13 Femoral Head Fractures

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Anatomical Fracture Location: Radiograph of Fracture Pattern

Femoral head fractures are intracapsular proximal femur fractures involving the articular surface of the femoral head. The average age of patients included in a meta-analysis of 29 articles (n = 398 fractures) was 38.9 years, with the mechanism of injury typically being high energy (89.4% motor vehicle collision, 4.3% falls from height) [1]. While several classification schemes exist, femoral head fractures are commonly classified utilizing the Pipkin classification [2, 3] This classification is composed of four categories: (1) femoral head fractures below the fovea capitis, (2) femoral head fractures above the fovea capitis, (3) femoral head fractures with associated femoral neck fractures, and (4) femoral head fractures of any type with associated acetabular fracture [4] (Fig. 13.1).

Preoperative Planning

Preoperative planning is completed with orthogonal radiography as well as computed tomography of the affected proximal femur and surrounding pelvis. These imaging modalities provide a full characterization of the femoral head fracture pattern, extent of displacement, concentricity of hip reduction, presence of loose bodies, as well as associated injuries including femoral neck and posterior wall acetabular fractures (Figs. 13.2 and 13.3). This is important in identifying components of the injury that need to be addressed during operative treatment, as well as guiding the surgical approach and sequence of intervention.

If preoperative imaging demonstrates nondisplaced or near-anatomic position (<2 mm displacement) of the fracture fragments in a Pipkin I or II fracture pattern, nonsurgical management may be considered. However, extension of Pipkin II fractures into the weight-bearing surface of the femoral head may make maintenance of an acceptable anatomic reduction difficult, often requiring direct open reduction and placement of implants to definitively stabilize the fracture fragments. Similarly, displaced Pipkin I fracture fragments may require fixation but are more commonly simply excised to avoid accelerated joint deterioration, as are any free fragments of comminution present in any femoral head fracture pattern. The presence of a femoral neck or posterior wall fractures in Pipkin III and IV patterns, respectively, further necessitates direct surgical reduction and fixation. In these cases, the associated injuries

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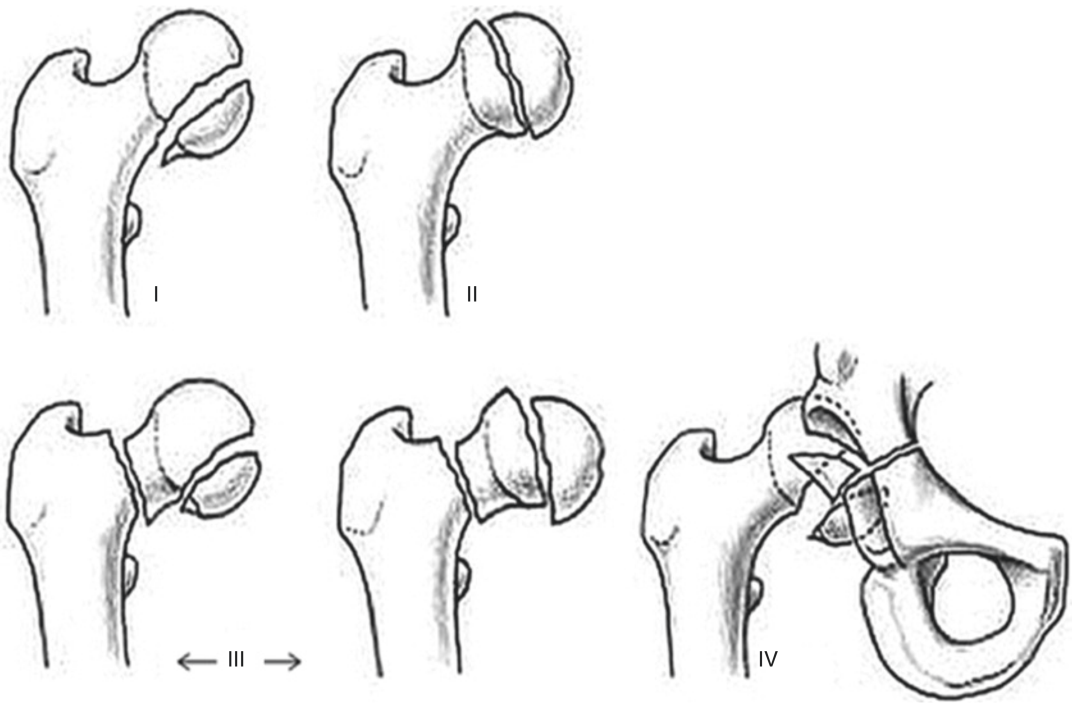


Fig. 13.1 Pipkin classification schematic (type III is any head fracture associated with femoral neck fracture). Taken with permission from "Femoral head injuries: which treatment strategy can be recommended?" (Henle et al. 2007) [5]

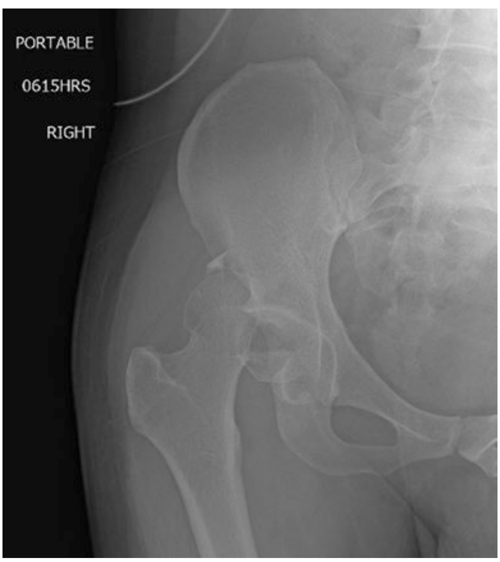


Fig. 13.2 Plain radiographs demonstrating the femoral head fracture-dislocation with an associated posterior wall acetabular fracture (Pipkin IV—not visualized well here). Attention should be paid to the incarcerated femoral head fracture fragment that may block successful closed reduction (Preoperative radiograph. Hamilton General Hospital, Hamilton, Ontario. Taken with patient permission, January 2017)

often dictate patient positioning and surgical approach, as outlined below. In select patients who are typically older and have preexisting hip arthritis or poor bone density, femoral head fractures may be best treated with a hemi- or total hip arthroplasty, particularly for Pipkin III or IV fracture patterns [1, 6]. However, for the purpose of this chapter, we will limit discussion for the treatment of these fractures to osteosynthesis-based management strategies.

Given the complete articular nature of femoral head fractures, selected internal fixation techniques must be taken care to avoid prominence at the articular surface to avoid accelerated wear [7]. This is classically accomplished with variable-pitch headless compression screws, bioabsorbable screws, or countersunk 2.7 or 3.5 mm lag screws [8, 9]. Care needs to be taken during dissection to preserve the intricate blood supply to the femoral head, including the terminal branches of the medial femoral circumflex artery (Fig. 13.4) [10].

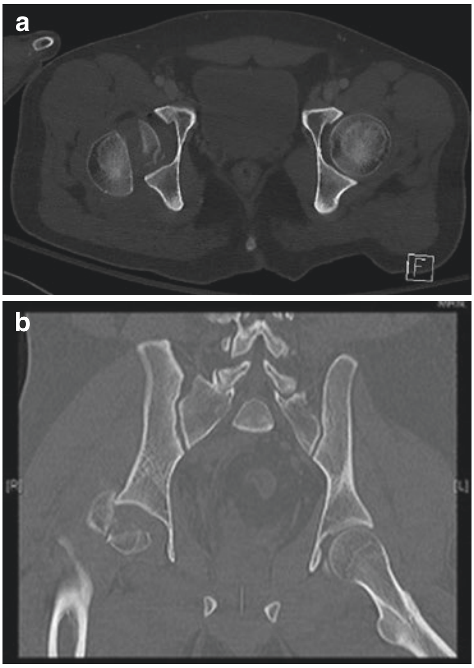


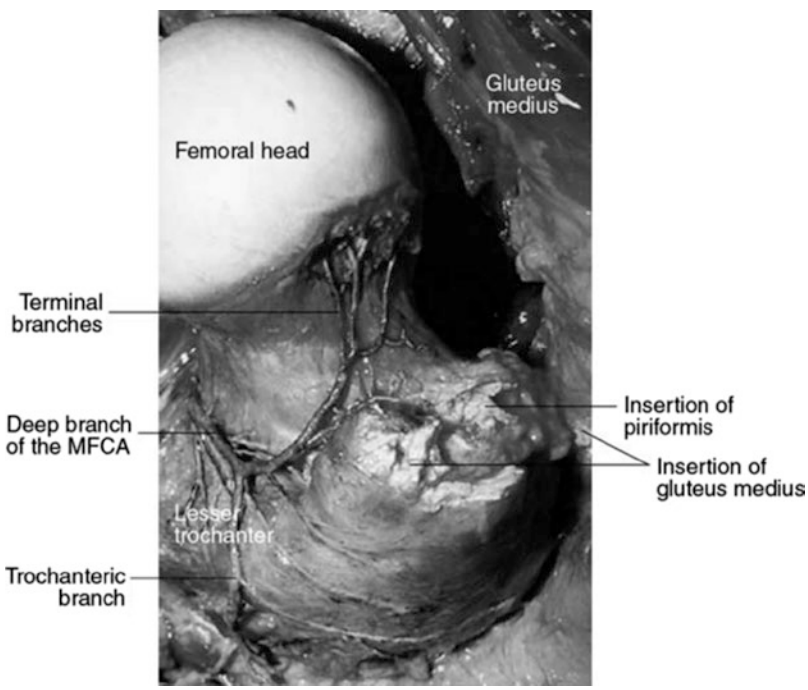
Fig. 13.3 Axial (**a**) and coronal (**b**) images from a CT scan of the same patient described above, with a large intra-articular femoral head fragment, small intra-articular loose bodies, and a grossly dislocated hip. There is also posterior acetabular wall impaction with a small peripheral rim posterior rim fracture that is not visualized in these select images (Preoperative computed tomography scan. Hamilton General Hospital, Hamilton, Ontario. Taken with patient permission, January 2017)

Patient Setup in Theater

Given the articular nature of the fracture, careful intraoperative assessment of the joint is required. This necessitates judicious use of fluoroscopy to evaluate that anatomic reduction of the proximal femoral articular surface has been achieved and ensure hardware does not violate the joint. As such, a fully radiolucent flattop table, or at least one that provides unencumbered fluoroscopic visualization of the hip and pelvis, should be utilized when treating these fractures.

Many femoral head fractures requiring operative intervention are treated with the patient in the supine position using an anterior (Smith-Petersen) hip approach [11]. A padded bump may be placed in the patient's midline at the lumbosacral region. The entire ipsilateral lower extremity is circumferentially prepped and draped with a stockinette used for the lower leg. This will allow adequate manipulation of the limb throughout the procedure. A radiolucent triangle or bump may be used to flex the knee and hip to take tension off of the iliopsoas and anterior hip structures. The surgeon should be positioned on the ipsilateral side of the injured extremity with image intensifier positioned on

Fig. 13.4 Anatomy of the femoral head, neck, and blood vessels. Adapted from Gautier E, Ganz K, Krugel N, Gill T, Ganz R: Anatomy of the medial femoral circumflex artery and its surgical implications. J Bone Joint Surg Br 2000;82:679–683



the contralateral side. The surgical assist should be situated on the same side as the surgeon and more cranially [12].

Alternatively, a posteriorly based approach may be used in the case of irreducible hip dislocations and Pipkin IV fractures where a posterior wall may also need to be addressed or when a trochanteric slide osteotomy and surgical hip dislocation may provide better access to the fracture. While the Kocher-Langenbeck approach may be done in the prone position for some isolated posterior wall acetabular fractures, lateral positioning is recommended when a femoral head fracture is present. The contralateral knee and ankle must be adequately padded to protect the common and superficial peroneal nerves, and the contralateral axilla should be free or gently supported with a small bump. A beanbag positioner or Stulberg pelvis supports may be used to maintain patient position, as long as they allow for free manipulation of the ipsilateral lower limb. Again, the entire lower limb is prepped and draped as outlined above, being careful to ensure that full access for the posteriorly based incision is available within the sterile field.

Closed Reduction Maneuvers

Femoral head fractures with associated persistent hip dislocation should be reduced promptly in a closed fashion. This should be completed under general anesthesia or deep procedural sedation with good relaxation. Care should be made to assess for femoral neck fractures prereduction to avoid displacement during reduction. As most of these fractures will be associated with posterior hip dislocations, one of several methods may be used to reduce the hip, all of which share common steps that rely on traction and countertraction principles. With the patient positioned supine and on a stable surface, which may be either the floor or a sturdy table, an assistant can stabilize the pelvis through downward pressure at the anterior superior iliac spines. The patient's dislocated hip can then be flexed along with the ipsilateral knee to relax the hamstrings. This is then followed by steady, longitudinal traction while simultaneously internally rotating and adducting the hip, which may be best achieved while situated on the opposite side of the patients injured hip. While applying traction, the hip is gently rotated while it is extended and brought into a reduced position. A knee immobilizer can be applied and possibly combined with traction to maintain the hip in a reduced position while further imaging is being arranged [13, 14].

Several structures may block adequate reduction of a femoral head fracture-dislocation, including incarcerated femoral head or acetabular fracture fragments, joint capsule, labrum, and ligamentum teres or muscle (rectus femoris, iliopsoas, piriformis, or gluteus maximus). Closed reduction of persistently displaced or incongruent femoral head fractures is not described or recommended and necessitates emergent open reduction.

Reduction Instruments

The most important factor in the reduction of these fractures is adequate visualization of the fracture fragments. Steps in maximizing exposure during the surgical approach are outlined below and can be thought as "tools" to help facilitate fracture reduction. Another adjunct when positioned supine is the use of in-line traction, through either a traction table or a femoral distractor placed across the hip joint, with one Schanz pin placed in the sciatic buttress of the pelvis and the other placed in the femur at the level of the lesser trochanter. While this may provide improved visualization, it may restrict the free movement of the entire lower limb, requiring frequent adjustment and reapplication of traction throughout the procedure. Alternatively, lateral traction may be applied through a Schanz pin inserted into the greater trochanter along the axis of the femoral neck. This may be secured to the table if attachments for lateral traction are available or manually manipulated using a T-handle chuck. The latter option carries the additional advantages of maintaining free mobility of the limb throughout the case and being applicable in either the supine or the lateral position.

Traction not only facilitates visualization but also provides adequate access to the hip to allow for the irrigation of any loose bodies originating from comminuted fragments out of the joint. Once the fracture is well visualized, hematoma and soft tissue must be meticulously cleared. Dental picks, small curettes, and high-pressure irrigation with a 10- or 20-cc syringe may be helpful in this step. Additionally, a small, sharp blade is often needed to clear the fringe of the fracture fragments where some comminution or delaminated cartilage may be present. These small, peripheral portions must be excised, as they may often hinder anatomic reduction of the main fracture fragments. Occasionally, larger segments of the femoral head donor site or fracture fragment may be marginally impacted, requiring elevation and backfilling of the underlying void with bone graft. Equipped with osteotomes and curettes, several sources of autograft are readily available in the surgical field, including iliac crest, posterior superior iliac spine, and the greater trochanter.

In order to obtain and maintain reduction, several additional instruments may be of use. This includes a dental pick to manipulate and stabilize small fragments or pointed reduction clamps (large and small) to control larger fragments (Fig. 13.5). Kirschner wires are often needed to provisionally stabilize reductions until final fixation is placed but may also be useful to "joystick" a fracture fragment into anatomic position.

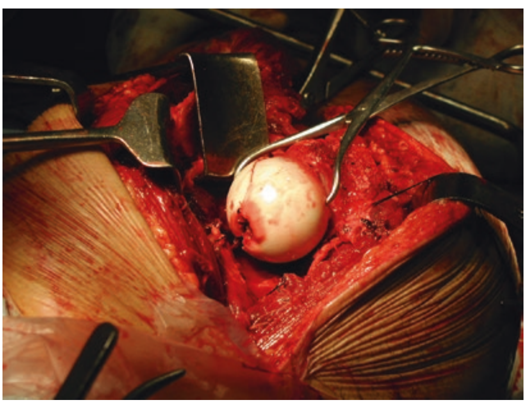


Fig. 13.5 Intraoperative photograph of a large Weber clamp being used to provisionally reduce and maintain a femoral head fracture fragment prior to placement of definitive fixation (Intraoperative photograph. Hamilton General Hospital, Hamilton, Ontario. Taken with patient permission, January 2017)

Not all femoral head fracture fragments are surgically repairable, and some may need to be excised. This is often made easier by using long, narrow clamps and grasps such as curved Kelly clamps, Kocher clamps, or pituitary rongeurs that can access tight spaces and minimize the need for further dissection.

Surgical Approach

Comprehensive exposure and visualization are important for adequate reduction and stabilization of femoral head fractures. This requires adequate access to the femoral head anteromedially as this is often the location of the main fracture plane. As mentioned earlier, this can be accomplished using either an anteriorly or posteriorly based approach, each with its own advantages and disadvantages.

An anterior (Smith-Petersen) approach to the hip provides adequate visualization of the femoral neck and head, avoids further compromise to the blood supply, and allows easy access to femoral head fragments without the need to dislocate the hip. The approach begins with the patient supine and the entire extremity prepped and draped as outlined above. A skin incision is made from the anterior superior iliac spine and continuing distally for 10 cm. The superficial internervous/intermuscular plane sits between sartorius (femoral nerve) and tensor fascia lata (TFL, superior gluteal nerve) muscles. The fascia overlying the TFL is very thin and will typically appear blue relative to the thicker, whiter fascia overlying the surrounding muscles. If using the Heuter modification, the TFL fascia is incised along its medial border, and then a deeper plane is developed within the TFL sheath by elevating the TFL muscle belly laterally [15]. Incising through the sartorius sheath is avoided with this modification, avoiding the risk of lateral femoral cutaneous nerve injury and operating in close proximity to the femoral nerve artery and vein. After going through the floor of the TFL sheath, the deeper plane between the rectus femoris (femoral nerve) and the gluteus medius (superior gluteal nerve) is identified. To help increase surgical exposure and access to the fracture fragments, the direct head of rectus femoris is tagged and released from its origin, with a short proximal stump remaining for later repair. The underlying lateral outcropping of the iliopsoas can be retracted medially, which can be made easier through flexion of the ipsilateral hip and knee using a radiolucent triangle or sterile bump under the knee. The remaining gluteus medius can be retracted laterally to directly view the underlying anterior hip capsule. A T capsulotomy can then be made after placement of stay sutures to assist with repair later in the case. The transverse limb of the "T" runs along the acetabular side of the joint, parallel to the labrum, while the vertical limb runs in-line with the femoral neck. The fracture and reduction can be assessed directly, without having to dislocate the hip. The typical anteromedial fracture location is best brought into view through external rotation, extension, and slight abduction of the hip.

Conversely, a posteriorly based approach such as a Kocher-Langenbeck or a digastric slide with surgical hip dislocation may be required to address irreducible fracture-dislocations, fractures with a posterior wall component, or far anteromedial head fractures [16, 17]. A posterior approach to the hip begins with the patient in the lateral position as outlined above. A skin incision is made below the iliac crest, lateral to the posterior superior iliac spine [18]. The incision is then extended distally past the greater trochanter in-line with the femur. The superficial dissection involves incising the fascia lata distally in-line with the skin incision and splitting gluteus medius proximally along an avascular plane. At this time, a persistently dislocated femoral head may be visible, and severe trauma may have occurred to the surrounding tissues. If possible, locate and tag the piriformis muscle, as well as the short external rotator muscles. If they are still intact, and a posterior wall fracture is to be addressed, they can be tagged and released 12–15 mm from their insertion to protect the blood supply to the femoral head as the medial femoral circumflex artery (MFCA) courses proximally. As these muscles are released and reflected, the sciatic nerve will also be retracted away from the working portion of the surgical field. Care should be taken to not extend the obturator externus as it protects the MFCA distally. This should then give access to clear any soft tissues or posterior wall fragments that may be impeding reduction. The femoral head can commonly be fixed through access provided by associated posterior wall fragments if present.

For fractures where more anteromedial femoral head exposure is required, a trochanteric slide can be undertaken; however, the blood supply to the femoral head and fracture fragments may be at increased risk during this exposure. As described by Ganz, an osteotomy of the greater trochanter is made with an oscillating saw, with a thickness of approximately 1.5 cm. The osteotomy should exit just anterior to the most posterior attachment of the gluteus medius muscle, protecting the deep branch of the MFCA (Fig. 13.6). Distally, the osteotomy should allow the entire origin of the vastus lateralis to remain attached and mobilized together with the trochanteric fragment [19]. To complete the surgical hip dislocation, a Z-shaped capsulotomy must be carefully performed to protect the terminal MFCA branches as they course superiorly along the femoral neck (Fig. 13.4). The capsu-

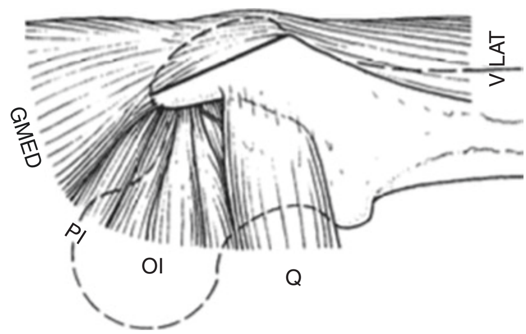


Fig. 13.6 Illustration depicting the direction of trochanteric osteotomy (*GMED* gluteus medius, *PI* piriformis, *OI* obturator internus, *Q* quadratus femoris, *VLAT* vastus lateralis). Adapted from Ganz, R., et al. "Surgical dislocation of the adult hip: a technique with full access to the femoral head and acetabulum without the risk of avascular necrosis." Bone & Joint Journal 83.8 (2001): 1119–1124

lotomy can be started anterolaterally, anterior to the lesser trochanter and then extended toward the acetabulum in a Z shape along the anterosuperior portion of the femoral neck and continued posteriorly along the acetabular rim, ending at the superior edge of the piriformis tendon (Fig. 13.7).

Once the capsulotomy is performed, the ligamentum teres should be released (if still intact) and the hip can then be safely subluxated or dislocated through flexion, external rotation, and placement of the leg into a sterile bag on the front side of the OR table. This should bring the femoral head and fracture clearly into view (Fig. 13.8).

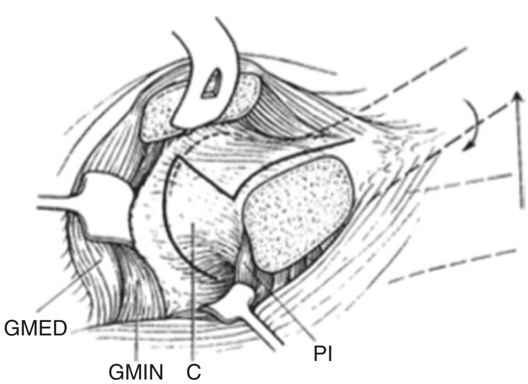


Fig. 13.7 Illustration depicting the "Z capsulotomy" (*GMIN* gluteus minimus, *C* capsule, *GMED* gluteus medius, *PI* piriformis, *OI* obturator internus). Adapted from Ganz, R., et al. "Surgical dislocation of the adult hip: a technique with full access to the femoral head and acetabulum without the risk of avascular necrosis." Bone & Joint Journal 83.8 (2001): 1119–1124

Open Reduction Maneuvers

Once adequate direct visualization is obtained, the fracture reduction is relatively straightforward. The challenge often comes in deciding whether a fragment should be excised or retained. When sufficiently large to allow for stable internal fixation, then the fragment should be fixed, and small or comminuted fragments can be excised without compromising patient outcomes (see footnote 2). Fragments that are not in the weight-bearing dome of the femoral head can also safely be excised. As outlined above, the major fracture site should be thoroughly cleared of any comminuted fragments and interposed hematoma or soft tissue. A combination of dental picks, pointed reduction clamps, and joystick k-wires can be used to obtain and provisionally maintain anatomic reduction of the articular surface (Fig. 13.9).

Anatomic reduction must be assessed using a combination of direct visualization, intraoperative examination, and fluoroscopic imaging. Clear visualization of the fracture is vital to restoring the articular surface. Reduction must be done using the chondral margins along the fracture planes. This may prove challenging if fragments have been excised or if marginal impaction is present. By additionally taking the hip through a range of motion, the surgeon can feel for the presence of any steps, gaps, or prominent hardware that may lead to blocks to non-fluid motion

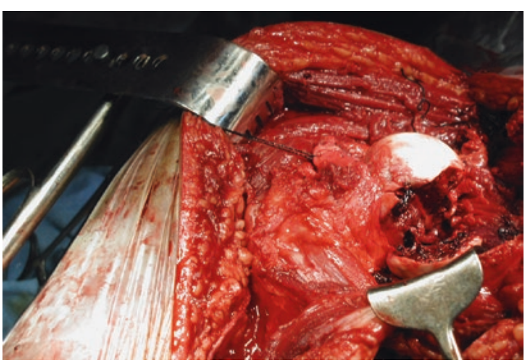


Fig. 13.8 Intraoperative photograph of a Pipkin II femoral head fracture approached using a surgical hip dislocation. Note the clear, unobstructed visualization of the entire fracture and femoral head

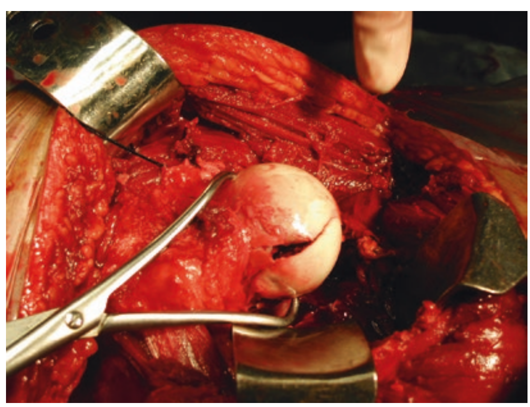


Fig. 13.9 Intraoperative photograph of a Pipkin II femoral head fracture. The fracture has been anatomically reduced using a large pointed reduction clamp. Note the small, non-weight-bearing fragment that has been excised

of the hip. Intraoperative fluoroscopy will also provide information pertaining to the quality of reduction and the presence of any hardware-related complications (Fig. 13.10). Care should be taken not only to obtain orthogonal views of the femoral head but also to obtain dynamic images throughout the range of motion. This will provide a more accurate representation of the reduction and implant positioning along the convex planes of the femoral head.

Fig. 13.10 Intraoperative fluoroscopy showing fixation of a Pipkin IV femoral head fracture with fixation of both the femoral head and acetabular rim in place, as well as screw stabilization of the trochanteric osteotomy (Intraoperative fluoroscopy. Hamilton General Hospital, Hamilton, Ontario. Taken with patient permission, January 2017)

Implant Insertion

Definitive fracture fixation must be performed using implants that will provide stable interfragmentary compression without being prominent beyond the articular surface. There are numerous implant options that can help accomplish this, including countersunk 2.0–3.5 mm lag screws, variable-pitch compression screws, and bioabsorbable pins. Typically at least two or three screws are placed to stabilize the main fragment, depending on its size and the quality of the bone (Fig. 13.11).

Summary of Tips and Tricks-Pitfalls

The operative management of femoral head fractures requires careful attention to avoid devastating complications such as avascular necrosis or early joint degeneration. To begin, a fully radiolucent OR table will aid greatly in fluoroscopic visualization through all planes of femoral head curvature intraoperatively. This is vital not only to the assessment of reduction but also in ensuring that there is no malpositioned or intra-articular hardware. Many of the challenges associated with the surgical treatment of these injuries can be alleviated by selection of the appropriate approach to facilitate fracture management. Both the Smith-Petersen approach and the digastric slide, surgical hip dislocation are

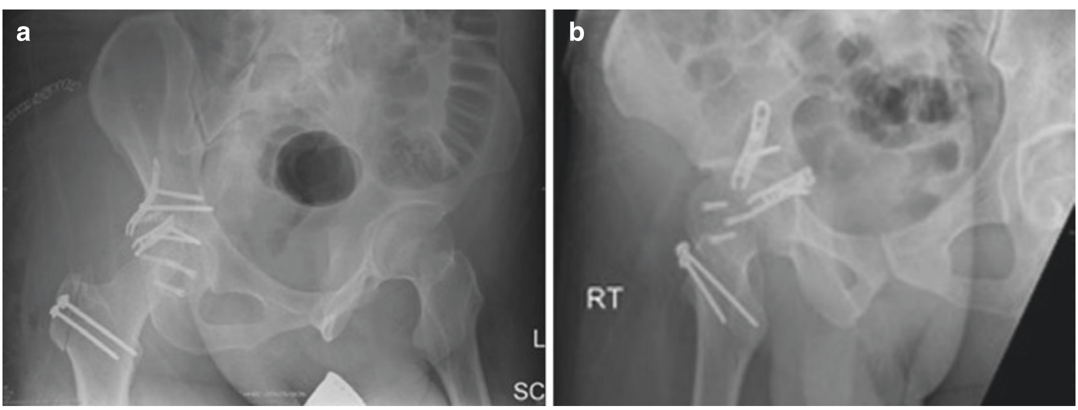


Fig. 13.11 Postoperative obturator (**a**) and iliac-oblique (**b**) radiographs of the right Pipkin IV fracture. The femoral head fracture was stabilized using three variable-pitch screws that were countersunk to avoid prominent hardware at the articular surface (Postoperative radiograph. Hamilton General Hospital, Hamilton, Ontario. Taken with patient permission, January 2017)

able to reach the anteromedial femoral head where most fractures are located. When positioned supine, a central sacral bump will aid in elevating the operative limb off of the table, which facilitates wide draping and unencumbered movement of the entire leg. A lateral traction Schanz pin placed at the lesser trochanter will provide additional control of the hip during the case without restricting free movement. With either approach used, efforts should be made to maximize exposure while avoiding risk of injury to key neurovascular structures. For the Smith-Petersen approach, the Heuter modification keeps surgical dissection away from the LFCN and femoral triangle. For posterior approaches, the MFCA and its branches are protected though a “Z” capsulotomy during a surgical hip dislocation, as well as ensuring that dissection does not come to close to the insertion of the short external rotators, or extend beyond the obturator externus during a Kocher-Langenbeck approach.

When it comes to fracture reduction, direct visualization of the chondral fracture margins is fundamental to anatomic restoration of the joint surface. This necessitates meticulous clearing of soft tissue, hematoma, and comminuted fragments and being prepared to elevate and backfill areas of marginal impaction with bone graft. Clamps and k-wires are key adjuncts in obtaining and provisionally maintaining fracture reduction until definitive hardware can be placed. Any implant that provides rigid, interfragmentary compression through at least two points may be used as long as hardware is countersunk below the chondral margin. The procedure should not be concluded without taking the hip though a range of motion to ensure that no blocks to motion exist by way of any large steps, gaps, loose bodies, or prominent hardware, which may lead to compromised outcomes.

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