Femoral Head Fractures Revisited

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Abstract

Background: Femoral head fractures have long been associated with a poor outcome. To date, only a few large series have adequate follow-up, and the description of injury types, treatment and outcome are often incomplete and thereby preclude comparison. Here, we retrospectively review our results with the treatment of a large series of femoral head injuries associated with posterior hip dislocations.

Patients and Methods: A retrospective review of posterior hip dislocations with femoral head fractures was done. Fractures were classified according to Pipkin, Brumback and to the AO classification. Outcome was based on physical and radiographic evaluation, in addition to the Merle d'Aubigné & Postel and the Thompson & Epstein scores.

Results: 33 femoral head fractures with posterior hip dislocations were treated at our institutions between 1970 and 1999. Nonoperative treatment was chosen in seven cases, open reduction and internal fixation (ORIF) in 20, and fragment excision in six. Average follow-up was 64 months (range 24–252 months). Of these, 56% had an excellent/good result, 16% did fair, and 28% had a poor outcome. Pipkin II fractures (Brumback 2A) did better than the Pipkin I (Brumback 1A) fractures, whereas the poorest outcome was seen in the Pipkin IV (Brumback 1B and 2B) fractures. There were four presurgical nerve lesions that were sequelae of the injury. Complications included heterotopic ossification (21%), deep infection (3%), avascular necrosis (6%), and recurrent dislocation (6%).

Conclusions: Posterior hip dislocations with femoral head fracture-dislocations represent severe injuries. Better visualization and ability to internally fix these fractures could potentially improve the outcome. We introduce a modified, anterolateral approach to femoral head fractures based on a digastric trochanteric osteotomy.

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Introduction

The most common mechanism of injury in a hip fracture-dislocation is the so-called dashboard injury [1], in which the generally unrestrained driver or passenger hits his knee on the dashboard during a collision with the force of the impact being transmitted along the axis of the femur [2]. The position of the hip such as adduction, flexion and rotation at the time of impact determines if the hip dislocates with or without fracturing the head and/or acetabulum. The association of femoral head fractures with hip dislocations has been reported to range from 4–17% [3–13]. Although still uncommon, the increase in high-speed traffic accidents and the improved resuscitation of the patients have resulted in a growing number of these fractures. Treatment protocols for femoral head fractures are difficult to establish because of their limited incidence and the different outcome classifications used in the literature. A review of the literature by Brumback et al [14] 15 years ago resulted in a total of 144 reported Pipkin cases. However, because of the lack of illustrations, radiographs, descriptions and follow-up, only 78 (54%) of these could be used in their analysis of outcomes. More recently, a review in the German literature encountered similar difficulties [15].

With controversies remaining on the classification, treatment and outcome of these fractures, we set out to critically review our own experience to help optimize the results in these often severe injuries.

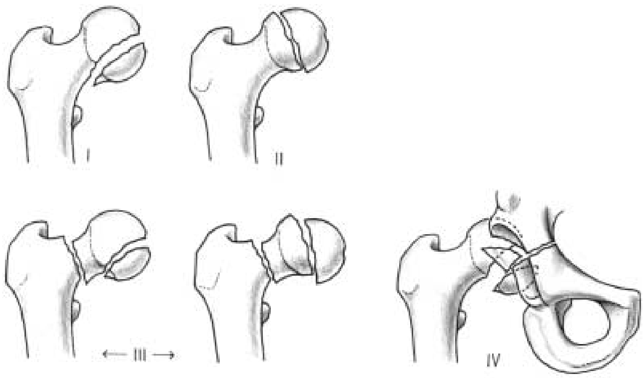

Figure 1. Diagram showing the Pipkin classification of femoral head fractures [16].

Table 1. Pipkin classification of femoral head fractures [16].

Type	Description
I	Hip dislocation with fracture of the femoral head caudad to the fovea capitis femoris
II	Hip dislocation with fracture of the femoral head cephalad to the fovea capitis femoris
III	Type I or II injury with associated fracture of the femoral neck
IV	Type I or II injury with associated fracture of the acetabular rim

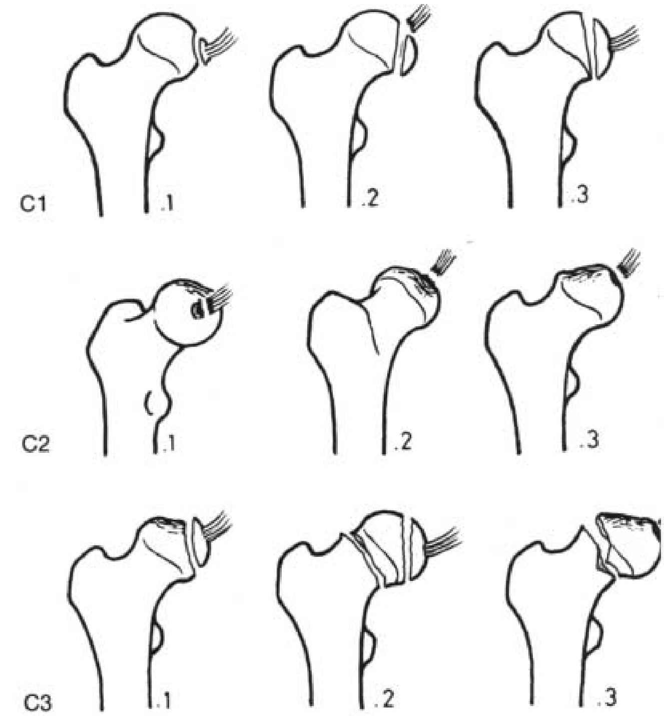

Figure 2. Diagram showing the AO classification of femoral head fractures [17].

Patients and Methods

A retrospective review of all posterior hip dislocations associated with a femoral head fracture that were treated at two large trauma centers was performed (n = 33). All results are based on review of the patient's medical record and radiographs at the latest follow-up (minimum follow-up of 2 years). Each fracture type was classified according to the Pipkin classification (Figure 1, Table 1) [16], the AO classification (Figure 2) [17] and the Brumback classification (Figure 3 and Table 2) [14] in order to provide the most comprehensive review possible. Outcome was based on two commonly used evaluations, the Merle d'Aubigné & Postel score (Table 3) [18], and the Thompson & Epstein score (Table 4) [19]. The Merle d'Aubigné & Postel score is based equally on pain, mobility and walking ability on a scale of 0–6 points each for a maximum of 18 points. For outcome

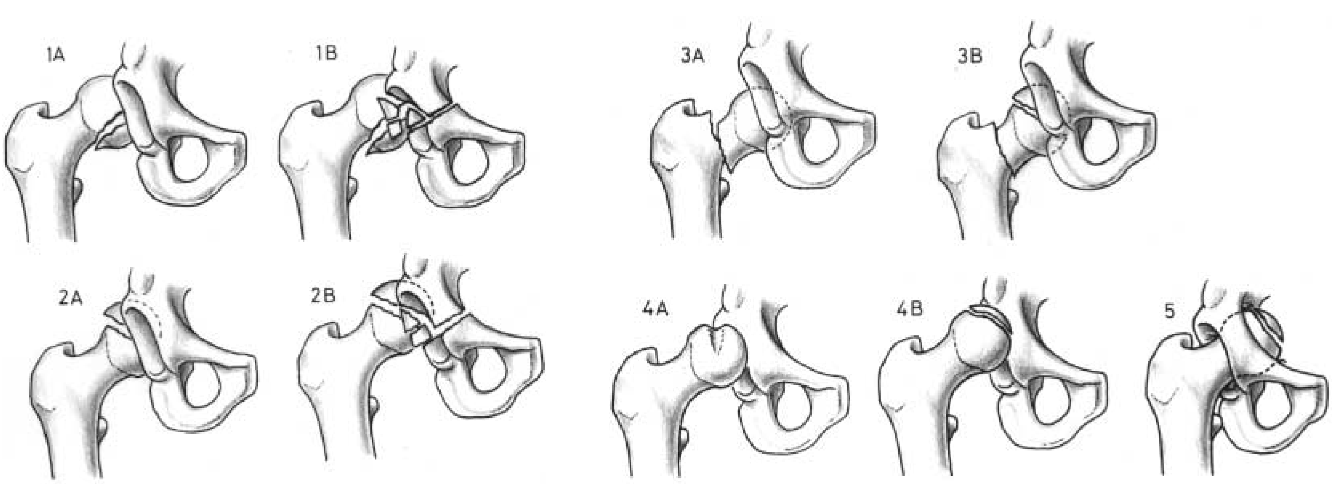

Figure 3. Diagram showing the Brumback classification of hip fracture-dislocations [14].

Table 2. Brumback classification of hip fracture-dislocations [14].

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

Table 3. Merle d'Aubigné & Postel score [18]. A total of 18 points is classified as excellent, 15–17 as good, 12–14 as fair, and less than 12 as poor.

	Pain	Mobility	Ability to walk
0	Intense and permanent	Ankylosis with bad position of the hip	None
1	Severe even at night	No movement; pain or slight deformity	With crutches only
2	Severe when walking; prevents any activity	Flexion under 40°	With canes only
3	Tolerable with limited activity	Flexion between 40 and 60°	With one cane, less than 1 h; difficult
4	Mild when walking; disappears at rest	Flexion between 60 and 80°; patient can reach his foot	A long time with a cane; a short time without a cane and with a limp
5	Mild and not constant; normal activity	Flexion between 80 and 90°; abduction of at least 15°	Without cane but with slight limp
6	None	Flexion more than 90°; abduction to 30°	Normal

Table 4. Thompson & Epstein score [19]. In case of discrepancy between the clinical and radiographic score, the lowest of the two determines the final score.

Excellent	No pain No limp Full hip motion	Normal femoral head-acetabular relationship Normal joint space Normal femoral head density No spur formation No soft tissue calcification
Good	No pain, slight limp At least 75% of normal hip motion	Normal femoral head-acetabular relationship Minimal joint space narrowing Mild deossification Minimal spur formation Minimal capsular calcification
Fair	Pain, but not disabling Antalgic gait Moderate limitation of hip motion	Normal femoral head-acetabular relationship Moderate joint space relationship Mottling of the femoral head Moderate spur formation Moderate soft tissue calcification Depression of subchondral bone in femoral head
Poor	Disabling pain Marked limitation of hip motion Adduction contracture Redislocation	Marked loss of joint space Increased density of femoral head Subchonral cyst formation Gross deformity of femoral head Severe spur formation Acetabular sclerosis

evaluation, the categories “excellent” (18 points) and “good” (15–17 points) were combined. The Thompson & Epstein score consists of determination of clinical and radiographic scores, each of which is given a rating of excellent, good, moderate, or poor. The worst of these (usually the radiographic one) determines the final score. Although some reports classify a hip prosthesis as a good result, we feel that with exception of a Pipkin III (Brumback 3B) fracture in an elderly patient, the treatment goal in Pipkin fractures should be to preserve the joint. In our patient analysis, therefore, we determined an arthroplasty as a poor outcome, whether it was done primarily or as a salvage option. A similar scenario holds true for a hip arthrodesis.

The incidence of complications including heterotopic ossification, avascular necrosis and posttraumatic arthrosis was also documented. For the heterotopic ossification the classification of Brooker et al [20] was used, while for posttraumatic arthrosis we followed the classification of Thompson & Epstein [19].

Results

A total of 33 femoral head fractures in 32 patients that were treated at our institutions between 1970 and 1999 were identified (Table 5). There were twelve females and 20 males. The average age at the time of injury was 39 years (range 17–75 years). The vast majority (22 patients) sustained the injury in a car accident. Seven other patients were involved in a motorcycle accident, one sustained a fall, one sustained a crush injury, and no information regarding the injury mechanism was available for one patient. 15 patients had multiple injuries, while for the other 17, the femoral head fracture was their only injury. The classification of all fractures according to Pipkin, AO and Brumback was determined from the operative notes and radiographs. A total of ten Pipkin I fractures were treated. All except one femoral head fracture-dislocation were reduced within 24 h. 25 patients (26 hips) underwent surgical treatment, whereas seven were treated nonoperatively. One had an unrecognized dislocated hip with a femoral head injury for 5 days before transfer to our hospital. Although we attempted to document the presence and amount of an associated depression fracture, a large number of older cases had no CT documentation, not allowing adequate analysis.

Surgical approaches varied from anterolateral (Watson-Jones; n = 5) to anterior (Smith-Peterson; n = 7), posterior (Kocher-Langenbeck; n = 9), and, more recently, with a so-called trochanter-flip (= digastric) osteotomy with anterior subluxation or dislocation for a less restricted view and handling (n = 5).

Follow-up of at least 2 years was available for all patients (average follow-up 64 months, range 24–252 months). One patient had become paraplegic (T10 level) at the time of the accident (Pipkin III or Brumback 3B), and was excluded from outcome analysis since he was wheelchair-bound. At the last follow-up (at 2 years), he had heterotopic ossification (Brooker type III), severe posttraumatic arthrosis, and lateral subluxation of the hip.

The overall outcome, regardless of fracture type or treatment, was excellent/good in 56%, fair in 16%, and poor in 28%. Table 6 summarizes the results per fracture type using both the Pipkin and the Brumback classification. These results emphasize once again that femoral head fractures represent severe injuries. The AO classification of femoral head fractures does not have a subgroup for an acetabular fracture in conjunction with a femoral head fracture (Pipkin IV). Outcome based on the AO classification can be extrapolated from the Pipkin fracture type since our Pipkin I fractures were all C1.2 fractures and the Pipkin II fractures were similar to the C1.3 fracture. There were four posttraumatic (presurgical) sciatic nerve injuries, with two mainly involving the peroneal division. Two of these patients almost completely recovered. There were no surgical nerve injuries. One patient developed a deep infection after osteosynthesis leading to a septic hip joint (Salmonella). There were a total of seven cases of significant heterotopic ossification (Brooker III or IV), four patients developed Brooker type I, and two patients had Brooker type II heterotopic bone. When separating by approach, the Kocher-Langenbeck (n = 9) resulted in two cases of type I or II heterotopic ossification (22%), whereas one had type IV (11%), none of these had type III. The anterolateral approach was associated with heterotopic ossification stage III in two out of four cases (50%), although these had concomitant factors (deep infection and paraplegia, respectively), and the anterior approach with stage III in one out of six (17%) and stage I in two out of six (33%). Five patients underwent a digastric osteotomy, of whom three (60%) developed significant (Brooker III or IV) heterotopic bone. One patient with Brooker IV heterotopic ossification underwent excision at 6 and 30 months after the initial injury, respectively. He is currently (almost 7 years post-injury) without symptoms and has returned full-time to his job

Table 5. Patient data. AL: anterolateral; AL*: traumatic avulsion of gluteal musculature of greater trochanter; AVN: avascular necrosis; fem hd ft: femoral head fragment; HO: heterotopic ossification; HR: hardware removal; I and D: irrigation and debridement; ITO: intertrochanteric osteotomy; KL: Kocher-Langenbeck; MCA: motorcycle accident; MVA: motorvehicle accident; n.a.: not available; ORIF: open reduction and internal fixation; PTA: posttraumatic arthritis; SP: Smith-Peterson; THP: total hip prosthesis; †: same patient, died of unrelated causes at 24 months postoperatively.

Case	Age/sex	Pipkin	Brumback	AO type	Cause	Treatment	Approach	Complications	Additional surgery	Follow-up (months)	Merle d'Aubigné & Postel Score	Thompson & Epstein Score	H.O. (Brooker)
1	17f	I r	1A	C1.2	MVA	Nonoperative	—	—	—	92	Fair	Fair	0
2	57f	I l	1A	C1.2	MVA	Nonoperative	—	Nerve injury	—	30	Good	Good	0
3	50f	I l	1A	C1.2	MVA	ORIF	AL	Nerve injury	Neurolysis p 8 mo partial recovery	51	Poor	Fair	0
4	47m	I l	1A	C1.2	MVA	ORIF	AL	PTA	ITO, HR	66	Fair	Fair	0
5	31f	I r	1A	C1.2	MVA	ORIF	AL	Infection	I and D, THP p 12 yr	192	Poor	Poor	III
6	44m	I r	1A	C1.2	MC	ORIF	KL	Nerve injury		24	Fair	Fair	I
7	29f	I r	1A	C1.2	MVA	ORIF	KL	—	—	70	Excellent	Good	0
8	67f	I l	1A	C1.2	MVA	Excision	KL	Nerve injury	—	24	Good	Good	0
9	21f	I l	1A	C1.2	MVA	Excision	KL	Recurrent hip luxation	ITO/acetabuloplasty, HR	54	Excellent	Good	0
10†	71m	I l	1A	C1.2	Falling tree	ORIF	AL*	HO	—	24	Good	Good	I
11†	71m	II r	2A	C1.3	Falling tree	ORIF	Trochanter-flip	HO	—	24	Excellent	Good	II
12	31m	II l	2A	C1.3	MVA	Nonoperative	—	AVN	ITO followed by hip arthrodesis, then THP	252	Poor	Poor	0
13	50m	II l	2A	C1.3	MVA	Nonoperative	—	—	—	92	Excellent	Fair	0
14	28m	II r	2A	C1.3	MC	Nonoperative	—	—	—	32	Excellent	Good	0
15	34m	II r	2A	C1.3	MVA	ORIF	Trochanter-flip	HO	Excision HO	30	Good	Good	III
16	19m	II r	2A	C1.3	MVA	ORIF	SP	—	—	24	Excellent	Excellent	0
17	31f	II r	2A	C1.3	n.a.	ORIF	SP	—	—	32	Good	Good	0
18	31m	II l	2A	C1.3	MC	Excision	SP	—	—	75	Excellent	Good	I
19	24m	III l	3B	C3.1	MC	ORIF	AL	HO, T10 paraplegia	Excision HO p18 mo	24	Poor	Poor	III
20	75m	IV r	1A	—	MVA	Nonoperative	—	—	—	43	Fair	Fair	0
21	44f	IV r	2A	—	MVA	Nonoperative	—	—	—	60	Good	Good	0
22	42m	IV l	2B	—	MVA	Excision	KL	PTA	THP p 12 mo	90	Poor	Poor	0
23	38m	IV l	1B	—	MVA	ORIF acetabulum, excision fem hd ft	KL	AVN	THP p 2 mo, revision THP p 13 yr	168	Poor	Poor	II
24	36m	IV l	n.a.	—	MC	ORIF	SP	PTA	THP p 4 yr	60	Poor	Poor	III
25	35f	IV l	1B	—	MVA	ORIF	SP	Malreduction	Re-ORIF p 6 wk	60	Fair	Poor	I
26	40m	IV r	1A	—	Fall	ORIF	Trochanter-flip	HO	HR/excision HO p 20 mo, THP p 25 mo	26	Poor	Poor	IV
27	42m	IV l	2A	—	MVA	ORIF fem hd	SP	Recurrent luxation	Hip arthrodesis p 2 mo	24	Poor	Poor	—
28	39m	IV r	1A	—	MC	ORIF	Trochanter-flip	—	—	37	Good	Good	0
29	37f	IV l	2A	—	MVA	ORIF fem hd	SP	—	—	168	Excellent	Excellent	0
30	41m	IV l	1A	—	MVA	ORIF	KL	HO	Excision HO p 6 mo/30 mo	64	Good	Good	I
31	38m	IV l	1A	—	MC	ORIF	Trochanter-flip	HO	—	33	Good	Good	II
32	35m	IV l	1B	—	MVA	ORIF	KL	—	—	34	Excellent	Fair	0
33	25f	IV r	1A	—	MVA	Excision	KL	—	—	48	Excellent	Good	0

Table 6. Results of current study by fracture classification. Table modified according to Marchetti et al. [25].

Results	Pipkin type I	Pipkin type II	Pipkin type III	Pipkin type IV	
Excellent/good	5/10 (50%)	7/8 (87.5%)		6/14 (43%)	
Fair	3/10 (30%)			3/14 (21%)	
Poor	2/10 (20%)	1/8 (12.5%)		5/14 (36%)	
Results	**Brumback type 1A**	**1B**	**2A**	**2B**	**3B**
Excellent/good	8/16 (50%)	1/3 (33%)	9/11 (82%)		
Fair	5/16 (31%)	1/3 (33%)			
Poor	3/16 (19%)	1/3 (33%)	2/11 (18%)	1/1 (100%)	

as a truck driver. Two patients developed recurrent dislocations; one of these was treated with an arthrodesis, the second one with a rotational intertrochanteric osteotomy and posterior acetabuloplasty. Two cases of avascular necrosis were seen; one of these had an unreduced fracture-dislocation for 5 days and was subsequently treated with a closed reduction, the other one had undergone a Kocher-Langenbeck approach for open reduction and internal fixation (ORIF) of the acetabulum and excision of the femoral head fragment. One patient (Pipkin IV, Brumback 1B) had a malreduction of the acetabular osteosynthesis and needed revision within 6 weeks. A trend was seen that Pipkin II and Brumback 2A fractures did better than Pipkin I and Brumback 1A and 1B injuries. However, with a multitude of fracture types, fixation types and approaches resulting in small groups, no statistical evaluation was deemed appropriate.

Discussion

Although a fairly significant amount of literature is available on femoral head fractures, a meta-analysis on this subject is complex. As was noted by the authors of a comprehensive review of the English literature 15 years ago [14], a few large "classic" series do not specify their results based on the fracture type, but merely on the treatment rendered (closed reduction, ORIF, or excision) [5, 7, 21–23]. In addition, different classification systems and treatments do not allow to compare the reported outcomes of these fractures. Most reports have focused on Pipkin fractures, which generally are shear-type femoral head fractures sustained after posterior dislocations. In the more recent literature, Brumback et al [14], DeLee et al [24] and Ganz [17] have reemphasized impaction/indentation and transchondral-type injuries as yet another important variant of femoral head fractures, usually seen with anterior fracture-dislocations [1]. As opposed to the Pipkin classification, these injuries are included in the Brumback classification [14], which makes this classification better applicable.

Similar to what is encountered in the literature, our series of 33 posterior hip dislocations with femoral head fractures predictably involved different fracture types, mechanisms of injury and treatments, making statistical analysis and/or recommendations solely based on our series impossible. For instance, the postoperative Salmonella infection of the hip seen in one of the Pipkin I fractures clearly skewed this relatively small group toward a poor outcome. The general consensus that Pipkin IV injuries lead to a worse outcome was reflected as a trend in our series, albeit not statistically significant.

Interestingly, the overall results of excellent/good in 56% of these femoral head fractures are surprisingly consistent with the other large series published over the years [6, 8, 10, 14, 16, 25–30]. Most of these series, including our own, represent an extended period of time during which treatments have evolved, and therefore also reflect somewhat of a learning curve. Nevertheless, with the more recent development of diagnostic modalities and surgical exposures, we feel that improvement of outcome is possible. This is exemplified by a more favorable outcome in four out of our five patients (80% good outcome) that underwent ORIF through our currently preferred trochanter-flip approach.

Based on our own experience and the literature, we present the following guidelines that include most well-known aspects but introduce an approach that is based on better knowledge of the vascular anatomy of the proximal femur.

Initial Evaluation and Treatment

Representing one of the few orthopedic emergencies, reduction of a femoral head fracture-dislocation should be performed immediately. This should be done with good muscle relaxation to prevent an iatrogenic femoral neck fracture during attempted reduction [11, 12, 16, 21, 22, 28]. Post-reduction evaluation should include a CT with small cuts (1.5–2 mm) to determine the adequacy of reduction, presence of comminution, indentation or impression, and to rule out intraarticular fragments [31]. Inability to reduce the fracture by closed means and/or interposition of bony fragments in the joint – as determined on CT – would mandate early surgery. In a series by Pape et al., this subset of patients that needed early surgery had a high incidence of postoperative complications including early total hip arthroplasty [29].

Recently, we have also included MRI to evaluate possible damage to the obturator externus muscle in hip dislocations and fracture-dislocations. This muscle protects the medial femoral circumflex artery, which is sufficient for the blood supply to the femoral head [21, 32]. Rupture of the obturator externus muscle would indicate extracapsular rupture of the vessel, warranting a microvascular exploration and potential repair. In addition, the MRI, and even better radial MRI will more clearly reveal any associated depression fracture of the femoral head [33, 34]. The information provided by these diagnostic modalities allows a more complete understanding of the fracture pattern to help decide on further treatment.

Definitive Treatment

Based on a careful evaluation of these radio-graphic studies, definitive treatment can be planned based on the patient's physiologic status. Pape et al [29] showed that a strategy of active treatment in multiple trauma patients produced few complications with satisfactory intermediate-term results. Closed anatomic reduction in Pipkin I and II (comparable to Brumback 1A and 1B fractures) appears to be the best option. If this cannot be obtained (as determined on post-reduction CT), osteosynthesis is likely to lead to a better result than excision. According to the literature, closed reduction leads to excellent/good results for Pipkin I and II fractures in about 75% of the cases, ORIF yields similar results in 64% of the cases, excision of fragments gives good/excellent results in only 50% of cases [6, 8, 9, 11–14, 25, 26, 28, 35–37]. In the older literature, Epstein advocated excision of the fragments, stating that up to one third of the non-weight-bearing portion of the femoral head can be excised without compromising the function [5, 7, 22]. However, maintenance of joint-congruity is a prerequisite for a good outcome which is reinforced by the more recent literature [4, 6, 8, 26, 35]. In cases where closed anatomic reduction is not possible, open reduction with screw fixation seems a worthwhile approach, based on the fact that blood supply to the inferior portion of the head can be maintained based on the capsular attachments alone (Pipkin I, Brumback 1) or the capsular attachment and the intact round ligament (Pipkin II, Brumback 2) [6, 8, 13, 28]. The vascularity of the fragment and the main head after fixation can be confirmed by 2-mm drillings [17] or intraoperative Doppler flow [21]. In case a large portion of the weight-bearing surface of the femoral head is involved and cannot be reduced and fixed, a more definitive procedure such as arthrodesis or arthroplasty has been suggested [5, 22]. Although no scientific data were provided, Epstein stated that this is indicated for femoral head fragments exceeding one third of the circumference. For the very rare Pipkin III or Brumback 3A fractures, total hip arthroplasty seems to be a reasonable indication for most older patients. The majority of Pipkin III fractures reported in the literature was treated with arthroplasty and reportedly did well, but this does not necessarily reflect a better outcome when regarding the long-term results of a joint prosthesis versus a joint-preserving procedure. In agreement with others, we advocate osteosynthesis for Pipkin III fractures in young patients [13, 17, 26, 37]. Similarly, a joint-preserving approach should be pursued for Pipkin IV (Brumback 1B or 2B) injuries, specifically in young adults [13, 15, 22, 23, 25], although this fracture type typically represents a poor prognosis [5, 8, 15]. The Brumback classification has not yet been shown to have predictive value for outcome as opposed to the Pipkin classification [25], but this could be due to lack of large enough groups [25, 27]. When we evaluated the combined data of our study with two others that used the Brumback as well as the Pipkin classification [25, 27] with Spearman's correlation for ordinal data, we could not detect any correlation or association with the outcome ($p > 0.05$).

Surgical Approach

Although initial damage to the cartilage at the time of injury undoubtedly plays a significant role in the determination of the final outcome of femoral head fracture-dislocations, we feel that the poor results in many of the cases are, to a large extent, caused by difficulties encountered in obtaining an adequate exposure, reduction, and subsequent osteosynthesis. Over the years, a variety of surgical approaches has been advocated for the treatment of femoral head fractures, including the anterolateral (Watson-Jones) [15, 21, 26, 28], lateral [4], medial (Ludloff) [10], anterior (Smith-Peterson) [27, 26, 35], and posterior (Kocher-Langenbeck) [36] approaches. Each of these approaches has advantages and disadvantages. The often quoted disadvantage of the anterior-based approaches has been the association with increased heterotopic ossification [6, 23]. On the other hand, a posterior-based approach has suboptimal access to the fracture fragments on the opposite side of the head. This is also reflected in our series by the fact that five out of nine patients who underwent a Kocher-Langenbeck approach had mere excision of the femoral head fragment because of limited access and visibility, whereas the anterior, anterolateral and trochanter-flip approach allowed fixation in the vast majority of cases (6/7, 5/5, and 5/5, respectively).

A recent comparative study between anterior and posterior approaches for Pipkin I and II fractures showed that the use of the anterior approach gave less blood loss, shorter operating times, and better visualization. However, more heterotopic ossification after the anterior approach was indeed seen in this study [23]. Another common criticism of an anterior-based approach is that it will damage most, if not all, remaining blood supply to the femoral head that was dislocated posteriorly [5, 7, 22]. However, this theory has not been strongly supported in recent literature, which shows that there is little-to-no interference with the blood supply to the femoral head via this approach [28]. Others have shown the anterolateral approach to be most favorable for Pipkin I, II and III fractures [15, 21, 26, 28]. The major advantage of this approach to femoral head fractures is considered to be the good visualization and ability to reduce and stabilize the fracture. Type IV fractures involve, by definition, the posterior aspect of the acetabulum, and in case of a large acetabular fragment and/or instability are best treated through a Kocher-Langenbeck approach [6, 23, 26, 28], but have the aforementioned difficulty to approach the femoral head fragment. It is here that the Brumback classification might be helpful, since some of the Pipkin IV fractures with little acetabular rim involvement (which would be classified as Brumback 1A or 2A) do not necessarily need acetabular fixation (as opposed to Brumback 1B and 2B fractures), thus allowing an anterior-based approach.

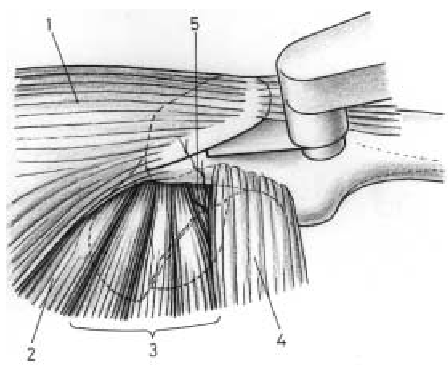

Figure 4a

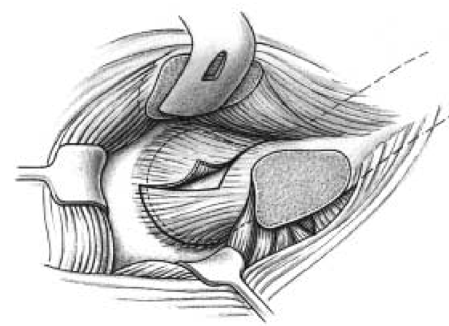

Figure 4b

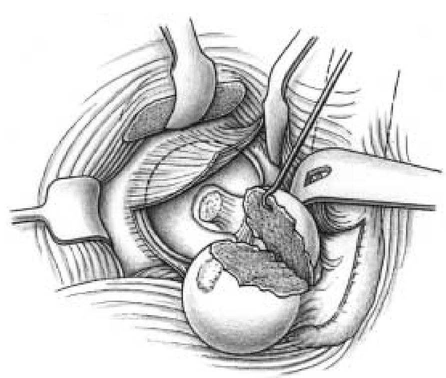

Figure 4c

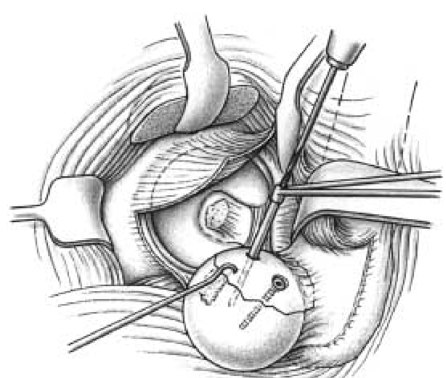

Figure 4d

Figures 4a to 4d. Surgical hip dislocation.
a) Diagram showing the line for the trochanteric osteotomy for the trochanteric flip (1: gluteus medius; 2: piriformis; 3: obturator internus and gemelli; 4: quadratus femoris; 5: deep branch of the medial femoral circumflex artery).
b) Diagram showing the Z-shaped capsulotomy. The femur is flexed and externally rotated. External rotators are left intact.
c) After Z-shaped capsulotomy, the femoral head is dislocated allowing easy visualization of the femoral head fracture.
d) Using standard techniques, the femoral head fracture can now be reduced and internally fixed [38].

Figure 5a

Figure 5b

Figure 5c

Figure 5d

Figure 5e

Figures 5a to 5e. a) 71-year-old man with bilateral fracture-dislocations of the femoral head (case 10/11; Pipkin I on the left and Pipkin II on the right side). Closed reduction was performed within 4 h.
b and c) A large displaced head fragment is seen after reduction on the anteroposterior pelvic radiograph on the left side (b) and the axial view on the right side (c).
d) Anatomic reduction and fixation with surgical dislocation of the head on both sides.
e) Anteroposterior pelvic radiograph at 12 months follow-up in this pain-free patient shows Brooker class I–II heterotopic ossifications and no signs of avascular necrosis or osteoarthritic changes. The patient deceased 24 months after surgery due to metastatic cancer.

Recently, we have started using a posterior-based approach with a trochanter-flip (digastric) osteotomy for femoral head fractures as well as other hip procedures [38–40]. Having experience with all exposures for internal fixation of femoral head fractures, we feel this approach permits direct inspection of the femoral head fracture allowing anterior subluxation or dislocation if needed, and includes access to the posterior wall of the acetabulum for internal fixation (Figures 4–6). Four out of five patients who were treated using this approach had

Figure 6a

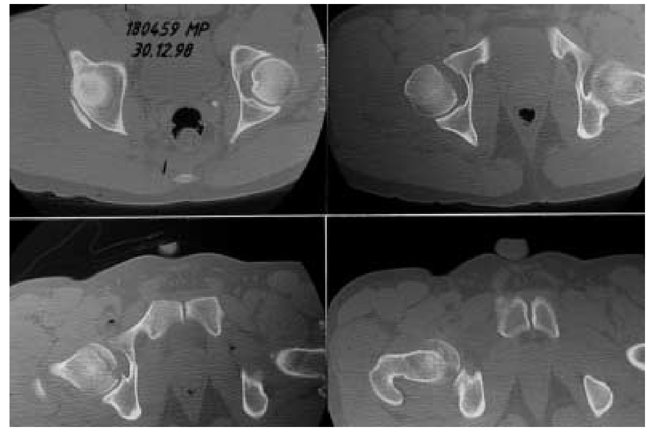

Figure 6b

Figure 6c

Figure 6d

Figure 6e

Figure 6f

Figures 6a to 6f. Displaced femoral head fragment.
a) Anteroposterior pelvic radiograph after closed reduction of a Pipkin IV fracture in a 39-year-old male patient (case 28).
b) An additional acetabular rim fracture (arrow) can be seen on the CT scan.
c to e) By the technique of surgical dislocation of the femoral head, the fragment could be easily visualized (c), reduced under visual control (d), and fixed with two 2.7-mm cortical screws (e). In addition, the pelvic rim fracture was fixed with two 3.5-mm cortical screws.
f) The anteroposterior pelvic radiograph demonstrates a normal hip joint morphology with a good functional outcome at 2 years follow-up.

a good result (80%). This compares favorably with the combined other approaches utilized in this series (45% excellent/good). We strongly feel that the superior visualization and ability to anatomically reduce and fix the fracture are the reasons for better outcomes although small sample size precludes statistical significance. Since there is less need for retraction and/or damage to the abductor muscles with this approach, the risk of significant iatrogenic heterotopic ossification is lowered. Of note is that the incidence of heterotopic ossification in our patients with femoral head fractures who underwent a trochanter-flip approach is higher than in a larger group that underwent this approach for elective (nontraumatic) hip surgery [38]. This suggests that the underlying cause for heterotopic ossification is – at least – partially trauma-related and beyond the surgeon's control.

Method of Fixation

Although most authors have used countersunk minifragment screws for fixation of the fragments, others have advocated Herbert screws [25, 41] or titanium screws to diminish the amount of MRI artifacts [36]. The successful use of absorbable pins in a series of five Pipkin fractures has also been described [9].

Complications

The reported complication rate of avascular necrosis (0–24%), posttraumatic arthrosis (0–72%), nerve injury (7–27%), and heterotopic ossification (2–54%) with this injury and its subsequent treatment have varied [4, 6, 8, 11, 12, 14, 16, 22, 23, 26, 28–30, 42]. Table 7 summarizes the complication rates reported in the literature. Of note is that the reported rates for posttraumatic arthrosis and avascular necrosis of the hip might be somewhat skewed in the older reports, since the determination for these conditions was generally made based on plain radiographs instead of the newer modalities such as SPECT scanning and MRI, which are better able to distinguish between the two [6]. The old belief that an antero(lateral) approach after posterior hip dislocation increases the risk of avascular necrosis does not seem to hold true. Interestingly, Stannard et al. recently showed that the Kocher-Langenbeck approach was associated with a 3.2 times higher incidence of avascular necrosis compared with the anterior approach [27].

Presurgical nerve injuries most often involve the peroneal division of the sciatic nerve and most often are self-limiting. This is reflected in our series and the literature.

As far as heterotopic ossification is concerned, there are no clear guidelines as to its prevention. The underlying mechanism has not yet been elucidated, but speculations have been made about the involvement of members of the bone morphogenetic protein (BMP) family. Associated head injury, age, sex, extensive muscle damage, and poor soft tissue handling are other factors involved. Until the exact etiopathogenesis is known, we cannot more specifically prevent and treat the formation of heterotopic bone. Although we do not routinely use indomethacin as prophylaxis, a 6-week course of indomethacin (25 mg orally 3×/day) can be given, if the patient has previously shown to form heterotopic bone and/or has a head injury. Radiation treat-

Table 7. Literature review of complication rates associated with femoral head fractures[a]. AVN: avascular necrosis; HO: heterotopic ossification; PTA: posttraumatic arthrosis.

Reference	Total number of patients	Nerve injury[b] (%)	HO[c] (%)	AVN (%)	PTA (%)
Brumback et al (14)	19	21	11 (I–II)	0	11 (severe)
Butler et al [4]	10			10	
DeLee et al [24]	13		7	13	54
Dreinhöfer et al [6]	22	7	54 (I)[d] 23 (II) 14 (III)	9	18 (mild) 5 (moderate)
Epstein et al [22]	46	11	2	24	24
Hougaard & Thomsen [8]	18		6	12	0
Lang-Stevenson & Getty [11]	7		14	14	29
Marchetti et al [25]	33	15	15 (I) 18 (II) 24 (III) 6 (IV)	10 6 (severe)	72 (mild)
Maroske et al [42]	11	27			22 (mild)
Pape et al [29]	14			57	36 (mild) 7 (severe)
Pipkin [16]	25		16 (IV)	8	8
Roeder & DeLee [12]	13	23	8	0	31
Schönweiß et al [26]	14	14	2 (I) 7 (II) 14 (III)	14	64 (mild) 21 (severe)
Stockenhuber et al [28]	8		38 (I) 25 (II)	13	13 (mild) 13 (severe)
Swiontkowski et al [23]	24		17 (III)[e] 25 (I–II)	8	8
Stannard et al [27]	22			23	
Yoon et al [30]	27			7	

[a] only series reporting over five patients
[b] most often involving the peroneal division of the sciatic nerve and temporary
[c] Brooker stage [20] between parentheses if available
[d] this is in 22 Pipkin fractures and 4 non-Pipkin classifiable fractures
[e] all after anterior (Smith-Peterson) approach

ment is another prophylactic measure often utilized, but has the potential to impair fracture healing and can lead to sarcomatous degeneration. Although the excision of heterotopic ossification can be challenging, it is often worthwhile for the patient.

Salvage Options

As stated previously, we believe that every effort should be made to preserve the joint, especially in the young patient. However, since this fracture type and its treatment have a high rate of posttraumatic arthrosis and a risk of avascular necrosis, these patients may return to the surgeon with severely impaired hip function. For large indentation fractures, the use of an inter-trochanteric osteotomy has been successful in our hands [43]. If a joint is not salvageable in a young active patient, a hip arthrodesis is the next best option. For the older patient, a joint replacement is of higher value.

In summary, we believe newer techniques and approaches allow us improved outcome of femoral head fractures. Anatomic reduction leading to a perfectly congruent joint is the goal of treatment. Careful evaluation of the reduction (pre- and postoperatively) using CT scan is mandatory. When surgery is required, it is most important to use an approach that gives an excellent view of and access to the fracture, thus allowing as perfect an anatomic reduction and fixation as possible. We recommend the trochanter-flip approach, which combines the advantage of an anterolateral approach and the advantage of avoiding extensive stripping of or damage to the abductor musculature. Lastly, for outcome studies – despite the solid entrenchment of Pipkin's name with these fractures – we recommend to include Brumback's classification to enable more robust comparisons between the recent studies.

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