome Measures

The assessment of patient outcome following hip dislocation or fracture-dislocations revolves around the patient's function and pain. Osteonecrosis, joint stiffness, and arthritis are the main limiting factors for patient outcomes; hence, evaluating outcomes using standardized hip scores, such as the Harris Hip score, WOMAC, and Merle d'Aubigné, are most commonly reported. These scores provide clinicians with insight into how the patients' hips are functioning, and they are used in combination with overall health scores such as SMFA and SF12.

Evidence

The probability of identifying large-scale, high-quality randomized trials (RCT) on the management of femoral head fractures was very low. Given the rarity of this type of fracture, we accepted a broad scope of designs and individual study features to provide a rough estimate about the likely outcomes and, whenever possible, some guidance for individualized care to clinicians and patients.

To find the best available evidence, we first searched for systematic reviews and meta-analyses in Ovid Medline, Embase, and the Cochrane Library. We limited our search to reviews published between January 1, 2006 and January 1, 2016, appearing in English, French or German. Individual studies included in these reviews were identified, and by an iterative process and screening of reference lists, we further identified potentially relevant studies published at any time. To be included in this review, individual studies (whether full-text publications or conference proceedings) had to fulfill the following criteria:

1. The investigation included ≥10 patients (this was an arbitrary threshold).
2. The study reported functional outcomes using an accepted scoring system (e.g., Thompson-Epstein, Merle d'Aubigné, or others).
3. The study provided some information about the demography of patients, the classification of fractures (e.g., Pipkin type, AO/OTA grading), and surgical details.

We excluded case reports and technical notes. While we made efforts to retrieve full-text articles not available even from a major university library (Charité Medical University Center, Berlin, Germany) through other access options, we deliberately stopped at this stage. We are aware of missing one historical review because of this decision [18].

We identified three systematic reviews meeting our primary screening criteria [26–28]. These reviews included 12 original studies of 285 patients [19, 20, 28–38]. Table 4.5 summarizes key characteristics of the studies. Of note, there were two reports of small RCTs comparing operative and non-operative treatment of femoral head fractures [28, 29]. They may be based on a single RCT with individual results published for Pipkin 1 and 2 fractures. In addition, we identified a classic paper (including 41 fractures) published in 1992 [19].

The overwhelming body of evidence on the management of femoral head fractures comes from retrospective cohorts susceptible to almost all thinkable sources of bias. There is selection bias, bias by indication, an uncertain number of patients lost to follow-up, and so on. This must be taken into consideration when interpreting the results. Apart from cumulative data, nine reports [20, 28–33, 35, 37] offered individual patient data (IPD) on 175 participants, which is a strength which is a strong point in this kind of study.

For a first assessment of treatment effects, we used a random-effects model (metaprop procedure in STATA 11.0) to summarize the frequency of "excellent" and "good" outcomes, as assessed by the Thompson-Epstein scale. In a heterogeneous population with different baseline risks and different treatment approaches, about 72% (95% confidence interval [CI] 65-78%) of all patients achieved excellent or good results (Figs. 4.13 and 4.14).

ORIF (as compared to any other treatment option) was associated with

1. A higher relative risk (RR) of heterotopic ossification of any Brooker grade (RR 1.44, 95% CI 0.97–2.14)
2. A lower relative risk of AVN (RR 0.34, 95% CI 0.09–1.19)
3. A higher likelihood of excellent or good outcomes according to Thompson-Epstein criteria (RR 1.26, 95% CI 1.03–1.54)
4. A higher likelihood of excellent outcomes according to Thompson-Epstein criteria (RR 2.77, 95% CI 1.51–5.06

Table 4.5 Study and patient profile of all included investigations

Author	Year	n	Mean age, years (SD)	Male patients	Pipkin type				Management				Outcome, Thompson-Epstein score			
					1	2	3	4	ORIF	Excision	Arthroplasty	Non-op.	Excellent	Good	Fair	Poor
Chen et al [28]	2011	16	37.5 (11.4)	13 (81%)	16	0	0	0	8	0	0	8	6	5	3	2
Chen et al [29]	2011	24	38.7 (11.0)	17 (71%)	0	24	0	0	12	0	0	12	7	8	7	2
Guimaraes [30]	2010	10	32.2 (12.6)	7 (70%)	6	3	0	1	10	0	0	0	6	2	1	1
Henle [31]	2007	12	39.8 (12.2)	10 (83%)	1	3	0	8	12	0	0	0	5	5	0	2
Kokubo [32]	2013	10	51.7 (16.1)	6 (60%)	5	2	0	3	4	4	0	2	2	7	0	1
Marchetti [33]	1996	33	33.6 (13.7)	22 (67%)	8	9	2	14	13	15	3	2	0	22	6	5
Mostafa [38]	2014	23	39.1 (8.8)	14 (61%)	5	18	0	0	23	0	0	0	18		5	
Norouzi [34]	2012	28	33 (13)	21 (75%)	13			8	13	4	2	9	20		8	
Oransky [35]	2012	21	42.0 (15.9)	14 (67%)	4	9	0	8	11	7	0	3	8	8	2	3
Park [36]	2015	59			15	28	9	7	23	25	7	4	34		25	
Stannard [20]	2000	22	37.2 (15.2)	14 (64%)	4	9	0	9	12	10	0	0	7	4	3	8
Yoon [37]	2001	27	40.4 (12.8)	22 (81%)	5	18	4	0	14	12	1	0	7	15	4	0

Fig. 4.13 Small heterotopic ossification 6 months after posterior dislocation of the hip and femoral head fractures with anterior approach

Individual findings are shown in Table 4.6.

Based on data from their systematic review, Wang et al concluded that "…the posterior approach decreased the risk of heterotopic ossification compared with the anterior approach for the treatment of Pipkin I and II femoral head fractures." [36] Unfortunately, this review cannot be reproduced using the information traced from original studies. There are multiple data extraction errors, and the presented summary estimates are erroneous. Stannard et al found no difference in Short-Form 12 physical component scores (PCS) between patients who underwent surgery by an anterior (n = 9) or a posterior (n = 13) approach. Mean PCS scores were 39.8 (SD 14.8) and 40.0 (SD 13.1), respectively [20].

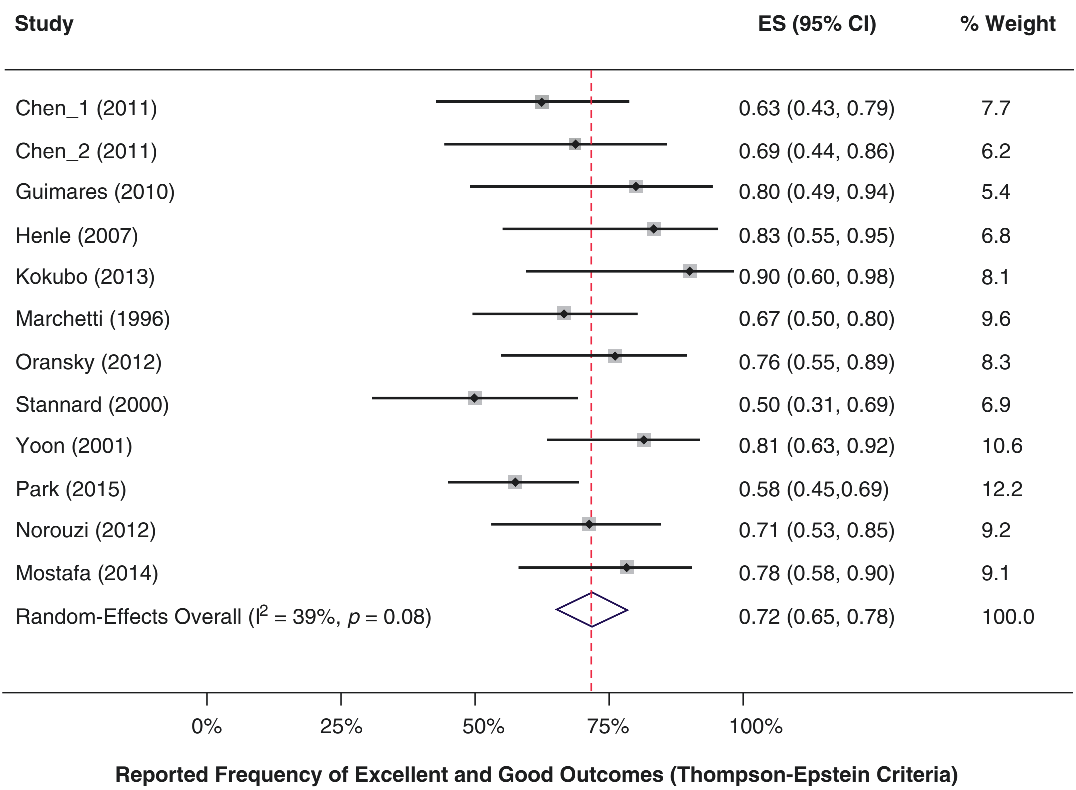

Fig. 4.14 Meta-analysis of excellent or good outcomes (according to Thompson-Epstein criteria) in patients with femoral head fractures of any grade undergoing any type of treatment

Table 4.6 Study and patient profile of included investigations

	ORIF	Other options
n	96	79
Mean age, years (SD)	35.8 (12.0)	41.9 (15.4)
Gender		
Male	68 (71%)	57 (72%)
Female	28 (29%)	22 (28%)
Pipkin classification		
1	22 (23%)	27 (34%)
2	46 (48%)	31 (39%)
3	2 (2%)	4 (5%)
4	26 (27%)	17 (22%)
Dichotomized Pipkin class		
1/2	68 (71%)	58 (73%)
3/4	28 (29%)	21 (27%)
Complications		
HO		
n	60	56
Brooker grade		
0	26 (43%)	34 (61%)
1/2	22 (37%)	14 (25%)
3/4	12 (20%)	8 (14%)
Any HO	34 (57%)	22 (39%)
AVN		
n	56	50
Any AVN	3 (5%)	8 (16%)
Thompson-Epstein		
n	96	79
Excellent	37	11
Good	38	38
Fair	10	16
Poor	11	14
Excellent/good	75 (78%)	49 (62%)
Fair/poor	21 (22%)	30 (38%)

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