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FRACTURES OF THE ACETABULUM
A clinical, radiological and experimental study

by
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Munksgaard
Copenhagen 1977

This study includes the following parts

PART ONE

A clinical study

by

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A radiological study

by

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PART TWO

An experimental study

by

Olle Lansinger and Bertil Romanus

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CLINICAL AND RADIOLOGICAL STUDY

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PART ONE
A CLINICAL AND RADIOLOGICAL STUDY

by
Olle Lansinger and Lars Irtam

INTRODUCTION

Acetabular fractures have since long attracted interest. In 1575 Ambroise Paré stated that "there is this danger in the dislocation of the hip that either the bone cannot be put into place again at least unless with much trouble, or else, being put in that it will presently fall out again". According to Nicoll (1966) this statement referred to fractures of the acetabulum which could either obstruct reduction or render it unstable.

Acetabular fractures with *central* dislocation of the femoral head were described by Calissen in 1778 (Schroeder 1909). In later years central acetabular fractures have been described with increasing frequency (Westerborn 1954, Stewart & Milford 1954, Rowe & Lowell 1961, Judet, Judet & Letournel 1964, Lehtonen 1968).

Posterior acetabular fractures were described in the 19th Century by Cooper (1824) and Malgaigne (1855). During the first 50 years of the 20th Century few reports were published on posterior acetabular fractures. In the middle of 1950 a careful study was carried out by Waller (1955) who examined 106 such fractures of a total of 2334 pelvic fractures during the period 1945-1954. He found that during this 10-year-period there was an increase from 2 per cent to 8 per cent which he ascribed to increasing traffic accidents.

As regards the *classification* of *central* acetabular fractures no general agreement seems to have been reached so far. Stewart & Milford (1954), Eichenholtz & Stark (1964) and Pearson & Hargadon (1962) based their different classifications of central acetabular fractures on the degree of central protrusion of the femoral head. Knight & Smith (1958), Rowe & Lowell (1961) and Judet, Judet & Letournel (1964) found it more important to take account of the distribution of the fracture lines.

Posterior acetabular fractures are as a rule classified depending on the degree of dislocation of the acetabular fragment, the comminution of the fracture and the stability of the joint (Thompson & Epstein 1951, Epstein 1961, 1974, Stewart & Milford 1954, Waller 1955).

As for *treatment* of acetabular fractures opinions differ.

Central fracture-dislocations offer some problems in that the surgical technique is difficult. Conservative measures have therefore been recommended (Böhler 1966, Stewart et al. 1975). There are few comparative studies of different treatments something which further adds to the problem of evaluation.

Posterior acetabular fractures without posterior dislocation of the femoral head and without posterior displacement of the acetabular fragment are treated either with traction or early mobilization without weight-bearing (Waller 1955).

Posterior acetabular fractures in combination with posterior dislocation of the femoral head (posterior fracture-dislocations) are as a rule treated by closed reduction of the femoral head followed by open fixation of the acetabular fragment (Waller 1955, Epstein 1974, Ender 1976), but the conservative approach with traction is also used (Böhler 1954, Brav 1962, Nerubay et al. 1973).

The object of the present investigation has been:

1. To carry out a clinical study based on 124 acetabular fractures in 123 patients treated during 1963-1973 at the Departments of Orthopaedic Surgery I and II, Sahlgren Hospital, Göteborg. Special consideration has been taken to frequency, classification, radiographic appearance, cause of injury, associated injuries and treatment.
2. To perform a clinical follow-up study of 101 hips in 100 patients during April 1974-January 1975.
3. To carry out a radiologic study with special reference to possible development of post-injury osteoarthritis and avascular necrosis of the femoral head.

BASIC MATERIAL

A STUDY OF 123 PATIENTS AND A REVIEW OF LITERATURE

Material

The material consists of 123 patients with 124 fractures admitted during 1963-1973 to the Departments of Orthopaedic Surgery I and II, Sahlgren Hospital, Göteborg.

Age and sex

Age and sex are presented in Figure 1. The men represent 68 per cent (82 patients) and the women 32 per cent (41 patients). The youngest patient was a 14-year-old girl and the oldest an 86-year-old lady. The mean age for the men was 47 years and for the women 51. The mean age for the total material was 49 years. The distribution of age with the peak incidence between 40-60 years corresponds well with the reports in the literature (Waller 1955, Trojan & Perschl 1956, Wechselberger 1956).

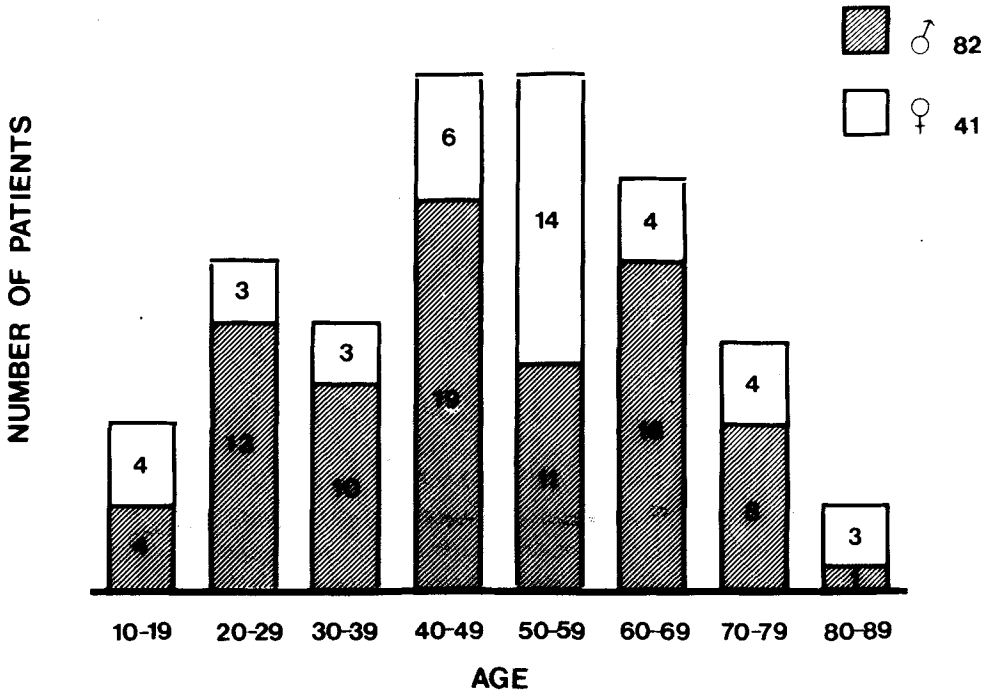


Fig. 1. Age and sex distribution in 123 patients with acetabular fractures.

Side of injury

Of the 124 fractures 61 were on the right side and 63 on the left.

Frequency

In 1928 Westerborn reported on 293 pelvic fractures. Among these he found 51 (47 central and 4 posterior) acetabular fractures, i.e. 17.4 per cent.

In 1943 Wilenius described 88 (82 central and 6 posterior) acetabular fractures in 428 pelvic fractures collected between 1922-1939, i.e. 20.6 per cent.

An increase from 2 to 8 per cent in posterior acetabular fractures over a 10-year-period was noted by Waller (1955) in 2334 pelvic fractures.

Wechselberger (1956) reported on 159 acetabular fractures in 754 pelvic fractures, i.e. 21 per cent.

In a material of 407 pelvic fractures Huittinen & Slätis (1972) found 103 acetabular fractures, i.e. 25.3 per cent.

Solheim & Skrede (1973) found central and posterior acetabular fractures in 11 per cent of all pelvic fractures which represented 0.4 per cent of all fractures studied.

Present investigation

During 1963-1973 648 patients with pelvic fractures were treated at the Sahlgren Hospital, Göteborg. Among these, 123 had acetabular fractures, i.e. 19 per cent which corresponds well with the frequencies reported in the literature.

Classification of acetabular fractures

Anatomy of the acetabulum

The acetabulum forms the central meeting point of the os ischium, the os ilium and the os pubis. It forms a deep circular socket for the articulating femoral head. Rowe & Lowell (1961) have divided the acetabulum into a superior, posterior and inner part. The superior third of the acetabulum, the superior dome, is the main weight-bearing area of the joint, and the posterior third has a stabilizing effect. The inner part of the acetabulum is much more thin-walled than the remaining acetabulum and increases the stability of the joint.

Judet, Judet & Letournel (1964) stated: "We consider the acetabulum to be located in the concavity of an arch formed by two columns of bone, one anterior and the other posterior. These columns converge and meet in a thick and compact zone of bone which is always spared by fractures of the acetabulum. This zone is situated below and in front of the iliac articular surface of the sacroiliac joint. The posterior or ilioischial column which is voluminous and thick descends caudad as far as the ischial tuberosity. This column is composed of the vertical portion of the ischium and of that portion of the ilium immediately above the ischium. On the anterolateral surface of the column lies the posterior part of the articular surface of the acetabulum, the posterior acetabular rim. On the medial surface of this column is the quadri-

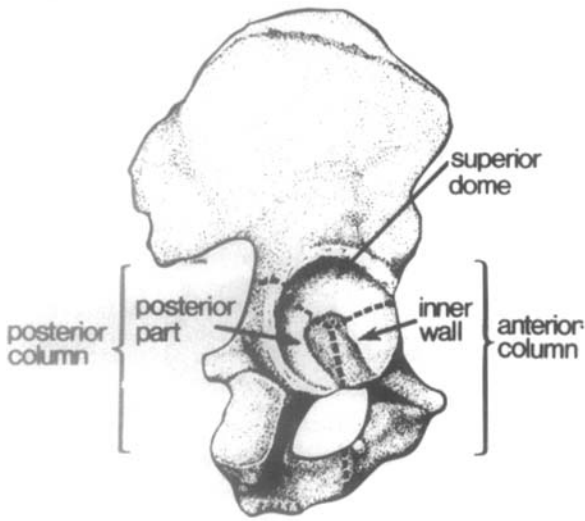


Fig. 2 A. External aspect of right acetabulum.



Fig. 2 B. Internal aspect of right acetabulum.

lateral surface. The anterior or iliopubic column runs obliquely downward, inward and anteriorly making an angle of about 60 degrees with the posterior column. The anterior column consists of a short segment of the ilium and of the pubis and extends up as far as the anterior inferior iliac spine. On the posterolateral surface of this column lies the anterior part of the articular surface of the acetabulum, the anterior acetabular rim. These two columns form an arch in which the superior angle or key-stone is formed by a rounded plate of compact iliac bone, the roof of the acetabulum” (Figs. 2 A and 2 B).

Central acetabular fractures

There are many suggestions on the classification of central acetabular fractures. Some authors make their classification according to the degree of central dislocation of the femoral head (Stewart & Milford 1954, Eichenholtz & Stark 1964). Others find it more important to take account of the distribution of fracture lines and which part of the acetabulum that becomes involved (Knight & Smith 1958, Rowe & Lowell 1961, Judet, Judet & Letournel 1964).

Stewart & Milford (1954) have suggested the following classification:

- Grade I: Linear and stellate fractures through the floor of the acetabulum. No dislocation of the femoral head.
- Grade II: Comminuted fractures with a mild to moderate central displacement of the femoral head and of the acetabular fragments.
- Grade III: Marked displacement of the fragments and protrusion of the head of the femur into the pelvis with or without comminution of the superior portion of the acetabulum.



Fig. 3. Right acetabulum with an isolated fracture of the posterior column.



Fig. 4. Right acetabulum with a transverse fracture.



Fig. 5. Right acetabulum with a T-fracture.



Fig. 6. Right acetabulum with a mixed fracture involving the iliac wing besides the two columns.

Grade IV: Central dislocation with an associated fracture of the head or neck of the femur.

Rowe & Lowell (1961) have classified their acetabular fractures into four groups: (Group I, III and IV are central fractures).

Group I: Linear undisplaced fractures with either single or stellate lines.

Group II: Posterior fractures with a small rim fracture or a large displaced posterior sector.

Group III: Innerwall fractures with minor, moderate, and severe intrapelvic displacement of the femoral head.

Group IV: Superior and bursting fractures with varying degree of disruption of the acetabular socket.

Judet, Judet & Letournel (1964) made a classification according to the involvement of the "iliopubic bone" as a fracture of the anterior column and to the involvement of the "ilio-ischial bone" as a fracture of the posterior column. Their classification is therefore:

- Isolated fractures of the columns (Fig. 3)
- Pure transverse fractures (Fig. 4)
- Combined fractures of both columns (Fig. 5)
- Mixed fractures (Fig. 6).

Present investigation

In the present investigation the central dislocation of the femoral head and the appearance of the superior dome have been estimated and a classification similar to that of Stewart & Milford (1954) has been used.

The position of the femoral head was classified as follows:

no dislocation

mild to moderate dislocation: < 15 millimeters of the centre of the femoral head in a central direction

severe dislocation: central dislocation \geq 15 millimeters

Mode of measurement

On AP views the lower borders of the sacro-iliac joints were combined by a horizontal line drawn across the pelvis. The center for each femoral head was determined and from each center a perpendicular was drawn to intersect with the horizontal pelvic line. The distance from the point where the perpendicular through the centre of the femoral head met the horizontal

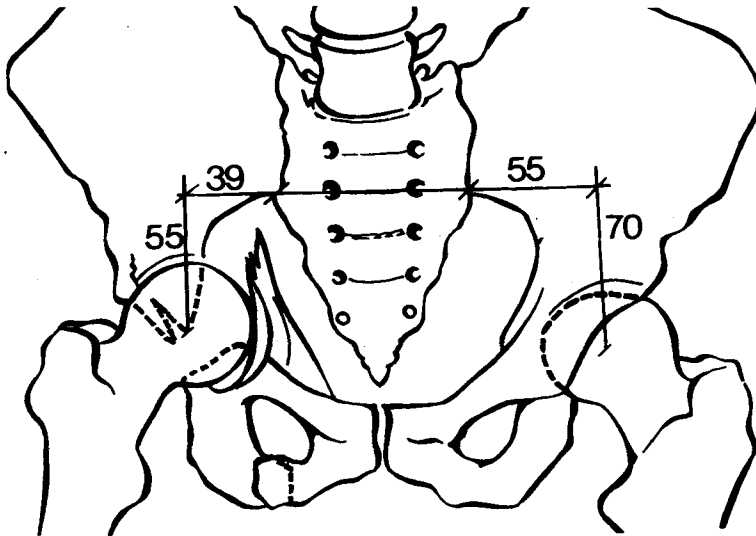


Fig. 7. Schematic illustration of measurement of the central dislocation of the femoral head in a patient with a severe central dislocation of the femoral head, where the fracture involves the superior dome.

pelvic line was then measured on each side to the lower border of the sacro-iliac joint (Fig. 7). The difference in distance decided the degree of medial dislocation. The same comparison of distance was made along the perpendicular to obtain information of the degree of superior dislocation.

Classification of own material

- I: Central fractures without central dislocation of the femoral head (Fig. 8).
 - A – Without displacement of the acetabular fragments.
 - B – With displacement of the acetabular fragments.
- II: Central fractures with mild to moderate central dislocation of the femoral head (Fig. 9).
 - A – The superior dome intact.
 - B – The superior dome fractured.
- III: Central fractures with severe central dislocation of the femoral head (Fig. 10).
 - A – The superior dome intact.
 - B – The superior dome fractured.

Central fractures in 85 patients are presented in Table 1. Age and sex distribution for patients with central acetabular fractures is presented in Figure 11.



Fig. 8. Radiograph of a central acetabular fracture without central dislocation of the femoral head in the right hip in a 37-year-old male.



Fig. 9. Radiograph of a central acetabular fracture with mild to moderate central dislocation of the femoral head where the superior dome is intact in the right hip in a 64-year-old male.



Fig. 10. Radiograph of a central acetabular fracture with severe central dislocation of the femoral head, where the superior dome is fractured, in the right hip in a 59-year-old female.

NUMBER OF PATIENTS

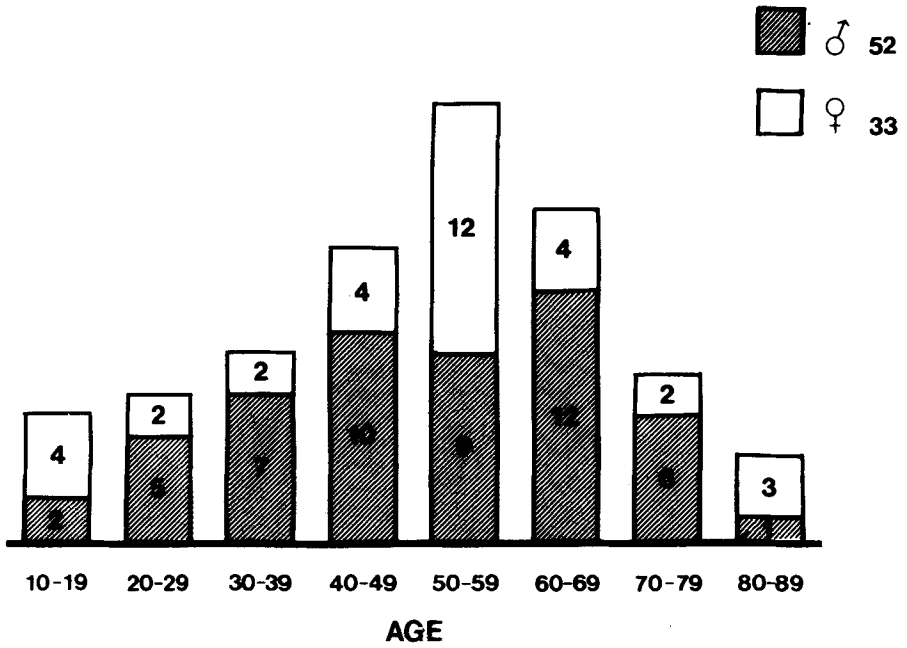


Fig. 11. Age and sex distribution in 85 patients with central acetabular fractures.

Table 1. Classification of central acetabular fractures, 85 patients

Type of fracture	Number of patients
Central fracture without central dislocation of the femoral head	
Without displacement of the acetabular fragments	19
With displacement of the acetabular fragments	26
Central fracture with mild to moderate central dislocation of the femoral head	
The superior dome intact	11
The superior dome fractured	8
Central fracture with severe central dislocation of the femoral head	
The superior dome intact	5
The superior dome fractured	16
Total	85

Posterior acetabular fractures

Thompson & Epstein (1951) suggested the following classification for posterior fracture-dislocations of the hip.

- Type I: Posterior dislocation of the femoral head without fracture or with no more than minor fracture of the posterior rim.
- Type II: Posterior dislocation of the femoral head with a large single fracture of the posterior rim.
- Type III: Posterior dislocation of the femoral head with a comminute fracture of the posterior rim.
- Type IV: Posterior dislocation of the femoral head with a fracture of both the rim and the floor of the acetabulum.
- Type V: Posterior dislocation of the femoral head with fracture of the femoral head with or without other fractures.

Stewart & Milford (1954) used a similar classification, dividing their posterior fractures into four grades, which corresponded to Type I, II, III, and V in the classification made by Thompson & Epstein.

Waller (1955) divided his posterior fractures into three types:

- Type I: Fracture of the posterior, superior part with no or only moderate displacement of the fragment (Fig. 12).
- Type II: Fracture with a single fragment of the posterior part with extensive displacement and usually dislocation of the femoral head (Fig. 13).
- Type III: Comminute fractures (Fig. 14).

Some authors have not found it necessary to subdivide posterior acetabular fractures into various types, like e.g. Rowe & Lowell (1961) and Judet, Judet & Letournel (1964).

Present investigation

For this investigation the classification of Waller (1955) has been used. In Table 2 a presentation of the types of posterior fractures in 39 patients is given. Four patients were classified as Type I, 15 as Type II, and 20 as Type III.

Table 2. *Posterior acetabular fractures in 39 patients classified according to Waller (1955).*

Type of fracture	Number of patients
Type I	4
Type II	15
Type III	20
Total	39



Fig. 12. Radiograph of a posterior acetabular fracture Type I in a 44-year-old male.



Fig. 13. Radiograph of a posterior acetabular fracture Type II in a 24-year-old male.



Fig. 14. Radiograph of a posterior acetabular fracture Type III in a 23-year-old male.

Of 39 posterior fractures, 32 were combined with a posterior dislocation of the femoral head. Thus, there was no femoral head dislocation in 7 and of these 4 were classified as Type I and 3 as Type III.

Age and sex distribution for patients with posterior fractures is presented in Figure 15.

Comment. In 7 patients there were fractures of combined posterior and central types. These were classified according to the fracture which appeared radiographically dominating. Five of these were central fractures which in addition had a minor fracture of the posterior acetabular rim without displacement. Two were posterior fracture-dislocations which in addition had central fractures: one without displacement of the acetabular fragments and one with a comminute central fracture with displacement of the acetabular fragments.

The radiographic appearance of the hip joint in the diagnosis of acetabular fractures

In 1955 Waller pointed out that a reliable radiologic view of the acetabulum could not be obtained only by AP (anteroposterior) and lateral projections. "The anterior and posterior acetabular margins are sometimes completely or partly superimposed and the head of the femur obscures the view. Since routine radiologic examinations mainly are confined to these projections posterior acetabular fractures might be overlooked."

In 1948 Urist described a series of 15 cases of posterior acetabular fractures of which 4 were not observed at the primary radiologic examination.

In 1955 Waller found 12 neglected cases in a material of 106 posterior acetabular fractures.

In 1968 d'Aubigne' stated "among the last 100 cases of old dislocation of the hip 47 were probably unrecognized in the hospital where they were admitted in emergency".

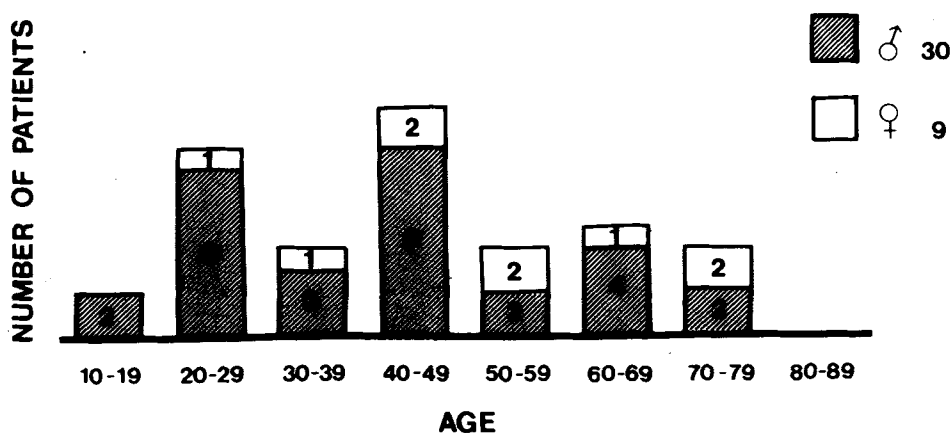


Fig. 15. Age and sex distribution in 39 patients with posterior acetabular fractures.

Waller in 1955 stressed the importance of oblique projections in posterior acetabular fractures. He suggested the following procedure: the patient is placed semiprone on the examination table with the injured hip down and the healthy side up (Fig. 16 A). The patient supports himself on one hand and on the flexed healthy leg so that he lies in approximately 45 degrees semiprone position. Supported by a few sandbags placed under the chest and thighs, the patient does not exert pressure on the injured hip. The x-ray tube is directed from behind at an angle of 10 degrees cranially and is centered on the gluteal fold. In this position the beams run tangentially to the upper acetabular rim which is depicted on the radiograph as a sharply arched line, which continues medially to form the posterior boundary of the incisura acetabuli. The postero-superior part of the acetabulum is depicted unobscured by other skeletal parts (Figs. 16 B and 16 C).

In central fracture-dislocation of the hip the AP view demonstrates disruption of the acetabulum. However, it may be difficult in this view to determine accurately the extent of displacement and the exact location of the fractured fragments.

Judet, Judet & Letournel (1964) suggest the following projections in the radiologic diagnosis of acetabular fractures.

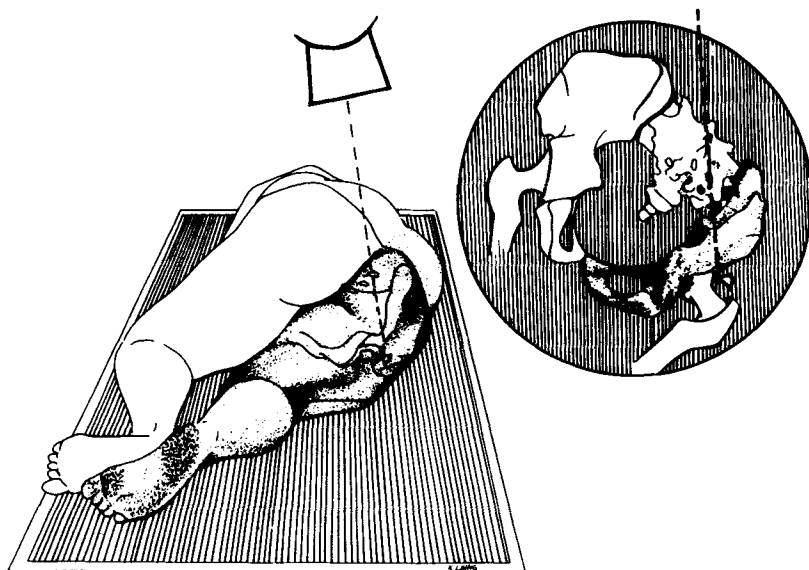


Fig. 16 A. Patient in semiprone position for radiographic demonstration of fracture of the posterior rim of right acetabulum according to Waller.



Fig. 16 B. Anteroposterior view of right hip with a posterior acetabular fracture.

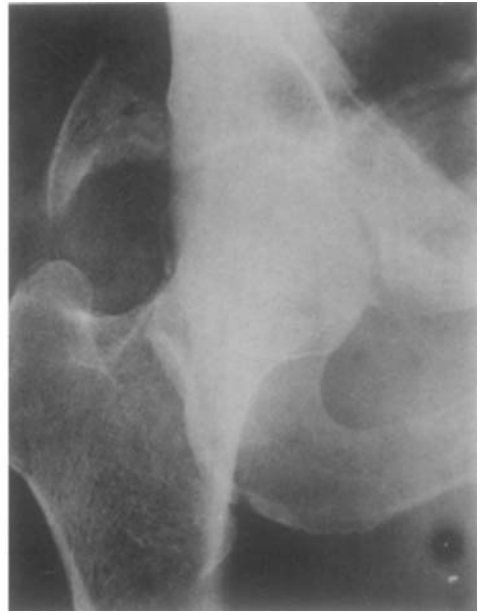
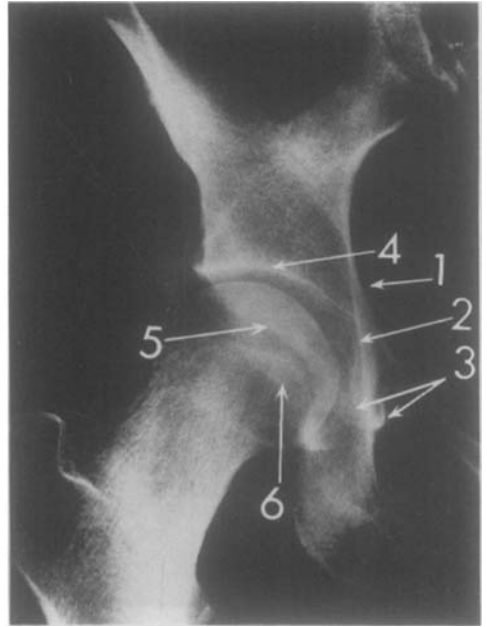
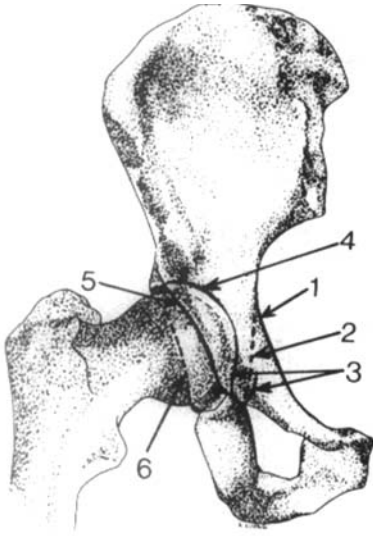


Fig. 16 C. The same patient examined with a posterior oblique view according to Waller, illustrating the size of the fragment and degree of displacement.

Anteroposterior view

The normal AP radiograph of the hip shows a number of characteristics which are necessary to recognize (Fig. 17).

1. The superior channel, a roentgenographic line corresponding to the arcuate line, which begins at the superior edge of the greater sciatic notch and extends downward to the pubic tubercle (a break in this line indicates fracture of the ilio-pubic column).
2. The ilio-ischial roentgenographic line formed by the posterior four fifths of the quadrilateral surface of the pelvic bone (see Fig. 2 B).
3. The roentgenographic U, composed laterally of the most inferior and anterior portion of the acetabular fossa and medially of the anterior flat part of the quadrilateral surface (normally the U and the ilio-ischial line intersect or are tangential).
4. The roof of the acetabulum, which is prolonged in a lateral to medial direction to end on the lateral branch of the U.
5. The edge of the anterior lip of the acetabulum.
6. The edge of the posterior lip of the acetabulum.



*Fig. 17. Schematic illustration and radiographic AP-view of right hip showing: 1) superior channel, the arcuate line; 2) ilio-ischial roentgenographic line; 3) roentgenographic U; 4) roof of the acetabulum; 5) anterior lip of the acetabulum; and 6) posterior lip of the acetabulum. (From Judet, Judet & Letournel, *J. Bone Jt Surg.* 1964, vol. 46-A, p. 1616, Fig. 2.)*

External oblique view

The three-quarter external oblique view – the alar projection – (Fig. 18) spreads out the iliac wing and the quadrilateral surface allowing the study of the posterior edge of the iliac bone and the anterior lip of the acetabulum.

Internal oblique view

The three-quarter internal oblique view – the obturator foramen projection – (Fig. 19) shows the entire iliopubic column in profile whereas the wing of the ilium is perpendicular to the film and viewed on edge. This projection also enables one to follow the posterior lip of the acetabulum prolonged by the curve of the posterior "horn" of the acetabular articular surface.

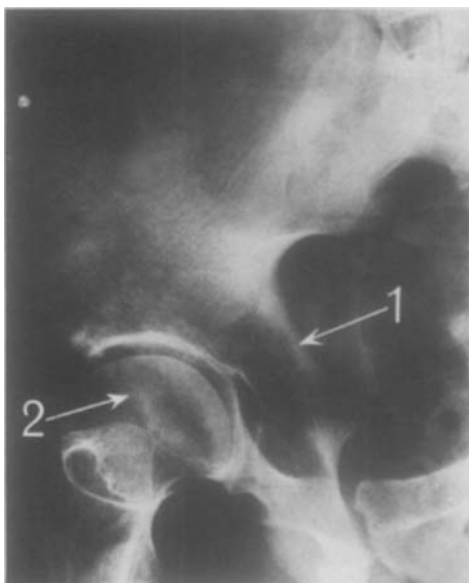
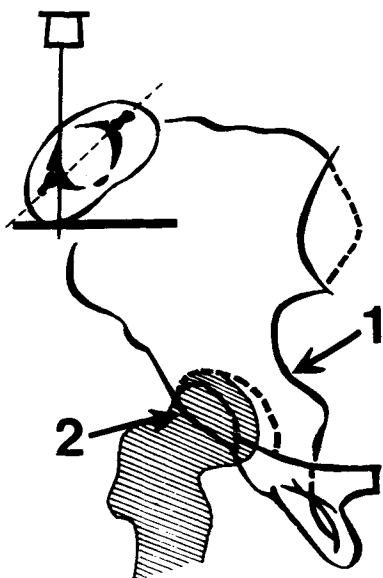


Fig. 18. External oblique view of right normal hip in schematic illustration and in radiograph. (Patient in supine position and rotated 45° to the right.) 1) Posterior edge of the ilium; 2) Anterior lip of the acetabulum.

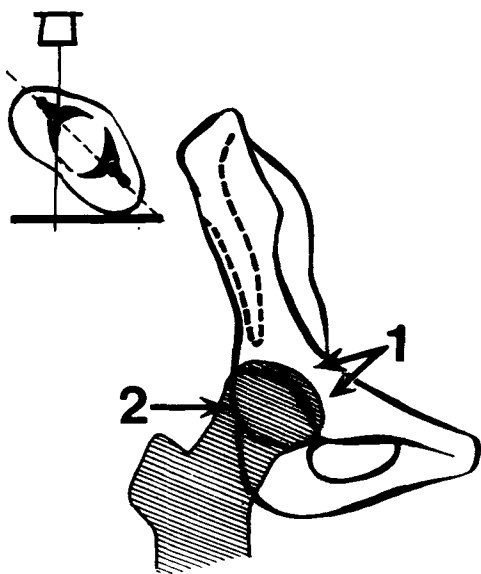


Fig. 19. Internal oblique view of right normal hip in schematic illustration and in radiograph. (Patient in supine position and rotated 45° to the left.) 1) Iliopubic column; 2) Posterior lip of the acetabulum.

Present investigation

The 85 patients with central acetabular fractures were all radiologically examined at the time of injury with AP views. In addition 3 patients were examined with oblique views according to the technique described by Judet, Judet & Letournel.

The 39 patients with posterior acetabular fractures were at the time of injury examined with AP views and in most of them a lateral projection was also made. In addition 7 were examined with oblique projections and 3 with tomography.

Comment. Only 3 of the 85 patients with central acetabular fractures were examined with oblique projections. Forty-five patients had central fractures without central dislocation of the femoral head and the treatment was for these patients strictly conservative. Further radiologic examination might for this reason have been regarded as superfluous. Forty patients had a central dislocation of the femoral head. In these cases the AP view demonstrated the disruption of the acetabulum, but it was sometimes difficult to determine accurately the extent of displacement and the exact location of the fractured fragments. However, even in these cases the therapeutic approach was conservative (35 of 40).

The 39 patients with posterior acetabular fractures were examined at the time of injury with AP projections and in most of them a lateral projection was also made. The lateral projection is important in the straight posterior dislocation of the femoral head which sometimes can be difficult to detect on an AP view. The straight lateral projection gives a good view of the acetabulum as this projection is close to the en-face view of the acetabulum. Seven patients were in addition examined with oblique projections and in 3 cases with tomography. The technique described by Waller (1955) was used and this examination was performed in 5 cases after closed reduction of the dislocated femoral head in order to get a more exact view of the size and position of the posterior acetabular fragment.

Cause of injury

On perusing the literature it becomes apparent that acetabular fractures of both central and posterior types mostly occur as a sequence to traffic accidents.

Waller 1955 found that 69 per cent of 106 so called dash-board fractures were due to traffic accidents. Lehtonen (1968) reported on traffic accidents as the cause of acetabular fractures during two periods. He found that between 1933 and 1953 traffic accidents were the cause in 45 per cent and between 1954 and 1962 there was an increase to 70 per cent. Göthlin & Hindmarsh (1970) reported on 120 central fractures and found road accidents to be the cause in 66 per cent. Nerubay et al. (1973) presented a material of 107 patients of whom 81 per cent were victims in road accidents. Stewart et al. (1975) found the cause to be traffic accidents in no less than 85 per cent of 220 cases of both fractures and dislocations. Vecsei (1975) studied the cause of injury between 1967 and 1973 and reported on 30 fractures all of which were obtained in traffic accidents.

Present investigation

The cause of injury is presented in Table 3. Road accidents were responsible in 61 per cent (75 of 123 patients). The remaining were due to falls from heights and on the same level excepting one who was involved in a rail-road accident and one in a tram accident. A relation of the frequency of fractures to the frequency of traffic accidents involving personal injury was made and is presented in Table 4.

Table 3. *Cause of injury in 123 patients with 124 acetabular fractures*

<u>Cause</u>	<u>Central fractures</u>	<u>Posterior fractures</u>	<u>Total</u>
Automobile accident driver or passenger	15	29	44
Motorcycle accident	0	1	1
Bicycle accident	1	0	1
Rail road accident	0	1	1
Tram accident☆	1	1	2
Pedestrian hit by car	29	0	29
Fall from height	21	2	23
Fall on the same level	<u>18</u>	<u>5</u>	<u>23</u>
Total	85	39	124

☆ One patient who sustained a central fracture of the left hip and a posterior of the right.

Table 4. *Number of injured in road accidents and number of patients with acetabular fractures in Göteborg 1963–1973*

<u>Year</u>	<u>Number of injured</u>	<u>Patients with acetabular fractures</u>	
		<u>No</u>	<u>Per mille</u>
1963	1558	7	4,5
1964	1660	10	6,0
1965	1460	9	6,2
1966	1144	9	7,9
1967	1149	9	7,9
1968	1384	5	3,6
1969	1378	4	2,9
1970	1398	3	2,2
1971	1482	7	4,7
1972	1341	9	6,7
1973	1356	3	2,2

Comment. In the present investigation the major cause of acetabular fractures was traffic accidents. Central fractures appeared mostly when the victim was hit directly by a moving object. In 15 of the 75 road accidents the central fracture was obtained with the patient still in the car. Sufficiently detailed information is difficult to obtain in each individual case as the sequence of events happens so fast that the patient cannot give an account of all particulars concerning the infliction of violence and position of the extremities. It may well be that all 15 patients had a direct blow to the trochanteric region. A blow against the knee and a subsequent posterior fracture occurred in no less than 29 of 39 fractures. This latter development corresponds well with the experience of e.g. Waller (1955).

Associated injuries

As a rule the trauma which causes an acetabular fracture is so violent in nature that other injuries arise simultaneously. Thus, both soft and other skeletal tissues can become involved. Any variety of associated injury may occur and Trojan & Perschl (1956) have listed no less than 46 different lesions accompanying acetabular fractures. In 79 acetabular fractures there was an associated injury in 55.7 per cent and in 10 patients the severity was such that death followed. Wechselberger (1956) reported on 57 acetabular fractures which were associated with other injuries in no less than 33 instances (58 per cent). Six patients died. Nerubay et al. (1973) reported a frequency of 41 per cent with associated skeletal injuries and 36 per cent with associated visceral injuries in 111 acetabular fractures.

Present investigation

For this investigation a distinction has been made between visceral and skeletal associated injuries. They are presented in Tables 5 and 6.

Comment. It must be remembered that one patient representing one acetabular fracture could have more than one associated injury.

It is thus evident from the tables that visceral injury was found in combination with acetabular fracture in 13 per cent and other skeletal injury in 49 per cent. No difference was noted in incidence between central and posterior fractures as regards skeletal injuries. For associated visceral injury this accompanied central fractures in 12 per cent and posterior fractures in 15 per cent.

As additional information it must be mentioned that Tables 5 and 6 do not comprise the following associated injuries which did not fall under the headings of the tables. There were 5 patients with posterior fracture of whom one had a dislocation of the humeroscapular joint, one an anterior dislocation of the contralateral hip without fracture, one a dislocation of the patella on the same side, one a rupture of the anterior cruciate ligament on the ipsilateral knee and one a dislocation of the elbow.

Table 5. *Associated visceral injuries in 16/123 patients (10 in the central and 6 in the posterior group)*

Type of injury	Central fractures No. of patients	Posterior fractures No. of patients	Total
Cerebral concussion	7	4	11
Pneumothorax	0	2	2
Rupture of the diaphragm	1	0	1
Rupture of the urinary bladder	3	0	3
Rupture of the aorta	1	0	1
Pulmonary contusion	2	1	3

Table 6. *Associated skeletal injuries in 60/123 patients (38 in the central and 22 in the posterior group)*

Site of fracture	Central fractures No. of patients	Posterior fractures No. of patients	Total
Face	3	10	13
Upper extremity	17	8	25
Chest	8	9	17
Spinal column	5	0	5
Femoral head	0	2	2
Femoral neck, medial and lateral	5	1	6
Great trochanter	2	0	2
Femoral shaft	2	1	3
Patella	0	4	4
Other site in lower extremity	13	3	16

Clinical appearance

Central acetabular fractures

Often patients with acetabular fractures have other injuries which may distract the examiner, who therefore can overlook the possibility of a hip condition. The patient will, however, complain of pain around the trochanteric region and in the groin. In extensive central fractures with a large hemorrhage there may be complaints of abdominal pain and the lower abdomen is tender on palpation and a slight *défense musculaire* might be palpable. However, testing the motion of the hip joint will always yield pain which should arise suspicion of a fracture and a radiologic examination should be carried out.

Posterior acetabular fractures

Posterior acetabular fractures can be difficult to detect especially in the absence of posterior dislocation of the femoral head. The trauma producing the acetabular fracture is often so great that the patient may sustain other injuries which distract attention from the hip region. Injuries of the acetabulum may therefore be overlooked initially (Waller 1955, d'Aubigné 1968).

In cases of posterior fracture-dislocation the typical position of the leg – adduction, inward rotation and shortening – usually betrays the character of the injury. The knee joint is often flexed and the big toe often rests upon the tarsus of the other foot. The femoral head may be felt in its posterior position. Passive and active movement of the injured hip is painful and abduction in particular is restricted.

In fractures with no dislocation of the femoral head and no or only slight dislocation of the acetabular fragment, the clinical picture is less clear. The leg of the injured side assumes no characteristic position and the femoral head cannot be felt.

In cases with patellar fractures sustained in the sitting position of an automobile driver, or passenger, special caution is required as a hip lesion may be present but overlooked.

“The essential safeguard against this error are, firstly to insist always on a full clinical survey of the whole body in cases of major injury, and secondly to make sure that the radiographs in every case of fractured femoral shaft take in the whole length of the bone and include the hip joint” (Adams 1972).

Symptoms from the sciatic nerve occur in a varying degree in posterior acetabular fractures and figures from 6 to 35 per cent have been reported. Stewart & Milford (1954) and Stewart et al. (1975) reported 13 and 19 per cent nerve injuries respectively. Waller (1955) in a material of 106 posterior acetabular fractures reported 22.6 per cent and Rowe & Lowell (1961) observed as many as 35 per cent. Brav (1962) reported 6.7 per cent. Epstein (1974) registered 13 per cent sciatic lesions in his material of posterior fracture-dislocations of the hip.

All authors who have described nerve injuries stress the importance of searching for the symptoms as early as possible.

Sciatic nerve injuries

Injury to the sciatic nerve is a common complication in association with fracture-dislocation of the hip (Stewart & Milford 1954, Waller 1955, Stewart et al. 1975). As mentioned above the frequencies of sciatic nerve palsy generally lie between 6 and 35 per cent.

The risk of damage to the sciatic nerve is great in posterior fracture-dislocations, due to the exposed position of the nerve, where it leaves the infrapiriform foramen to continue downwards close to the posterior acetabular rim. Fractures of the acetabular rim with displacement of the fragments carry a great risk of injury to the nerve either as simple stretching or as laceration of the nerve by displaced fragments (Waller 1955).

Present investigation

Sciatic nerve involvement with peroneal paresis was registered in 8 patients. Seven had a

posterior fracture-dislocation and one a central acetabular fracture without central dislocation of the femoral head. At follow-up the paresis remained in 5 patients.

Case reports

1. 62-year-old man with a central acetabular fracture without dislocation of the femoral head but with a slightly medially dislocated fragment of the acetabulum. He was treated with the extremity of the injured side on a sledge. After 1 week a peroneal paresis was detected. This remained at the time of follow-up 2 years following the injury.

2. 58-year-old woman with a posterior fracture-dislocation, Type III. She was operated immediately because of the peroneal paresis. At the operation a large posterior fragment was observed being dislocated cranially and posteriorly. The sciatic nerve was squeezed and hematomatous. The nerve was placed back in its original position after the fracture had been fixed with two screws. At follow-up 11 years after the injury there was still a partial peroneal paresis.

3. 24-year-old man with a posterior fracture-dislocation, Type II. A large posterior fragment was dislocated posteriorly. Because of the patient's bad general condition operation was not done until 4 weeks had elapsed. At operation a sharp fragment directed against the sciatic nerve was detected. The sciatic nerve was freed and put aside and the acetabular fragment was fixed with a cancellous screw. Eleven years following the injury a partial peroneal paresis remained.

4. 42-year-old man with a posterior fracture-dislocation, Type III. The patient was admitted to another hospital and the posterior fracture-dislocation was overlooked. After 2 months the dislocation was observed. There was a total peroneal paresis which still remained 11 years following the injury.

5. 50-year-old woman with a posterior fracture-dislocation, Type III. Acute reduction with good replacement of the fragments. Treated by traction for 6 weeks. At follow-up 2 years later there was still a partial peroneal paresis.

6. 21-year-old man with a posterior fracture-dislocation, Type II. Because of the patient's bad general condition the dislocation was not reduced until after 8 days when the patient was operated still unconscious. The sciatic nerve was freed and the acetabular fragment put into place and fixed with two pins. At the follow-up after 4 years the paresis was gone.

7. 22-year-old man with a posterior fracture-dislocation, Type III. Acute reduction of the femoral head was performed and the acetabular fragments fell into place. The first 5 days a partial peroneal paresis was noticed. After 2 weeks the paresis was gone.

8. 33-year-old man with a posterior fracture-dislocation, Type III. Operation was performed after 3 days and the fragments were put into place and fixed with two pins. During the operation the sciatic nerve was identified as normal. He was treated with traction for 6 weeks, and after 2 weeks a partial peroneal paresis was noticed. At the follow-up after 3 years the patient had no symptoms of peroneal paresis.

Comments. The division of the sciatic nerve into its two main branches, the tibial and peroneal nerves, is demonstrable already at the origin of the nerve trunk from the lumbosacral plexus. The nerve fibers of the tibial and peroneal nerves run quite separately but perineural fibrous tissue binds the two branches together so that they present as a single nerve to the naked eye. The peroneal portion of the sciatic nerve always lies laterally, i.e. close to the posterior acetabular rim. Thus, this branch is more exposed to injury by e.g. displaced fracture fragments from the posterior acetabular rim. These anatomical circumstances explain the clinical observation that peroneal paresis is a fairly common complication in these fractures (Waller 1955).

Treatment of acetabular fractures

Treatment of central acetabular fractures. A review of literature

Central acetabular fractures without central dislocation of the femoral head or the acetabular fragments are generally treated by conservative methods. Some recommend bed rest only (Rowe & Lowell 1961, Judet, Judet & Letournel 1964, Solheim & Skrede 1973) and others a short period of traction (Wechselberger 1956, Pearson & Hargadon 1962, Eichenholtz & Stark 1964).

However, there is a diversity of opinion on the treatment of central acetabular fractures with central dislocation of the femoral head. There are many who advocate a rather strict conservative line of treatment (Eichenholtz & Stark 1964, Nicoll 1966, Böhler 1966, Tipton et al. 1975, Jahna 1976) and many who advocate surgical treatment (Armstrong 1948, Westerbom 1954, Judet, Judet & Letournel 1964, Letournel 1966, Paleari & Gualtieri 1971). Further on some surgeons point out that most central dislocations should and can best be treated by conservative methods and recommend open reduction and osteosynthesis only in fractures engaging the superior dome where closed treatment has failed in reducing both the femoral head and the acetabular roof accurately (Rowe & Lowell 1961, Göthlin & Hindmarsh 1970, Carnsale et al. 1975).

There is, however, a general consensus of opinion that the ultimate aim should be as perfect a restoration of the acetabular-femoral head relationship as possible. Maintenance of the congruity between the acetabular surfaces and the head of the femur is regarded as the important goal in the treatment of these fractures (Göthlin & Hindmarsh 1970, Carnsale et al. 1975, Tipton et al. 1975).

However, this goal is sometimes difficult to achieve and incongruity between the articular surfaces becomes accepted as this in many cases do not seem to result in impaired function (Rowe & Lowell 1961, Austin 1971, Tipton et al. 1975).

Conservative treatment

Many writers regard bed rest as an adequate therapy in the case of acetabular fracture without displacement (Rowe & Lowell 1961, Judet, Judet & Letournel 1964). In the treatment of central fracture-dislocations traction has for many decades been used as the principle means of achieving reduction and preserving the correct position. In the application of traction a variety of techniques have been employed. Traction has been applied either as skin traction (Pearson & Hargadon 1962) or via a pin through the femoral condyles or through the tibial tuberosity or pins through the proximal femur, with the traction in a lateral direction (Lipscomb 1961). Double traction has frequently been used, i.e. longitudinal and lateral traction in conjunction (Gelehrter 1969, Renné & Schmelzeisen 1975, Tipton et al. 1975).

Some authors have emphasized the importance of reduction performed under general anesthesia, in severe cases (Tipton et al. 1975).

As regards the duration of traction, opinions differ. Periods up to 12 weeks have been reported (Carnsale et al. 1975, Tipton et al. 1975).

Urist (1947, 1948) reported on 16 patients with central fracture-dislocations. Irrespective of the position of the femoral head there was a good response to conservative treatment with traction and at follow-up 1-3 years later the results were interpreted as excellent. However, in bursting fractures, where reduction was impossible, conservative treatment resulted in great disability. He therefore suggested either fusion or arthroplasty for this latter group.

In 1954 Stewart & Milford reviewed 193 patients with fracture-dislocation of the hip. Twenty-eight of these had central fractures and 23 were treated conservatively. Seven years later a follow-up comprised 18 of the conservatively treated patients and 9 of these exhibited excellent or good results whereas the results in the remaining 9 were fair or poor.

Stewart et al. (1975) reported on 23 conservatively treated patients and found that the results in 11 were excellent or good and in 12 fair or poor. They stated "the innerwall fractures and explosive dome fractures of the acetabulum that are not suitable for open reduction (and very few are) can best be treated by skeletal traction".

In 1961 Rowe & Lowell described a series of 93 patients with fractures of the acetabulum with and without dislocation of the femoral head. There were 76 central fractures and of these 64 were treated conservatively. The average time of follow-up was 6 years and the results were excellent or good in 80 per cent (51 of 64), fair in 12 per cent (8 of 64) and poor in 8 per cent (5 of 64). In linear undisplaced fractures there were 100 per cent excellent or good results, in the innerwall fractures 90 per cent excellent or good results, and in the superior dome fractures 37 per cent excellent or good results and 63 per cent fair or poor results. These authors stated that the important factor was the reduction of the femoral head to its normal position under the dome. They found surgical reduction of the displaced central wall of the acetabulum unnecessary and the only indication for operation of central fractures was bursting or severely displaced fractures engaging the superior dome.

In 1962 Pearson & Hargadon reviewed 80 patients with fractures and fracture-dislocations of the central part of the acetabulum. The results in 50 patients, all of whom were treated conservatively, were reported with an account of three clinical types of fractures. Type I and II were central fractures without central dislocation of the femoral head and Type III was central fractures with a central protrusion of the femoral head. Mean time for follow-up was 2.5 years. The overall results in their three groups were good and the patients had minor complaints. They found good or excellent results in more than 80 per cent. In the two groups in which there was no central protrusion of the femoral head the results were good or excellent in more than 90 per cent. These authors found these fractures to be adequately treated with simple measures such as rest and a short period of skin traction. The results in patients with a central protrusion of the femoral head were worse than in those without central protrusion. However, 15 patients of 23 with central dislocation of the femoral head had no or only slight pain (65 per cent). They found better results in patients (12) in whom closed reduction was not attempted.

In 1964 Eichenholtz & Stark made a review of 35 patients with central acetabular fractures. They divided their fractures into three types based on the degree of penetration of the femoral head into the pelvis. Twenty-eight patients were treated conservatively and 21 of these were followed-up. Sixteen (75 per cent) achieved satisfactory results. Six patients were operated

upon and in 5 the results were satisfactory. These authors believe that traction is valuable in early treatment of displaced fractures even if there is no intrapelvic protrusion of the femoral head, in order to minimize pain and diminish deformity. According to their experience a stabilization will occur after 2-4 weeks so that no further traction is necessary and very little displacement will take place. However, they stress that weight-bearing must be avoided for at least 4 months. They pointed out the ability of the hip joint to produce a new acetabulum in patients with displaced fractures. An autogenous intrapelvic mold arthroplasty was produced. Thus, they recommended closed treatment for central acetabular fractures.

In 1975 Tipton et al. reviewed 24 patients with central fracture-dislocation of the hip. All patients were treated conservatively with traction through the tibial tuberosity or combined traction. They used the same classification as Rowe & Lowell (1961) and their material comprised 15 patients with innerwall fractures and 8 of these had excellent or good results. Nine patients had superior dome or bursting fractures and 6 of these achieved good results. However, of the 15 patients with innerwall fractures 5 of 7 treated with combined traction had good or excellent results, and of the patients with superior dome fractures 5 of 6 treated with combined traction had good results. These authors recommend conservative treatment for central fracture-dislocations with combined traction for 12 weeks.

Further authors with experience of conservative treatment claim satisfactory results in 70-90 per cent (Göthlin & Hindmarsh 1970, Austin 1971, Solheim & Skrede 1973, Nerubay et al. 1973).

In Table 7 a summary is given of the results of conservative treatment of central acetabular fractures as reported in the literature.

Surgical treatment

The possibilities of surgical treatment were discussed as early as in the beginning of this century (Tillmans 1905, ref. Lehtonen 1968). As the surgical technique is regarded as cumbersome and difficult operative treatment was for long time resorted to only in occasional cases. The first open reduction was performed by Vaughn in 1912 and Levin in 1943 was the first to use internal fixation in the treatment of central acetabular fractures (Barnes & Stewart 1976). During the last 15 years thorough studies by French investigators have been published. Operations for acetabular fractures were undertaken after careful consideration on the basis of pathoanatomical findings and were performed using screws and other devices for fixation (Judet, Judet & Letournel 1964, Judet & Letournel 1974).

In 1948 Armstrong described 101 patients with fracture-dislocation of the hip. Fifty patients were followed up and 7 of these had central acetabular fractures. All 7 patients were treated conservatively and they all developed osteoarthritis. Based on this he suggested that in cases of central fractures an arthrodesis should be primarily performed.

In 1928 Westerborn reported 500 cases of pelvic fractures. The acetabular floor was fractured in 64 and in 21 the femoral head was dislocated centrally to a varying degree. In 1954 the author reviewed 51 of the 64 patients. Only 26 (51 per cent) recovered to the working capacity they had had previous to injury and 25 (49 per cent) were more or less disabled. He recommended cup-arthroplasty in central fracture-dislocation.

Table 7. *Reported results of conservative and surgical treatment of central acetabular fractures*

Author	No. of pat. followed up	Results of conservative treatment				Results of surgical treatment			
		Excel- lent	Good	Fair	Poor	Excel- lent	Good	Fair	Poor
Stewart & Milford 1954	22	2	7	1	8	0	1	1	2
Wechselberger 1956	37	18		10	9				
Rowe & Lowell 1961	76	51		8	5	11		0	1
Zeumer 1966	25	7	9	5	4				
Nerubay et al. 1973	53	31		6	3	4		5	4
Solheim & Skrede 1973	52	—	35	6	4	—	4	1	2
Judet & Letourne1 1974	180					120	31	15	14
Ecke et al. 1975	48					—	23	15	10
Stewart et al. 1975	28	11		12		0	1		4
Tipton et al. 1975	24	3	11	7	3				
Trojan 1975	29					7	16	3	3
Vecsei 1975	16					5	7	2	2
	590	185		91		230		84	

Judet, Judet & Letournel (1964) recommended that all acetabular fractures with displacement should be treated with open reduction and osteosynthesis of the acetabular fragments. They carefully described the classification and surgical approach for these fractures. In 1974 Judet & Letournel reported on 244 patients with acetabular fractures, all treated surgically. Sixty-four of these had posterior fractures and 180 central fractures (fractures of the iliopubic column, fractures of the ilioischial column, transverse fractures and mixed fractures). Results were excellent in 67 per cent, good in 17 per cent, fair in 8 per cent and poor in 8 per cent.

Vecsei in 1975 reviewed 30 patients with fracture-dislocation of the hip which were operated upon in Vienna between 1965 and 1973. Twenty-six of these were given an adequate follow-up. He used a classification like Judet, Judet & Letournel (1964). Sixteen of these fractures were central fracture-dislocations and he found excellent results in 5, good in 7, fair in 2, and poor in 2.

Johansson & Olerud (1971) reported on 16 operated patients and their preliminary impression of the results were satisfactory. Experience of the same kind has been reported by Elliott (1956), Paleari & Gualtieri (1971) and Batra (1976).

In Table 7 a summary is given of the results of surgical treatment of central acetabular fractures as reported in the literature.

Present investigation

The material of central acetabular fractures for the present investigation consisted of 85 patients with 85 fractures. Of these 5 were treated *surgically*. Of 80 patients treated *conservatively* there was no central dislocation of the femoral head in 45. Thirty-five patients had a central dislocation of the femoral head of varying degree. Sixteen of these had the superior dome intact and 19 had not.

Table 8 gives the type of fracture and their treatment and Table 9 the time for immobilization and hospital stay.

Details of treatment

Central fractures without dislocation of the femoral head (45 patients)

A — Without displacement of the acetabular fragments (19 patients).

All patients were immobilized in bed. Only one was put into traction for one week.

Time of immobilization was 2-3 weeks. No information could be obtained when weight-bearing was instituted.

B — With displacement of the acetabular fragments (26 patients).

All patients were immobilized in bed, two only were put into traction. Traction through the tibial tuberosity was maintained in one patient for 2 weeks and in the other for 4 weeks. The mean time of immobilization was 3 weeks and following this a non-weight-bearing period for 2-3 weeks was prescribed.

Table 8. *Type and treatment of 85 central acetabular fractures*

Type of fracture	No. of patients	
	Treated conservatively	Treated surgically
Central fracture without central dislocation of the femoral head		
Without displacement of the acetabular fragments	19	
With displacement of the acetabular fragments	26	
Central fracture with mild to moderate central dislocation of the femoral head		
The superior dome intact	11	
The superior dome fractured	8	
Central fracture with severe central dislocation of the femoral head		
The superior dome intact	5	
The superior dome fractured	11	5
Total	80	5

Table 9. *Mean times of immobilization and hospital stay for patients with central acetabular fractures treated conservatively and surgically*

Type of fracture	Treated conservatively		Treated surgically	
	Immobilization (weeks)	Hospital stay (weeks)	Immobilization (weeks)	Hospital stay (weeks)
Central fractures without central dislocation of the femoral head	2-3	3-4		
Central fractures with mild to moderate central dislocation of the femoral head	4-5	6-7		
Central fractures with severe central dislocation of the femoral head	6-7	9-10	6-7	16

Central acetabular fractures with mild to moderate central dislocation of the femoral head (19 patients)

A – Superior dome intact (11 patients).

Seven patients were immobilized in bed without traction. Four were treated by traction through the tibial tuberosity. Time of immobilization was 4-5 weeks followed by a 4-week-period of non-weight-bearing.

B – Superior dome fractured (8 patients).

Two patients were immobilized in bed without traction. Six were treated by traction applied through the tibial tuberosity. Time of immobilization and non-weight-bearing was the same as under A.

Of those 10 patients who were treated by traction through the tibial tuberosity a good reduction of the femoral head was obtained in 8. In 4 of these the superior dome was intact and in the remaining 4 the superior dome was fractured.

With good reduction of the femoral head is meant that the femoral head has been reduced to its normal position. Any further differentiation into acceptable, poor and no reduction has not been made. Those cases in which the femoral head has not been reduced to its normal position will in the following be called less satisfactory reduction.

Central fractures with severe central dislocation of the femoral head treated conservatively (16 patients)

A – Superior dome intact (5 patients).

Three patients were immobilized in bed without traction. Two were treated with traction. (One with closed reduction under anesthesia followed by traction through the proximal femur; one with a combined traction through the tibial tuberosity and proximal femur.) Time of immobilization was 6-7 weeks. The time for non-weight-bearing has not been obtained.

B – Superior dome fractured (11 patients).

Four patients were immobilized in bed without traction. Seven were treated by traction which was supplied through the tibial tuberosity in 2. In addition, 5 had a traction applied to the proximal femur. Moreover, one patient was treated with closed reduction under general anesthesia. (This patient was for 3 weeks put into traction through the tibial tuberosity but this gave no reduction of the femoral head. After 3 weeks a closed reduction under anesthesia was performed and a lateral traction through the proximal femur was applied.) Time of immobilization was 6-7 weeks. The period of non-weight-bearing has not been obtained.

Of those 16 patients with central fractures with severe central dislocation of the femoral head, 9 were treated with traction. In 6 of these (4 with superior dome involvement) a good reduction was obtained of the centrally dislocated femoral head. In 3, reduction was less satisfactory.

In 2 cases traction through the tibial tuberosity was applied which did not yield a satisfactory reduction of the femoral head. In 5 cases the traction through the tibial tuberosity was combined with lateral traction through the proximal femur and in 4 of these a good reduction of the femoral head was obtained. In 2 cases a manual reduction in general anesthesia was carried out; it was combined with traction through the tibial tuberosity and proximal femur in one of them and through the proximal femur only in the other. In both cases a good reduction was obtained.

Central acetabular fractures with severe central dislocation of the femoral head treated surgically (5 patients)

Five patients were treated with open reduction and osteosynthesis. Four of these were postoperatively put into traction which was applied through the tibial tuberosity. Mean time of immobilization was 6-7 weeks.

Case reports

1. 43-year-old woman. The femoral head was at the time of injury dislocated medially-cranially 45 mm. At the operation the acetabular fragment was fixed with a cerclage. Reduction of the femoral head was not achieved and postoperatively it was still dislocated 40-45 mm.
2. 52-year-old man. The femoral head was dislocated medially-cranially 20 mm. The acetabular fragment was fixed with one screw. Postoperatively the femoral head remained dislocated 20 mm.
3. 17-year-old woman. The femoral head was dislocated 20 mm medially. The acetabular fragments were fixed with two plates and screws. There was a good reduction of the femoral head and postoperatively the femoral head was in its normal position.
4. 23-year-old woman. The femoral head was dislocated medially-cranially 20 mm. The fragments were fixed with three cerclages. There was a good reduction of the femoral head (Fig. 28).
5. 36-year-old man. The femoral head was dislocated medially-cranially 25 mm. The acetabular fragments were fixed with a plate and four screws. One did not succeed in reducing the femoral head to its normal position and postoperatively the femoral head was dislocated 15 mm medially.

Comment. The majority of cases with central dislocation of the femoral head has been treated conservatively. Traction treatment has been resorted to and in most cases this has been applied through the tibial tuberosity. In 7 patients lateral traction was applied to the proximal femur. This is according to many (e.g. Lipscomb 1961, Lidström 1961, Nicoll 1966) the most logic way of applying traction when the femoral head is dislocated centrally as the line of traction then will be in alignment with the axis of the femoral neck. Little influence seems, however, to be exerted on the acetabular fragments. When the fractured acetabulum exhibits a persistent dislocation of the fragments despite traction, open reduction appears indicated. One of the arguments advanced by those who advocate surgical intervention, is that only by operative means a restoration of the acetabular fragments can be obtained and along with this an acceptable position of the femoral head.

On the other hand some authors (Rowe & Lowell 1961, Eichenholtz & Stark 1964, Austin 1971) have the opinion that the realignment is unnecessary for good results. They were im-

pressed by the tendency of displaced and centrally dislocated hips treated by closed means to establish a satisfactory pseudo-acetabulum after destruction and medial displacement of the inner acetabular wall.

In the present investigation only 5 patients were operated upon. They all had in common a severe central dislocation of the femoral head with fracture of the superior dome.

Treatment of posterior acetabular fractures. A review of literature

Posterior acetabular fractures were first described in 1824 by Sir Astley Cooper (Waller 1955). In 1855 Malgaigne described 12 cases and pointed out that a posterior acetabular fracture should be suspected when redislocation occurred after reduction of the hip.

With time some advocated conservative treatment and others surgical. In cases of posterior fracture-dislocation there is, however, today a common agreement that reduction of the dislocated femoral head should be carried out as an emergency procedure (Stewart & Milford 1954, Waller 1955, Rowe & Lowell 1961, Lehtonen 1968, Epstein 1974, Stewart et al. 1975).

Campbell (1936) collected 80 cases of posterior dislocation of the hip. Of these 30 were combined with posterior acetabular fractures. He divided his posterior fractures into three groups depending on the degree of posterior dislocation of the femoral head. Nine could be traced and followed-up, all treated conservatively and all but one showed excellent results. The author pointed out that all these fractures did well if they were treated with early reduction of the dislocation and immobilization in bed with traction for 6 weeks.

Funsten et al. (1938) reported on 20 patients with traumatic dislocation of the hip. In 9 of these the lesion was combined with a posterior fracture of the acetabulum. According to the nature of the trauma Funsten et al. gave these injuries the name "dash-board dislocations". A follow-up of 8 patients was carried out after 3 years. All were treated conservatively and the result was good in 4, fair in 2 and poor in 2.

In a series of 101 traumatic dislocations of the hip Armstrong (1948) described 50 patients in 43 of whom the dislocation of the femoral head was combined with a fracture of the posterior part of the acetabulum. Fifteen of these were followed-up after 3-4 years. All but one patient were treated conservatively. He found complete recovery in 63 per cent of these patients. He stated that fractures of the posterior acetabulum with displacement of marginal fragments are usually corrected by manipulative reduction or by traction.

Urist (1948) described 23 patients with fracture-dislocation of the hip. Eighteen had fracture of the posterior superior part of the acetabulum and 13 were adequately followed-up. Eleven of these were operated upon and 2 were treated conservatively by traction. Of the patients treated by surgery 5 had excellent or good results, 3 fair and 3 poor. Both patients treated by immobilization in bed and traction had poor results. He stated that minor fractures of the posterior acetabular rim could be treated by conservative methods. In cases in which a significant posterior acetabular fragment remained displaced after reduction of the femoral head the final result was only fair or poor on account of degenerative changes in the hip joint. He recommended that posterior rim fractures with displacement of the fragment should be treated by open reduction and internal fixation.

Stewart & Milford (1954) collected 193 patients with fracture-dislocations of the hip over a 30-year-period. Adequate follow-up was made in 123 patients. Of these 96 had posterior fractures. These authors made a classification of posterior fracture-dislocation into four grades where Grade I was a posterior dislocation of the femoral head with no or only a slight fracture of the posterior rim without consequence and Grade IV was a posterior dislocation of the femoral head with a fracture of the femoral neck. Posterior dislocation of the femoral head with a large single fragment or a comminute fracture of the posterior acetabular rim (Grade II and III respectively) accounted for 57 patients. Forty-two of these were treated conservatively. Sixteen were reported with excellent or good results, 26 with fair or poor results. Fifteen patients were treated surgically. Six had excellent or good results and 9 had fair or poor results. Mean-time for follow-up was 7 years. These authors stress the importance of early treatment and advised open procedures only when closed reduction failed, when the joint was unstable after closed reduction of the femoral head and when at radiologic examination loose fragments were found in the joint.

Waller (1955) gave an account of 106 patients with posterior acetabular fractures collected over a 10-year-period. Follow-up examinations were available in 87 patients with a mean time for follow-up for 3 years and 11 months. Of the 87 patients 60 were treated conservatively and 27 were operated upon. Of the 60 patients treated by conservative methods 18 had fractures graded as Type I and 42 as Type II and Type III. In Type I he found excellent or good results in 72 per cent, in Type II in 30 per cent and in Type III in 11 per cent. Twenty-seven patients with fractures graded as Type II and III were operated upon. In patients with Type II fractures he found excellent results in 6 patients, good in 2, fair in 2, and poor in none. In patients with Type III fractures he found excellent results in 5, good in 4, fair in 3, and poor in 5. Waller recommended open treatment in posterior acetabular fractures of Type II and III and he stated that Type I fractures are the only posterior acetabular fractures suited to closed treatment.

Rowe & Lowell (1961) collected 93 patients with fracture-dislocation of the hip. Seventeen of these had fracture of the posterior rim of the acetabulum. Six of these 17 patients were treated conservatively and 11 operatively. Three of the conservatively treated patients had excellent or good result, 3 poor. Eight of the operatively treated patients had excellent or good result, 3 poor. These authors recommend open treatment when there is a large displaced posterior acetabular fragment that must be reduced and fixed to restore stability of the joint or when displacement of a bone fragment is associated with sciatic nerve pressure or injury. According to these authors closed treatment is satisfactory when the fragments are small and their reduction and fixation are not necessary to restore stability of the hip joint.

Nerubay et al. (1973) gave an account of the Tel Aviv Clinic cases between 1950 and 1969. During this period the authors collected 107 patients with 111 acetabular fractures where follow-up was available in 85 patients with 89 fractures. Thirty-six of these were posterior fractures and the mean-time for follow-up was 6 years. Twenty-nine of these 36 patients were treated conservatively and they found excellent or good results in 80 per cent and fair or poor in 20 per cent. Only 7 patients were operated upon and the results were good in one, fair in

2, and poor in 4. Thus, these authors reported good results with conservative treatment and recommend open treatment only for fractures that could not be reduced conservatively, for fractures that remained unstabled after closed reduction of the femoral head and in lesions of the sciatic nerve by compression of the femoral head or bony fragments without recovery for 1-2 weeks.

Solheim & Skrede (1973) presented a material of 95 patients with fracture of the acetabulum. Sixty-six of these were followed-up. Fifty-two were central acetabular fractures and 14 posterior acetabular fractures. Twelve of the 14 patients with posterior fractures were operated upon with good results in 60 per cent. Only 2 patients were treated conservatively, one was given good result and one poor. They recommended open treatment in all posterior acetabular fractures with dislocation of the acetabular fragment.

Epstein (1974) gave an account of 242 posterior fracture-dislocations of the hip. Two hundred and three belonged to Type II-IV in the classification described on page 17. Ninety-five patients were treated conservatively with closed reduction of the femoral head followed by immobilization in bed with or without traction. Sixty-one were treated with closed reduction of the femoral head followed by open fixation of the acetabular fragment and 47 were treated by primary open reduction of the femoral head and osteosynthesis of the acetabular fragment(s). Satisfactory results were obtained in 14 per cent in the first group, 44 per cent in the second group and 63 per cent in the third group. From this series he concluded that early primary open reduction with removal of all loose fragments of bone and cartilage and restoration of stability by internal fixation of the fracture of the acetabular rim offers the best prognosis in delaying the appearance of posttraumatic osteoarthritis and to minimize its severity.

On materials varying in size conservative treatment has been suggested irrespective of size and displacement of fragment and good results have been registered in 60 to 80 per cent (Brav 1962, Nicoll 1966). The mode of treatment has varied somewhat and in some cases traction is advocated, in others immobilization in bed only.

Surgical treatment has been suggested by Lehtonen (1968), Judet, Judet & Letournel (1964), Johansson & Olerud (1971).

In Table 10 a summary of reported results of conservative and surgical treatment of posterior acetabular fractures is presented.

Present investigation (Tables 11 and 12)

Conservative treatment (19 patients)

The Type I-fracture was treated with immobilization in bed without traction. Time for immobilization was 1-2 weeks. Fifteen fractures of Type II and III were treated conservatively. Of these, 9 were immobilized in bed without traction, the remaining 6 being treated with traction through the tibial tuberosity. In 9 patients the fragment still remained dislocated after reduction of the femoral head. Three of these were treated with traction and 6 were immobilized in bed without traction. There was no redislocation of the femoral head in any of the patients. Times for immobilization and hospital stay are presented in Table 12.

Table 10. *Reported results of conservative and surgical treatment of posterior acetabular fractures*

Author	No. of pat. followed up	Type of fracture	Results of conservative treatment				Results of surgical treatment			
			Excel- lent	Good	Fair	Poor	Excel- lent	Good	Fair	Poor
Urist 1948	13		0		0	2	5		3	3
Stewart & Milford 1954	57	II + III	16		26		6		9	
Waller 1955	87	I	3	10	5	0				
		II	1	6	10	6	6	2	2	0
		III	0	2	10	7	5	4	3	5
Rowe & Lowell 1961	17		3		3		8		3	
Brav 1962	70		42		10		14		4	
Nerubay et al. 1973	36		23		5	1	0	1	2	4
Solheim & Skrede 1973	14		—	1	0	1	—	8	0	4
Epstein 1974	203	II	0	7	7	8	0	14	6	1
		III	0	1	15	19	0	32	10	19
		IV	0	5	10	23	0	11	7	8
Judet & Letournell 1974	64						53	2	6	3
Ecke et al. 1975	47					—	27	7	13	
Stewart et al. 1975	81	II + III	39		18		17		7	
Trojan 1975	36									
	725		159		186		238		142	

Table 11. *Type and treatment of 39 posterior acetabular fractures*

Type of fracture	No. of patients	
	Treated conservatively	Treated surgically
Type I	4	
Type II	5	10
Type III	10	10
Total	19	20

Table 12. *Mean times of immobilization and hospital stay for patients with posterior acetabular fractures treated conservatively and surgically*

Type of fracture	Treated conservatively		Treated surgically	
	Immobilization (weeks)	Hospital stay (weeks)	Immobilization (weeks)	Hospital stay (weeks)
Type I	1-2	2-3	-	-
Type II	3-4	4	4-5	7-8
Type III	4-5	7	5-6	8-9

Surgical treatment (20 patients)

In this material 20 patients with Type II- and III-fractures were operated upon. The indication for operation in 15 patients was a remaining large displacement of one or several posterior fragments after reduction of the femoral head. Three patients were operated upon because of impossibility to reduce the femoral head, one patient because of redislocation of the femoral head after reduction and one patient because of sciatic nerve involvement with acute peroneal paresis.

Sixteen patients were operated upon within 1 week, one after 2 weeks, one after 3 weeks and 2 after 4 weeks. Various types of operative fixation were employed (Palmer's pin, screw and cerclage).

Twelve of the patients operated upon were immobilized postoperatively in bed without traction, 7 were put into traction and one had a plaster of Paris. Times for immobilization and hospital stay are presented in Table 12.

Summary on diagnosis and treatment of acetabular fractures

In summary there is agreement among most surgeons who treat fractures of the acetabulum on the following.

1. For a detailed analysis of acetabular fractures the radiologic examination should include several projections of the joint.
2. When the femoral head is dislocated posteriorly acute reduction should be performed.
3. A large posterior acetabular fragment associated with instability requires open reduction and fixation of the acetabular fragment.
4. The presence of a bone fragment in the hip joint blocking the reduction of a posteriorly dislocated femoral head is an indication for open reduction.
5. A sciatic nerve palsy in combination with a posteriorly dislocated acetabular fragment requires early surgical exploration.

The principle point of disagreement concerns the management of central acetabular fractures with displacement of fragments and central dislocation of the femoral head.

Chapter 3

A FOLLOW-UP STUDY OF 100 PATIENTS

Material

A follow-up of acetabular fractures treated during 1963-1973 was carried out from April 1974 to January 1975. Of the original 123 patients with 124 fractures the follow-up comprised 100 patients representing 101 fractures. Twenty of the patients had died. Two were not accessible to any verbal or functional inquiry. One patient could not be traced.

Of the 100 followed-up patients 35 were women and 65 were men.

The mean age for the whole material at follow-up was 45 years, for women 47 years and for the men 43 years.

In Tables 13 and 14 the classification is presented of central and posterior fractures at follow-up.

Deceased patients

Three patients died in connection with the injury, one as an immediate consequence to the accident, one after 8 days in pneumonia and one after 2 months in myocardial infarction. Seventeen patients died of various causes unrelated to the injury 1-7 years after the accident.

Mode of follow-up

Ninety-five patients were questioned and examined by myself. One patient was examined by another orthopaedic surgeon. Three patients refused examination and one lived abroad. These 4 patients replied to a written questionnaire.

Three patients, who had a hip arthroplasty or hip fusion performed at a later date as a reconstructive procedure, were given a final clinical and radiologic rating for their hips prior to this later operation. (One patient with a central fracture with severe central dislocation of the femoral head was operated upon after 3 years with a Smith-Petersen cup. One patient with a posterior fracture-dislocation of Type III treated surgically was operated upon with an arthrodesis 2 years after injury. One patient with a posterior fracture-dislocation of Type II combined with a fracture of the femoral head had a Moore prosthesis implanted at the time of injury and after 2 years a Girdlestone procedure was performed.)

Table 13. *Type and treatment of 66 central acetabular fractures (Follow-up series)*

Type of fracture	No. of patients	
	Treated conservatively	Treated surgically
Central fracture without central dislocation of the femoral head		
Without displacement of the acetabular fragments	13	
With displacement of the acetabular fragments	17	
Central fracture with mild to moderate central dislocation of the femoral head		
The superior dome intact	11	
The superior dome fractured	7	
Central fracture with severe central dislocation of the femoral head		
The superior dome intact	4	
The superior dome fractured	9	5
Total	61	5

Table 14. *Type and treatment of 35 posterior acetabular fractures (Follow-up series)*

Type of fracture	No. of patients	
	Treated conservatively	Treated surgically
Type I	3	
Type II	5	10
Type III	9	8
Total	17	18

Time of follow-up

The time of follow-up varied from 1-12 years with a mean time of 6.1 years. The distribution of the material according to the time of follow-up was:

9 – 12 years	25 patients
7 – 9 "	19 "
5 – 7 "	17 "
3 – 5 "	14 "
1 – 3 "	25 "

Results

Assessment of results

It has become apparent from the literature that the assessment of results varies considerably due to the type of evaluation used (Anderson 1972). To minimize the examiner's subjective opinion and also to make an attempt to cover as many functional activities as possible in an objective way a numerical system suggested by d'Aubigné & Postel (1954), later modi-

Table 15. *Assessment table*

Points	Pain	Walking	Total motion (degrees)
1	Severe, spontaneous	Bedridden or few yards. Two sticks or crutches	0-30
2	Severe on attempting to walk. Prevents all activity	Time and distance very limited with or without sticks	31-60
3	Pain tolerable. Permitting limited activity	Limited with one stick (less than 1 hour). Difficult without stick. Able to stand long periods	61-100
4	Pain only after some activity, disappears quickly at rest	Long distances with one stick. Limited without a stick	101-160
5	Slight or intermittent pain on starting to walk but getting less with normal activity	No stick but a limp	161-210
6	No pain	Normal	211-

Table 16. *Results concerning pain (101 fractures in 100 patients)*

Pain	Points	Central fractures	Posterior fractures	Total
Severe, spontaneous	1	-	-	-
Severe on attempting to walk Prevents all activity	2	3	3	6
Pain tolerable. Permitting limited activity	3	11	4	15
Pain only after some activity, disappears quickly at rest	4	11	7	18
Slight or intermittent pain on starting to walk but getting less with normal activity	5	5	3	8
No pain	6	36	18	54
		66	35	101
Mean value		4,9	4,8	4,9

fied by Charnley (1972), has been used (Table 15).

The results of the follow-up are presented in Tables 16-28.

Pain

A summarizing presentation for all fractures is made in Table 16.

Central fractures (66 patients)

Thirty patients had a *central fracture without central dislocation of the femoral head* (Table 17). The results concerning pain for this type of fracture were very satisfactory. Twenty-six patients (87 per cent) had no or only slight or intermittent pain. Mean value was 5.6 points. On comparison between patients with and without displacement of the acetabular fragments it is surprising to see that patients with displacement had better results than those without displacement of the acetabular fragments.

A *mild to moderate central dislocation of the femoral head* was present in 18 patients (Table 18). Nine patients had no or only slight or intermittent pain and 4 had pain only after some activity (72 per cent). Mean value was 4.5 points. The superior dome was intact in 11 patients and fractured in 7. Pain was less pronounced in patients with the superior dome intact (4.7 points) than in those with the superior dome fractured (4.1 points).

Thirteen patients with a *severe central dislocation of the femoral head were treated conservatively* (Table 19). Six patients had no pain and 2 pain only after some activity (61 per cent). Mean value was 4.5 points. The superior dome was intact in 4 patients and 3 of these had no pain and one had pain only after some activity (5.5 points). In 9 patients the superior dome was fractured and the mean value for these patients was 4.0 points.

Five patients with a *severe central dislocation of the femoral head were treated surgically* (Table 19). In all patients the superior dome was fractured and the mean value for pain was 3.6 points.

Table 17. *Results concerning pain and walking in central fractures without central dislocation of the femoral head (30 fractures in 30 patients)*

Pain Points	Without dislocation of acetabular fragments	With dislocation of acetabular fragments	Walking Points	Without dislocation of acetabular fragments	With dislocation of acetabular fragments
1	—	—	1	—	—
2	1	—	2	1	—
3	1	—	3	1	—
4	2	—	4	1	—
5	—	2	5	—	2
6	9	15	6	10	15
	13	17		13	17
Mean value	5.2	5.9		5.3	5.9

Table 18. Results concerning pain and walking in central fractures with mild to moderate central dislocation of the femoral head (18 fractures in 18 patients)

Pain Points	Superior dome intact	Superior dome fractured	Walking Points	Superior dome intact	Superior dome fractured
1	—	—	1	—	—
2	—	1	2	1	1
3	2	2	3	—	—
4	3	1	4	—	—
5	2	1	5	4	2
6	4	2	6	6	4
	<u>11</u>	<u>7</u>		<u>11</u>	<u>7</u>
Mean value	4,7	4,1		5,3	5,1

Table 19. Results concerning pain and walking in central fractures with severe central dislocation of the femoral head (18 fractures in 18 patients)

Pain points	Superior dome intact treated conservatively	Superior dome fractured		Walking points	Superior dome intact treated conservatively	Superior dome fractured	
		Treated cons.	Treated surg.			Treated cons.	Treated surg.
1	—	—	—	1	—	—	—
2	—	1	—	2	—	3	—
3	—	4	2	3	—	1	—
4	1	1	3	4	—	—	—
5	—	—	—	5	—	2	4
6	3	3	—	6	4	3	1
	<u>4</u>	<u>9</u>	<u>5</u>		<u>4</u>	<u>9</u>	<u>5</u>
Mean value	5,5	4,0	3,6		6,0	4,1	5,2

Correlation between results concerning pain in patients with good and less satisfactory reduction of the femoral head following conservative treatment (Table 20).

A mild to moderate or severe central dislocation of the femoral head was present in 31 of the 61 conservatively treated patients. It was mild to moderate in 18 and severe in 13. The superior dome was intact in 15 of the 31 patients and fractured in 16.

In the 15 patients with the superior dome intact a good reduction of the femoral head was achieved in 6 patients. In the remaining 9 the reduction was less satisfactory. The pain recorded for the reduced cases was 4.5 points and for the others 5.2 points.

Table 20. Correlation between results concerning pain and walking in patients with good and less satisfactory reduction of the femoral head following conservative treatment (31 fractures in 31 patients)

Points	Central fractures with mild to moderate dislocation of the femoral head								Central fractures with severe dislocation of the femoral head							
	Superior dome intact				Superior dome fractured				Superior dome intact				Superior dome fractured			
	Good reduction		Less satisfactory reduction		Good reduction		Less satisfactory reduction		Good reduction		Less satisfactory reduction		Good reduction		Less satisfactory reduction	
	Pain	Walking	Pain	Walking	Pain	Walking	Pain	Walking	Pain	Walking	Pain	Walking	Pain	Walking	Pain	Walking
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	1	-	-	1	1	-	-	-	-	-	-	1	3
3	1	-	1	-	2	-	-	-	-	-	-	-	2	1	2	-
4	2	-	1	-	-	-	1	-	1	-	-	-	1	-	-	-
5	-	1	2	3	1	1	-	1	-	-	-	-	-	1	-	1
6	1	3	3	3	1	3	1	1	1	2	2	2	1	2	2	1
	4	4	7	7	4	4	3	3	2	2	2	2	4	4	5	5
Mean value	4.3	5.8	5.0	5.0	4.3	5.8	4.0	4.3	5.0	6.0	6.0	6.0	4.0	5.0	4.0	3.4

On judging the influence of the degree of reduction on the degree of pain in the 16 patients with the superior dome fractured no difference could be found between those with a good reduction and those with a less satisfactory reduction (4.1 versus 4.0 points).

Posterior fractures (35 patients)

The intensity of pain in posterior fractures could be related to the type of fracture (Table 21).

Only 3 patients had a *Type I-fracture*, and all 3 were free from pain.

Type II-fracture was present in 15 patients. Ten patients had no or only slight or intermittent pain and 3 had pain only after some activity. The mean value was 5.2 points. Those patients treated conservatively had better results than those treated surgically (5.4 versus 4.9 points).

Seventeen patients had a *Type III-fracture*. Nine patients were treated conservatively and 8 surgically. The result concerning pain was 4.2 points in those treated conservatively and 4.6 in those treated surgically.

In 8 patients with Type II- and III-fractures, conservatively treated, the acetabular fragment remained dislocated after reduction of the femoral head. The mean value for these patients was 4.6 points.

Table 21. Results concerning pain in posterior fractures (35 fractures in 35 patients)

Points	Type I	Type II		Type III		Type II and III
	Treated conservatively	Treated conservatively	Treated surgically	Treated conservatively	Treated surgically	Treated conservatively with the fragment remained dislocated
1	—	—	—	—	—	—
2	—	—	1	1	1	—
3	—	—	1	1	2	1
4	—	1	2	4	—	4
5	—	1	—	1	1	—
6	3	3	6	2	4	3
	<u>3</u>	<u>5</u>	<u>10</u>	<u>9</u>	<u>8</u>	<u>8</u>
Mean value	6.0	5.4	4.9	4.2	4.6	4.6

Walking

A summarizing presentation for all fractures is made in Table 22.

Central fractures (66 patients)

Central fractures without central dislocation of the femoral head (Table 17). Twenty-five of 30 patients had normal walking (80 per cent). The mean value was 5.6 points.

A *mild to moderate central dislocation of the femoral head* was present in 18 patients and 10 of these had normal walking (Table 18). The mean value was 5.2 points. Whether the superior dome was fractured or not did not appear to influence the walking capacity in these patients.

Of the 13 patients with *severe central dislocation of the femoral head treated conservatively* 7 had a normal walking (Table 19). An interesting observation was made in the 4 patients in whom the superior dome was intact. The grading was 6 in all. In those 9 patients who had the superior dome fractured the result was graded as 4.1.

In those 5 patients with *severe central dislocation of the femoral head treated surgically* the mean value was 5.2 points (Table 19).

Correlation between results concerning walking in patients with good and less satisfactory reduction of the femoral head following conservative treatment (Table 20)

Of 16 patients with varying degree of central dislocation of the femoral head and the superior dome fractured a good reduction could be achieved in 8. These patients had a better grading (5.4 points) than those 8 patients in whom a less satisfactory reduction was obtained (3.8 points). A good reduction in 6 of those 15 patients who had the superior dome intact did also result in better walking than for those with less satisfactory reduction (5.8 versus 5.2 points).

Table 22. *Results concerning walking (101 fractures in 100 patients)*

<u>Walking</u>	<u>Points</u>	<u>Central fractures</u>	<u>Posterior fractures</u>	<u>Total</u>
Bedridden or few yards				
Two sticks or crutches	1	—	—	—
Time and distance very limited with or without sticks	2	6	3	9
Limited with one stick (less than 1 hour), Difficult without stick				
Able to stand long periods	3	2	3	5
Long distances with one stick				
Limited without a stick	4	1	2	3
No stick but a limp	5	14	2	16
Normal	6	43	25	68
		66	35	101
Mean value		5.3	5.2	5.3

Posterior fractures (35 patients)

Results concerning walking in posterior fractures are given in Table 23.

All 3 patients with *Type I-fracture* had normal walking.

Twelve of the 15 patients who had a *Type II-fracture* had normal walking, including all 5 patients treated conservatively.

Of 17 patients with *Type III-fracture* 9 were treated conservatively and 8 surgically. The result in walking was 5.2 points in those treated without operation and 4.5 points in those operated upon.

In 8 patients with Type II- and III-fractures treated conservatively the acetabular fragments remained dislocated after reduction of the femoral head. Mean value for these patients was 5.6 points.

Total motion

The range of total motion (flexion, abduction, adduction, inward- and outward rotation) for each group is presented in Tables 24 and 25.

Central fractures (63 patients) (Table 24)

In 23 of the 29 patients with *central fractures without central dislocation of the femoral head* a normal range of motion was registered. The remaining 6 patients had decreased mobility which foremost concerned flexion and rotation.

In 7 of the 16 patients with *central fractures with mild to moderate dislocation of the femoral head* there was a restriction of motion, particularly concerning flexion and rotation. The remaining 9 had a normal range of motion.

Table 23. Results concerning walking in posterior fractures (35 fractures in 35 patients)

Points	<u>Type I</u>	<u>Type II</u>		<u>Type III</u>		Type II and III treated conservatively with the fragment remained dislocated
	Treated conservatively	Treated conservatively	Treated surgically	Treated conservatively	Treated surgically	
1	—	—	—	—	—	—
2	—	—	1	—	2	—
3	—	—	1	1	1	—
4	—	—	1	1	—	1
5	—	—	—	2	1	1
6	<u>3</u>	<u>5</u>	<u>7</u>	<u>5</u>	<u>4</u>	<u>6</u>
	3	5	10	9	8	8
Mean value	6.0	6.0	5.1	5.2	4.5	5.6

Table 24. Results concerning mobility in central fractures (63 patients)

Total Motion	Points	Central fractures without central dislocation of the femoral head		Central fractures with mild to moderate central dislocation of the femoral head		Central fractures with severe central dislocation of the femoral head		
		Without displacement of fragments	With displacement of fragments	Superior dome intact	Superior dome fractured	Superior dome intact	Superior dome fractured	
							Treated conservatively	Treated surgically
0-30	1	-	-	-	-	-	-	-
31-60	2	-	-	-	-	-	-	-
61-100	3	-	-	-	-	-	1	1
101-160	4	2	-	1	2	-	5	2
161-210	5	1	3	3	1	2	2	1
211-	6	<u>10</u>	<u>13</u>	<u>5</u>	<u>4</u>	<u>2</u>	<u>1</u>	<u>1</u>
		13	16	9	7	4	9	5
Mean value		5.6	5.8	5.4	5.3	5.5	4.3	4.4

Table 25. Results concerning mobility in posterior fractures (34 patients)

Total Motion	Points	Type I	Type II		Type III	
			Treated conservatively	Treated surgically	Treated conservatively	Treated surgically
0-30	1	-	-	-	-	-
31-60	2	-	-	-	-	-
61-100	3	-	-	1	-	1
101-160	4	-	-	2	2	2
161-210	5	-	-	1	1	1
211-	6	<u>2</u>	<u>5</u>	<u>6</u>	<u>6</u>	<u>4</u>
		2	5	10	9	8
Mean value		6.0	6.0	5.2	5.4	5.0

In 8 of the central fractures with mild to moderate dislocation a good reduction was obtained of the femoral head and 5 of these patients had a normal range of motion. Of the remaining 3 patients 2 had 5 points and one had 4 points.

Among those 8 patients in whom reduction had been less satisfactory 4 had 6 points, 2 had 5 points and 2 had 4 points.

In the 13 patients with *central fractures with severe central dislocation of the femoral head treated conservatively* only 3 had a normal range of motion. Four patients had 5 points, 5 had 4 points and one had 3 points. No difference in range of motion was registered between those with a good reduction (6 patients) and those with less satisfactory reduction of the femoral head (7 patients).

One of the 5 patients with *central fractures surgically treated* had normal motion. Four patients had a decreased range of motion (3-5 points).

Posterior fractures (34 patients) (Table 25)

Twenty-three patients had a normal range of motion. Three patients had 5 points, 6 had 4 points and 2 had 3 points.

Summary of results in pain and walking

To facilitate the comparison of the results of this investigation with the radiologic findings and with other reported results it has been found of practical value to make a summary of the results in groups of excellent, good, fair and poor.

The results concerning pain and walking have been summarized as follows:

Excellent: 12 points, Good: 10-11 points, Fair: 8-9 points, Poor: 2-7 points.

The results as graded above are presented in Tables 26 and 27.

Seventy-three per cent of the whole material had excellent or good result, 12 per cent fair and 16 per cent poor.

Results concerning total motion have been excluded from this summary. A correlation between the results concerning pain and walking, and total motion has been made and is presented in Table 28. From this it can be seen that a close relationship exists.

Central fractures (66 patients)

Central fractures without central dislocation of the femoral head (30 patients). Ninety per cent had excellent or good results. Twenty-three patients had excellent result, 4 good, 1 fair and 2 poor. Those 3 patients with fair or poor results had all central fractures without displacement of the acetabular fragments.

Central fractures with mild to moderate central dislocation of the femoral head (18 patients). Sixty-seven per cent had excellent or good results. Five patients had excellent result, 7 good, 4 fair and 2 poor. Eleven patients had the *superior dome intact*; the result was excellent in 3, good in 6, fair in 1, and poor in 1. Reduction of the femoral head has not influenced in the results in this group. In 7 patients the *superior dome was fractured*; the result was excellent in 2, good in 1, fair in 3, and poor in 1. In those 4 patients with fair or poor result there was

Table 26. Results concerning pain and walking graded in excellent to poor in 66 patients with central acetabular fractures.

Result	Without central dislocation of the femoral head	With mild to moderate central dislocation of the femoral head		With severe central dislocation of the femoral head			Total
		Superior dome intact	Superior dome fractured	Superior dome intact	Superior dome fractured		
					Treated conservatively	Treated surgically	
Excellent	23	3	2	3	2	—	33
Good	4	6	1	1	1	1	14
Fair	1	1	3	—	2	4	11
Poor	2	1	1	—	4	—	8
	30	11	7	4	9	5	66

Table 27. Results concerning pain and walking graded in excellent to poor in 35 patients with posterior acetabular fractures

Result	Type I	Type II		Type III		Total
		Treated conservatively	Treated surgically	Treated conservatively	Treated surgically	
Excellent	3	3	6	2	4	18
Good	—	2	1	4	1	8
Fair	—	—	—	1	—	1
Poor	—	—	3	2	3	8
	3	5	10	9	8	35

Table 28. Correlating results between pain and walking and total motion in 96 patients with 97 acetabular fractures

Result pain and walking	Total motion						Total
	≥ 211	210-161	160-101	100-61	60-31	30-0	
Excellent	42	5	1	—	—	—	48
Good	14	6	1	—	—	—	21
Fair	3	3	5	1	—	—	12
Poor	—	2	11	3	—	—	16
	59	16	18	4	—	—	97

a good reduction of the femoral head in 2 and a less satisfactory reduction in 2.

Central fractures with severe central dislocation of the femoral head treated conservatively (13 patients). Fifty-four per cent had excellent or good result. Five patients had excellent result, 2 good, 2 fair, and 4 poor. In 4 patients the *superior dome was intact*; the result was excellent in 3, and good in 1. In 2 patients there was a good reduction of the femoral head and in 2 the reduction was less satisfactory. In 9 patients the *superior dome was fractured*; the result was excellent in 2, good in 1, fair in 2, and poor in 4. In 4 patients there was a good reduction of the femoral head. One of these had excellent result, 2 fair and 1 poor. In 5 patients there was a less satisfactory reduction of the femoral head. One of these had excellent result, 1 good and 3 poor.

Of 31 patients treated conservatively with a mild to moderate or severe central dislocation of the femoral head the *superior dome was intact* in 15. Eighty-seven per cent had excellent or good result and 13 per cent fair or poor. Six patients had excellent result, 7 good, 1 fair, and 1 poor. In 6 patients there was a good reduction of the femoral head. Any difference in the results between patients with good and less satisfactory reduction was not obtained.

In 16 patients with a mild to moderate or severe central dislocation of the femoral head treated conservatively the *superior dome was fractured*. Six of these patients had excellent or good result (38 per cent) and 10 fair or poor (62 per cent). Four had excellent result, 2 good, 5 fair, and 5 poor. Good reduction of the femoral head was obtained in 8 patients. Two of these had excellent result, 1 good, 4 fair, and 1 poor.

Central fractures with a severe central dislocation of the femoral head treated surgically (5 patients). One patient had good result and 4 fair.

Posterior fractures (35 patients)

Type I (3 patients). All 3 patients had excellent result.

Type II – treated conservatively (5 patients). Three patients had excellent result and 2 good. In all the femoral head was dislocated posteriorly.

Type II – treated surgically (10 patients). Six patients had excellent result, 1 good, 0 fair, and 3 poor. In all patients the femoral head was dislocated posteriorly. A poor result was recorded in the following 3 patients. 1. A 74-year-old woman who was treated with acute reduction of the femoral head and put into traction. After 4 weeks there was a redislocation posteriorly of the femoral head. Open reduction of the femoral head and fixation of the acetabular fragment was performed. 2. A 60-year-old man. Closed reduction of the femoral head failed and after 3 days an open procedure was performed. Because of fracture of the femoral head the patient was operated with a Moore prosthesis. The posterior acetabular fragment was put into place and fixed with two pins. After 6 months pain progressed to a degree which eventually made a Girdlestone procedure necessary 2 years after injury. 3. A 77-year-old man who was treated with acute reduction of the femoral head. After 3 days the joint was opened and the posterior acetabular fragment put into place and fixed with two pins.

Type III – treated conservatively (9 patients). Two patients had excellent result, 4 good, 1 fair, and 2 poor. Seven patients had at the first radiologic examination a posterior dislocation of the femoral head and in 2 patients no posterior dislocation could be observed. These 2 pa-

tients had excellent and good result. A poor result was recorded in the following 2 patients: 1. A 40-year-old man. The posterior dislocation of the femoral head was not noticed until after 2 months. 2. A 50-year-old woman who was treated with traction through the tibial tuberosity for 3 weeks following acute reduction of the femoral head.

Type III – treated surgically (8 patients). Four patients had excellent result, 1 good, 0 fair, and 3 poor. In all patients but one there was a posterior dislocation of the femoral head. A poor result was recorded in the following 3 patients: 1. A 58-year-old woman with a comminute fracture of the acetabulum. She was operated upon acute with open reduction of the dislocated femoral head and fixation of a big posterior acetabular fragment with two pins. In addition this patient had a central fracture and after the operation the femoral head was dislocated 10 mm medially. She was postoperatively treated with traction through the tibial tuberosity for 6 weeks. 2. A 47-year-old woman who was treated with acute closed reduction after 6-12 hours. After 1 week she was operated upon and a big posterior acetabular fragment was put into place and fixed with two pins. Postoperatively she was immobilized in bed for 7 weeks. Two years after the injury she developed necrosis of the femoral head leading to arthrosis. 3. A 20-year-old man who was treated with acute closed reduction of the femoral head. Because of redislocation he was operated after 8 days with open reduction of the femoral head and osteosynthesis of the posterior acetabular fragments.

Of 32 patients with posterior acetabular fractures classified as Type II- and III-fractures, 14 were treated conservatively and 18 surgically. Of those treated conservatively 79 per cent had excellent or good results and 21 per cent fair or poor. Five patients had excellent result, 6 good, 1 fair, and 2 poor. Of those patients treated surgically 67 per cent had excellent or good result and 33 per cent poor. Ten patients had excellent result, 2 good, 0 fair, and 6 poor.

There were poor results in 8 patients of whom 5 had unfavourable features, i.e. redislocation of the femoral head, delayed reduction of the femoral head, never reduced dislocation of the femoral head and a central fracture in addition to the posterior.

Time of onset of post-injury symptoms

Those patients who did not have 6 points for pain and walking were interrogated as to the time of onset of symptoms. Eighty per cent maintained that their discomfort had developed at the accident and remained stationary ever since. Eight per cent had a *début* after 1-2 years, 2 per cent after 2-4 years and 10 per cent after 4 years.

Working capacity

Central fractures (66 patients)

Central fractures without central dislocation of the femoral head (30 patients). Five patients were retired at the time of injury. Four received sick compensation for other reasons. Two had changed to lighter work. One received sick compensation because of the hip injury. One still received rehabilitation treatment (1 year follow-up). Seventeen remained in their original work which for 9 was of the heavy type, i.e. labour. Two were house wives and 6 had a lighter type of work.

Central fractures with mild to moderate central dislocation of the femoral head (18 patients). Two patients were retired at the time of injury. One received sick compensation due to additional injury (fracture of the tibia). Two received sick compensation because of hip discomfort. Two had changed to lighter work. Eleven remained in their original work, which in 5 was of the heavy type. Six had a lighter type of work.

Central fractures with severe central dislocation of the femoral head treated conservatively (13 patients). Three patients were retired at the time of injury. One had changed to lighter work. Two received sick compensation because of hip discomfort. Seven returned to their original work which for one patient was of the heavy type. Two were house wives and 4 had a lighter type of work.

Central fractures with severe central dislocation of the femoral head treated surgically (5 patients). One patient received sick compensation because of hip discomfort. Two had changed to lighter work. One was still at school (could not partake in physical exercise). One returned to original work as a heavy worker.

Posterior fractures (35 patients)

Type I (3 patients). All 3 patients returned to their original work. One was a heavy worker and 2 had a lighter type of work.

Type II – treated conservatively (5 patients). One patient had changed to a lighter work. The remaining 4 returned to their original work. Of these one was a heavy worker and 3 had a lighter type of work.

Type II – treated surgically (10 patients). One patient was retired at the time of injury. One was still in school (had done his military service and could partake in physical exercise). One received sick compensation due to hip discomfort. One had changed to lighter work. Six remained in their original work which for 4 was of the heavy type. Two had a lighter type of work.

Type III – treated conservatively (9 patients). One patient was retired at the time of injury. One received sick compensation due to hip discomfort. Two had changed to lighter work. Five remained in their original work. Of these one was a heavy worker and 4 had a lighter type of work.

Type III – treated surgically (8 patients). Two patients had sick compensation due to hip discomfort. One had changed to lighter work. Five remained in their original work which for 2 was of a heavy type. One patient was a house-wife and 2 had a lighter type of work.

RADIOLOGIC FOLLOW-UP STUDY

Degenerative changes

Osteoarthritis and avascular necrosis of the femoral head are late complications which are considered to yield poor results. In Table 29 a summary of late complications as reported in the literature is presented.

Osteoarthritis

Of 1152 reported patients (Table 29) osteoarthritis was found in 6.6 to 62 per cent.

Avascular necrosis of the femoral head

Avascular necrosis of the femoral head developed in 4 to 30 per cent (Table 29).

As regards posterior fractures Stewart & Milford (1954) and Brav (1962) noted that this complication occurred less frequently in fractures treated by conservative methods. However, Waller (1955) presented a higher percentage of avascular necrosis in patients not being operated upon.

Most authors stress the importance of early reduction of the posteriorly dislocated femoral head in order to minimize the frequency of necrosis and arthrotic changes (Stewart & Milford 1954, 1975, Brav 1962, Epstein 1974). When reduction was delayed for more than 12 hours the incidence of avascular necrosis became three times as frequent (Brav 1962).

In a material of 242 patients with posterior dislocations and fracture-dislocations Epstein (1974) noted 18 per cent avascular necrosis. In those patients treated with primary open reduction of the femoral head the frequency of avascular necrosis was 5.3 per cent and in the remainder 21 per cent.

Ectopic ossification

Ectopic ossification occurs to a varying extent after acetabular fractures. This has particularly been the case when surgical treatment has been carried out. Stewart & Milford (1954) noted 2.2 per cent in their patients treated conservatively. Waller (1955) found 14 cases in 106 posterior acetabular fractures (13.1 per cent). Ten of these cases belonged to the operated category and 4 to the group treated conservatively. Brav (1962) reported a frequency of 13.2 per cent and Judet & Letournel (1974) a frequency of 20.2 per cent.

As a rule ectopic ossification has not been accompanied by any symptoms and no special treatment has been recommended.

Table 29. *Frequency of osteoarthritis and necrosis of the femoral head and ectopic ossification reported in the literature in patients with fracture-dislocation of the hip*

Author	No. of pat. followed up	Mean time of follow-up-years	Type of fracture	Osteo-arthrosis per cent	Avascular Necrosis per cent	Ectopic ossification per cent
Stewart & Milford 1954	77	7,0	Posterior acetabular fractures Central fractures	60 59	30 (17) 23	
Waller 1955	87	3,9	Posterior acetabular fractures	44,8 (50)	19,6 (26)	13,1☆
Wechselberger 1956	37	6	Central fractures	53	27	2,7
Rowe & Lowell 1961	93	6,0	Posterior acetabular fractures Central fractures	23 17	23 8	15
Brav 1962	91	6,7	Posterior fracture-dislocation	50	25 (13,5)	13,2
Pearson & Hargadon 1962	50	2,5	Central fractures	62		
Göthlin & Hindmarsh 1970	51	6,0	Central fractures	33		
Austin 1971	25		Central fractures	44	4	
Nerubay et al. 1973	89	6,0	Posterior acetabular fractures Innerwall fractures Superior dome fractures	22 31,4 50,2	13,8 2,8 17,0	
Solheim & Skrede 1973	66	4,4	Posterior acetabular fractures Central fractures	36 25		
Epstein 1974	242	7,3	Posterior fracture-dislocation	36	18	4
Judet & Letournel 1974	244		All acetabular fractures	6,6	8,6	20,2

The figures within parenthesis represent the frequencies for patients treated conservatively.

☆ 14 of 106 patients.

Present investigation

At the clinical follow-up a radiologic study was also performed. The purpose of the radiologic examination was to determine the frequency and the degree of possible degenerative changes of the fractured joint and the frequency of ectopic ossification.

Examination technique

In 83 patients both hips were examined in the supine position, but no examination with weight-bearing on the hip was carried out.

An AP view was taken with the thigh slightly inward rotated and with the centre of the beam directed to the femoral head. Furthermore, a projection according to Cleave – also called Lauenstein's projection – was made. This implies an AP view of the acetabulum with the thigh abducted 45° and with an external rotation of about 60° . In patients with a decreased mobility of the hip joint, this projection was made in the utmost position the patient could attain. In Cleave's projection the acetabulum appears mainly the same as in the AP view projection but the femoral head becomes externally rotated, thus visualizing anterior and posterior parts of the femoral head.

In 10 patients there were some diagnostic doubts whether degenerative lesions were present or not. These patients were also examined under weight-bearing conditions, i.e. in a standing position. An AP view of each hip was taken as well as an "en face" view. An "en face" view implies a semilateral projection of the hip where the centre of the beam was directed transversally through the pelvis and centralized through a point slightly posterior to the opposite femoral head. The object of that particular projection was to obtain a beam direction parallel to other parts of the joint space than those demonstrated on the AP projection. The "en face" projection demonstrates parts of the anterior joint space, the central joint space, and parts of the posterior joint space. In order to get an ideal positioning of each hip, fluoroscopy was utilized.

All films obtained at the follow-up study were studied together with all earlier films in order to make a complete review of each case.

Definitions and classifications

Osteoarthritis

The earliest radiologically definable stage of osteoarthritis of the hip is narrowing of the joint space. The width of the joint space reflects the thickness of the articular cartilage. In this study the joint space was interpreted as abnormally decreased if it was more than 1 millimeter narrower than the contralateral normal side.

The presence of osteophytes without a concomitant narrowing of the joint space was accordingly excluded as a single criterion of the diagnosis of osteoarthritis of the hip. These considerations have also been suggested by Danielsson (1964) and Ahlbäck (1971).

In this study a two stage classification of osteoarthritis was utilized:

Grade 1: Mild to moderate arthrosis

Slight to moderate narrowing of the joint space. None or only slight secondary changes of sclerosis and/or cyst formation in the acetabulum and/or the femoral head. No, slight or moderate formation of osteophytes.

Grade 2: Severe osteoarthritis

Advanced or total obliteration of the joint space. Marked secondary changes of sclerosis, cyst formation and large osteophytes. The obliteration was considered advanced when the joint space was found to be less than 1 millimeter.

Avascular necrosis of the femoral head

The radiographic appearance of avascular necrosis is an archlike radiolucency which occurs parallel to the subchondral surface of the femoral head. Its presence alone, without any of the other characteristic features, was regarded good evidence of ischemic necrosis.

A narrow lip of sclerotic bone surrounds the radiolucent zone. At first, the joint space is normal, but later, when the necrotic ischemic bone collapses, the articular surface is flattened and the articular cartilage destroyed (Edeiken & Hodes 1975).

Material

Ninety-three patients with 94 acetabular fractures were examined radiologically. Of 100 patients followed up clinically, 6 could not be assessed by radiologic examination. Four of these refused any clinical or radiologic examination and instead replied to a written questionnaire. Two patients could be examined clinically but refused radiologic examination.

Moreover one patient with a posterior fracture dislocation with damage to the femoral head has been excluded as the acute procedure following injury was an arthroplasty with a Moore prosthesis which after 2 years was removed and turned into a Girdlestone hip.

Results

In 2 patients mild to moderate arthrotic changes were observed at the first radiologic examination.

At the follow-up arthrotic changes were found in 37 out of 94 hips (39 per cent). The distribution of arthrotic changes within the different types of acetabular fractures is demonstrated in Table 30. The 37 patients who developed osteoarthritis had a mean age of 46 years at the time of injury; 21 were men and 16 women. The mean time for follow-up of the 37 patients with osteoarthrotic changes was 5 years and 5 months. (The mean time for follow-up of the whole material was 6.1 years.)

There were 8 patients who developed necrosis of the femoral head in addition to arthrotic changes (Table 31). Five of these patients had a central fracture and 3 a posterior fracture of Type II or III in combination with a posterior dislocation of the femoral head.

Table 30. Results of radiologic follow-up (osteoarthritis) in comparison to clinical rating

Type of fracture	Normal joint space				Grade I arthrosis				Grade II arthrosis				Total
	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor	
Central fractures without central dislocation of the femoral head													
Without displacement of the acetabular fragments	9	1	1					1				1	13
With displacement of the acetabular fragments	12	3								1			16
Central fractures with mild to moderate central dislocation of the femoral head													
Superior dome intact	2	2				3	1					1	9
Superior dome fractured	2	1	1				2					1	7
Central fractures with severe central dislocation of the femoral head													
Superior dome intact	1	1			1					1			4
Superior dome fract. treated conservatively			1		1					1	1	3	7
Superior dome fract. treated surgically			1			1	1				2		5
Posterior fractures													
Type I	2												2
Type II treated cons.	3	1					1						5
Type II treated surg.	5				1	1		1				1	9
Type III treated cons.	2	3		1		1	1					1	9
Type III treated surg.	1	1			3							3	8
	<u>39</u>	<u>13</u>	<u>4</u>	<u>1</u>	<u>6</u>	<u>7</u>	<u>5</u>	<u>2</u>	<u>2</u>	<u>1</u>	<u>3</u>	<u>11</u>	<u>94</u>
		57				20				17			

Table 31. *Avascular necrosis of the femoral head in 8 patients*

Type of fracture	No. of patients	Time until reduction of the femoral head	Damage to the femoral head visible on original radiograph	Changes first visible on radiograph	Clinical rating
Central fractures without central dislocation of the femoral head					
Without displacement of the acetabular fragments	1	—	—	2 years 6 months	poor
With displacement of the acetabular fragments	1	—	—	9 months	excellent
Central fractures with mild to moderate central dislocation of the femoral head					
Superior dome intact					
Superior dome fractured	1	not reduced	—	7 months	poor
Central fractures with severe central dislocation of the femoral head					
Superior dome intact	1	not reduced	lateral superior part	12 months	excellent
Superior dome fractured treated conservatively	1	1 day	—	10 months	poor
Superior dome fractured treated surgically					
Posterior fractures					
Type I					
Type II treated surgically	1	< 12 hours. Redislocation after 4 weeks	anterior part	1 year 6 months	poor
Type III treated surgically	2	1. < 12 hours	—	10 years 9 months	poor
		2. < 12 hours	medial ant. part	11 months	poor

Two deceased patients with a posterior fracture Type III operated upon could be examined 4 years after injury. They both developed arthrosis Grade II and necrosis of the femoral head. Time for reduction was within 12 hours and no damage to the femoral head could be observed at the time of injury for either of these patients. Changes were first visible on radiograph at 3 months.

Central fractures (61 patients)

Twenty-three patients had radiologic evidence of osteoarthritis (38 per cent). Eleven had mild to moderate arthrotic changes (Grade I) and 12 had severe arthrotic changes (Grade II). In addition 5 had necrosis of the femoral head.

Central fractures without central dislocation of the femoral head (29 patients). Twenty-six patients had no signs of osteoarthritis or avascular necrosis (90 per cent). Mild to moderate arthrotic changes were found in one patient and severe arthrotic changes in 2. These latter both had necrosis of the femoral head. One of them, a 68-year-old woman, had sustained a minor acetabular fracture when falling on the same level. After 2 1/2 years she developed necrosis of the femoral head (Fig. 20). The other patient, a 66-year-old man, had sustained a central acetabular fracture with 10 millimeter medial dislocation of a fragment. The radiologic examination at the time of injury showed mild to moderate osteoarthritis and 9 months after injury the patient developed a severe osteoarthritis and femoral head necrosis.

At the time of injury there was a dislocation between the acetabular fragments exceeding 3 millimeter in 16 patients. In all those patients the fracture gap had been filled in with bone and a congruent socket had developed (Fig. 22).

Central fractures with mild to moderate central dislocation of the femoral head (16 patients). In 8 patients no signs of osteoarthritis or femoral head necrosis could be detected (50 per cent). Six patients had mild to moderate and 2 severe arthrotic changes. In one patient with severe arthrotic changes mild to moderate osteoarthritis had been observed at the time of injury. The other patient with severe osteoarthritis had in addition necrosis of the femoral head.

In 8 patients there was a good reduction of the femoral head. Five of these had no arthrotic changes, nor any femoral head necrosis and 3 had mild to moderate osteoarthritis.

In 8 patients there was less satisfactory reduction of the femoral head. In 3 of these there were no signs of degenerative changes. Of the remaining 5, 3 had mild to moderate and 2 severe osteoarthritis. One of the latter developed necrosis of the femoral head.

Central fractures with severe central dislocation of the femoral head treated conservatively (11 patients). Three patients had no signs of osteoarthritis. Two patients had mild to moderate and 6 had severe osteoarthritis. One of the patients with mild to moderate arthrotic changes and one of the 6 patients with severe arthrotic changes had femoral head necrosis.

In 6 patients there was a good reduction of the femoral head. In 3 of these no signs of osteoarthritis or femoral head necrosis could be detected. One had mild to moderate and 2 had severe arthrotic changes.

In 5 patients a less satisfactory reduction was obtained. All of these had osteoarthrotic changes, one mild to moderate and 4 severe. One of the patients sustained a pertrochanteric fracture at the time of injury. He developed a severe osteoarthritis which eventually was treated by an arthroplasty according to Smith-Petersen.

Central fractures with severe central dislocation of the femoral head treated surgically (5 patients). One patient had no signs of osteoarthritis. Two patients had mild to moderate and 2 had severe arthrotic changes.

In 14 patients with mild to moderate or severe central dislocation of the femoral head treated conservatively a good reduction of the femoral head had been achieved. There was no re-dislocation centrally of the femoral head. There seems to have been little influence on the centrally dislocated fragments by traction. Further, it seems that in the healing procedure nature had filled in the space between the femoral head and the fragments and that a smooth congruent articulating surface had developed.

In those 13 patients with mild to moderate or severe central dislocation of the femoral head treated conservatively, in whom less satisfactory reduction had been achieved a new "pseudo-acetabulum" or "false joint" between the two joint components was observed (Fig. 25).

Correlation between osteoarthrotic changes and reduction of the femoral head

A correlation between arthrotic changes and reduction of the femoral head in 27 patients with mild to moderate or severe central dislocation of the femoral head treated conservatively is presented in Table 32. In 4 of 6 patients with good reduction of the femoral head and the superior dome intact there were no signs of osteoarthrotic changes. In 5 of 6 patients with less satisfactory reduction of the femoral head and the superior dome fractured there were arthrotic changes, mild to moderate in one and severe in 4.

In 13 patients the superior dome was intact. Six of these had no signs of osteoarthritis (46 per cent). Five patients had mild to moderate and 2 severe arthrotic changes (54 per cent).

In 14 patients the superior dome was fractured. Five of these had no signs of osteoarthritis (36 per cent). Three patients had mild to moderate and 6 severe arthrotic changes (64 per cent).

Posterior fractures (33 patients)

Fourteen patients had radiologic evidence of osteoarthritis (42 per cent). Nine patients had mild to moderate and 5 severe arthrotic changes. In addition 3 patients had necrosis of the femoral head.

Table 32. *Correlation between degenerative changes and reduction of the femoral head in 27 patients with varying degree of central dislocation of the femoral head treated conservatively*

Radiologic appearance	Good reduction		Less satisfactory reduction	
	Superior dome intact	Superior dome fractured	Superior dome intact	Superior dome fractured
No signs of osteoarthrotic changes	4	4	2	1
Grade I – osteoarthritis	2	2	3	1
Grade II – osteoarthritis	–	2	2	4
	6	8	7	6

Type I (2 patients). Two patients with posterior fractures of this type were radiologically examined and none of them showed any sign of osteoarthritis.

Type II – treated conservatively (5 patients). Four patients had no signs of osteoarthritis and one had mild to moderate arthrotic changes.

Type II – treated surgically (9 patients). Five patients had a normal joint space without any radiologic signs of osteoarthritis or femoral head necrosis. Three patients had mild to moderate and one had severe arthrotic changes. This patient also developed femoral head necrosis. One patient had at the time of injury a fracture of the femoral head with a little fragment dislocated. The fragment was removed and the dislocated posterior acetabular fragment was fixed with two pins. This patient had at the time of follow-up 11 years after the operation mild to moderate arthrosis.

Type III – treated conservatively (9 patients). Six patients had no signs of osteoarthritis, 2 had mild to moderate and one had severe osteoarthritis.

Type III – treated surgically (8 patients). Two patients had no signs of osteoarthritis, 3 had mild to moderate and 3 had severe osteoarthritis. Two of the latter developed a femoral head necrosis.

Fourteen patients classified as Type II and III were treated conservatively and in 4 of these degenerative changes were observed (29 per cent). Seventeen patients classified as Type II and III were treated surgically. Ten of these had osteoarthrotic changes (60 per cent), of which 3 had femoral head necrosis.

Thirty patients were not included in the radiologic follow-up study. Only 6 of these had been radiologically examined for more than 1 year following the injury. They are specified as follows:

One patient with a posterior acetabular fracture Type III combined with a posterior dislocation of the femoral head treated surgically was examined up to 2 years and 6 months after injury. At the time of injury no damage of the femoral head was observed. After 1 month ectopic ossification was noted and after 3 months necrosis of the femoral head developed and also a total destruction of the joint cartilage.

One patient with a posterior fracture Type III treated surgically was examined up to 4 years and 2 months after injury. He developed necrosis of the femoral head and ankylosis of the hip joint and ectopic ossification.

One patient with a central fracture with severe central dislocation of the femoral head and fracture of the superior dome was examined up to 3 years and 9 months after injury. A mild to moderate osteoarthritis could then be observed. This patient had been treated conservatively without traction.

The other 3 patients had all central fractures without central dislocation of the femoral head and were examined up to 4 years after injury. None of them showed any sign of osteoarthritis or femoral head necrosis.

Correlation between clinical results and radiologic findings in 94 hips with acetabular fractures

In those 57 hip joints without radiologic signs of osteoarthritis or femoral head necrosis the clinical results were excellent to good in 52 cases (91 per cent). Of the 47 patients with clinically excellent results 39 had no radiologic evidence of osteoarthritis (83 per cent) (Table 33).

Ectopic ossification

Of 99 patients radiologically examined for more than 1 year ectopic ossification was observed in 13 patients (Table 34). Two of these patients had been treated conservatively and 11 surgically. The changes usually developed 1-4 weeks after the injury and no special treatment was given.

Table 33. *Correlation between clinical results and radiologic findings in 94 hips with acetabular fractures*

Clinical results	No signs of arthrotic changes or necrosis of the femoral head	Grade I Arthrotic changes	Grade II Arthrotic changes	
			without necrosis of the femoral head	with necrosis of the femoral head
Excellent	39	6	1	1
Good	13	7	1	—
Fair	4	5	3	—
Poor	1	2	5	6
	57	20	10	7

Table 34. *Ectopic ossification in 13 patients*

Type of fracture	No. of patients	Changes first visible on radiographs	Combined with other radiologic findings	Clinical results
Central fracture with severe dislocation of the femoral head. The superior dome fractured treated conservatively	1	4 weeks	grade II	good
Central fracture with severe central dislocation of the femoral head. The superior dome fractured treated surgically	4	1. 4 weeks 2. 2 weeks 3. 1 year 4. 4 weeks	— grade II grade I grade I	fair fair good fair
Posterior fractures				
Type II treated surgically	3	1. 3 months 2. 3 weeks 3. 7 years	— grade II —	excellent poor excellent
Type III treated cons.	1	4 weeks	—	good
Type III treated surgically	4	1. 3 months 2. 4 weeks 3. 1 month 4. 4 years 2 months	grade I — grade II + necrosis grade II + necrosis	excellent good dead dead

CASE REPORTS

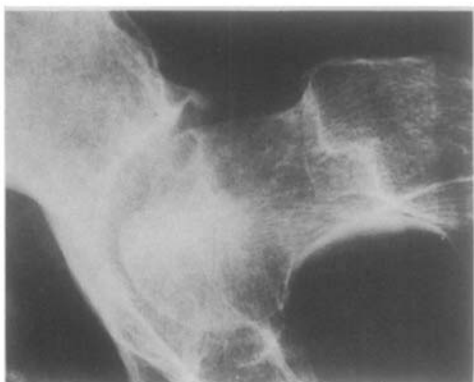


A

Fig. 20. 68-year-old female. Fall on the same level. A: Radiograph at time of injury. Central acetabular fracture without dislocation of the femoral head or the acetabular fragments in the left hip. Conservative treatment with immobilization in bed for 1 week. B–C: Radiographs 2 years and 6 months after injury. AP-view (B) and Cleave's projection (C). Osteoarthrosis and femoral head necrosis including deformation of a superior section of the femoral head. D: Radiograph 3 years and 6 months after injury. Progress of the osteoarthrosis. E: Radiograph at follow-up 4 years and 4 months after injury. Total destruction of the joint. Clinical result: poor. Mobility: 4 points.



A



C



D



E



A



B

Fig. 21. 37-year-old male. Pedestrian hit by car. A: Radiograph at time of injury. Central acetabular fracture without central dislocation of the femoral head but with displacement of the acetabular fragment in the right hip. Conservative treatment with immobilization in bed without traction for 1 month. B: Radiograph at follow-up 10 years after injury. No degenerative changes. Clinical result: excellent. Mobility: 6 points.



A



B



C

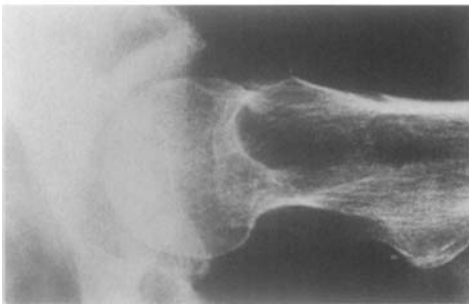
Fig. 22. 34-year-old male. Traffic accident. Car driver. A: Radiograph at time of injury. Central acetabular fracture without central dislocation of the femoral head but with displacement of acetabular fragments in the left hip. Conservative treatment with immobilization in bed without traction for 4 weeks. B–C: Radiographs at follow-up 7 years after injury. AP-view (B) and Cleave's projection (C). The femoral head in its ordinary position. The fracture gap has been filled in with bone. No degenerative changes. Clinical result: good. Mobility: 6 points.



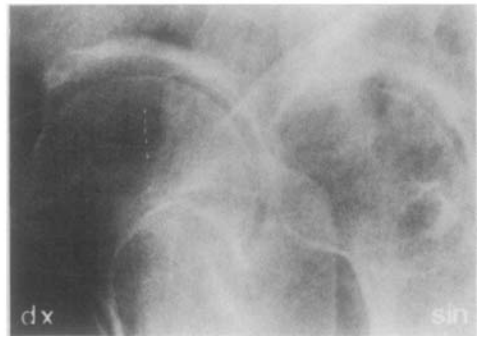
A



B



C



D

Fig. 23. 47-year-old male. Fall from 5 meters. A: Radiograph at time of injury. Central acetabular fracture with moderate central dislocation of the femoral head. The superior dome fractured. Conservative treatment with traction through the tibial tuberosity for 1 week, followed by mobilization without weight-bearing for 6 weeks. B–D: Radiographs at follow-up 5 years after injury. AP-view (B), Cleave's projection (C), and lateral view, standing position (D). No degenerative changes. Clinical result: excellent. Mobility: 6 points. Returned to his original work as a heavy worker 10 weeks after the accident.



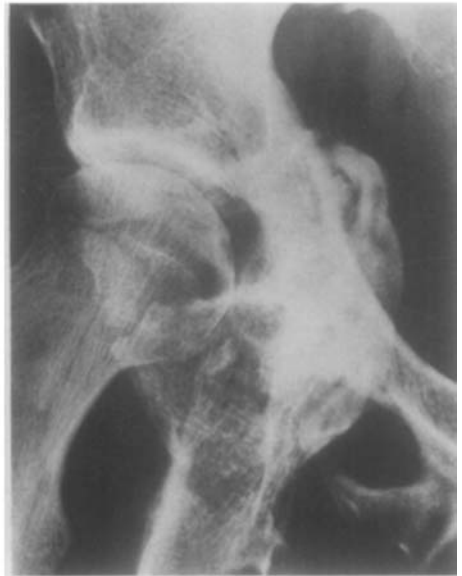
A



B



C



D

Fig. 24. 24-year-old male. Traffic accident. Car driver. **A:** Radiograph at time of injury. Central acetabular fracture with severe central dislocation of the femoral head. The superior dome intact. Conservative treatment with combined traction through the tibial tuberosity and the proximal femur for 7 weeks. **B:** Radiograph 1 month after injury. Good reduction of the femoral head. **C:** Radiograph 3 months after injury. **D:** Radiograph at follow-up 6 years and 3 months after injury. Deformed joint. No degenerative changes. Clinical result: excellent. Mobility: 6 points. Works as a sailor.

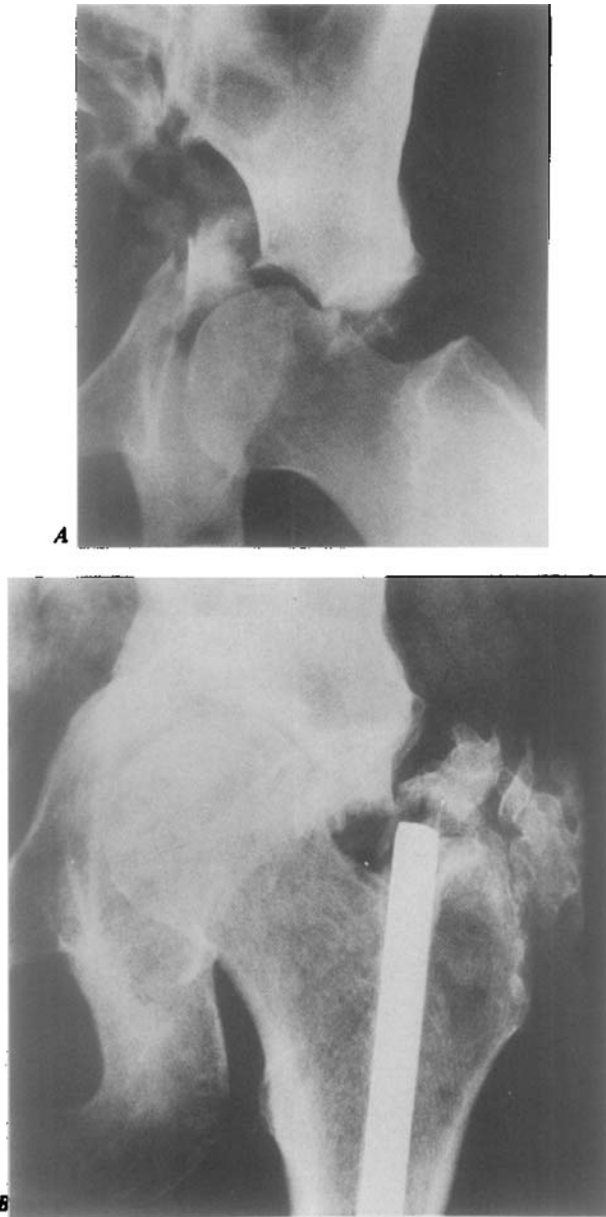


Fig. 25. 49-year-old female. Fall from 10 meters. A: Radiograph at time of injury. Comminute central acetabular fracture with severe central dislocation of the femoral head. The superior dome fractured. Conservative treatment with immobilization in bed without traction for 8 weeks. B: Radiograph at follow-up 8 years and 9 months after injury. The femoral head in unchanged position. Remodelling of the acetabulum with formation of a new "pseudoacetabulum". Osteoarthritis Grade II and ectopic ossification. Clinical result: good with no pain, but a slight limp. Mobility: 5 points.



A



B

C



Fig. 26. 57-year-old female. Pedestrian hit by car. A: Radiograph at time of injury. Central acetabular fracture with severe central dislocation of the femoral head. The superior dome fractured. Conservative treatment with closed reduction under general anesthesia followed by combined traction through the tibial tuberosity and the proximal femur for 13 weeks. B: Radiograph 1 month after injury. Good reduction of the femoral head. C: Radiograph at follow-up 1 year and 6 months after injury. Osteoarthrosis Grade II. Clinical result: fair. Mobility: 4 points



A

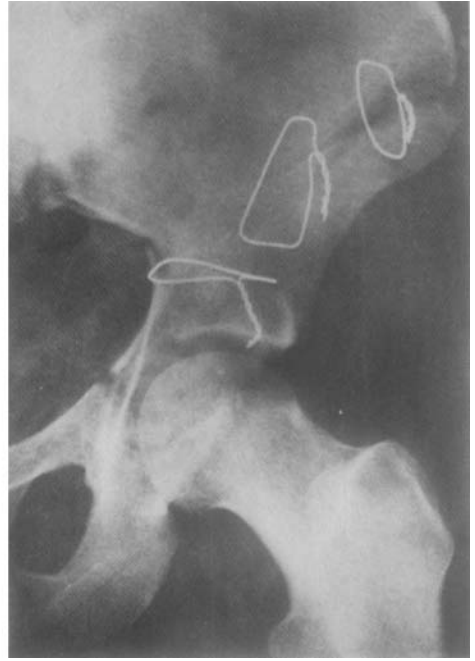


B

Fig. 27. 33-year-old male. Traffic accident. Car driver. **A:** Radiograph at time of injury. Central acetabular fracture with severe central dislocation of the femoral head. The superior dome fractured. Conservative treatment with combined traction through the tibial tuberosity and the proximal femur for 6 weeks. **B:** Radiograph at follow-up 2 years and 5 months after injury. Remodelling of the acetabulum. Osteoarthrosis Grade I. Clinical result: excellent. Mobility: 4 points.



A



B



C

Fig. 28. 23-year-old female. Pedestrian hit by car. A: Radiograph at time of injury. Central acetabular fracture with severe central dislocation of the femoral head. The superior dome fractured. Treatment with open reduction and osteosynthesis with three cerclage wires followed by traction through the tibial tuberosity for 6 weeks. B: Radiograph 1 day postoperatively. Good reduction of the femoral head and the acetabular fragments. C: Radiograph at follow-up 4 years after injury. No degenerative changes. Ectopic ossification. Clinical result: fair. Mobility: 6 points.



A



B

Fig. 29. 47-year-old male. Traffic accident. Car driver. A: Radiograph at time of injury. Posterior fracture-dislocation Type II. A large posterior fragment dislocated proximally and posteriorly. Conservative treatment with closed reduction of the femoral head followed by traction through the tibial tuberosity for 6 weeks. B: Radiograph after closed reduction of the femoral head. The posterior fragment in good position. C-E: Radiographs after 4 years. AP-view (C). No degenerative changes. The posterior fragment appears to be redislocated. Tomography (D) and oblique projection (E) show clearly the displacement of the fragment. F: Radiograph at follow-up 7 years and 4 months after injury. The fragment is still dislocated. No degenerative changes. Clinical result: good. Mobility: 6 points.



C



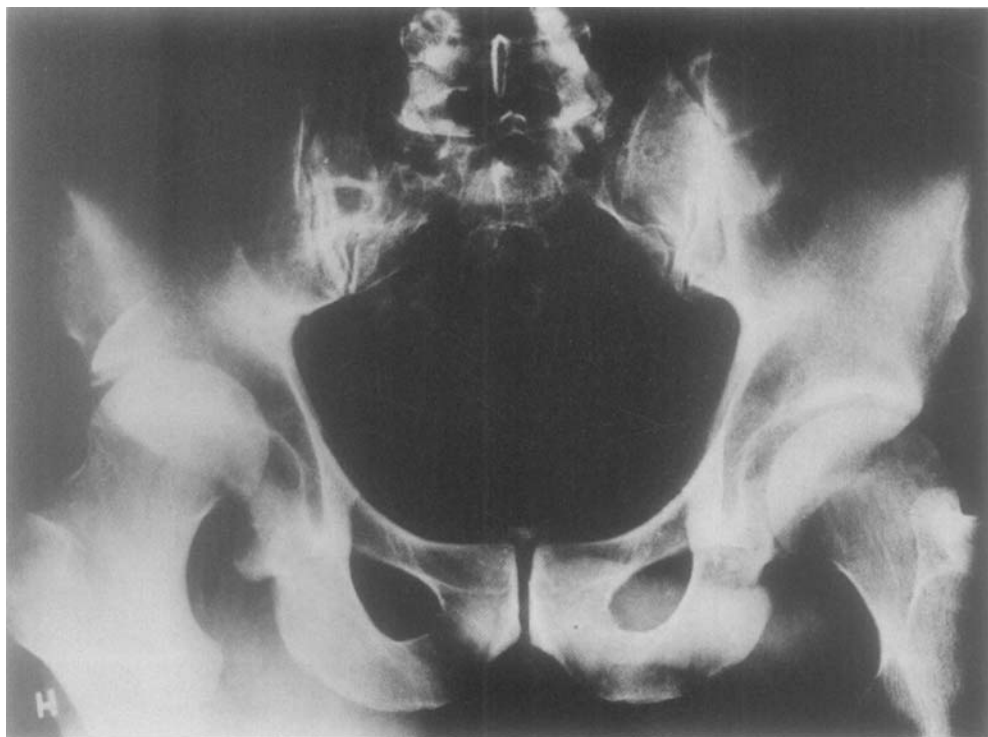
D



E

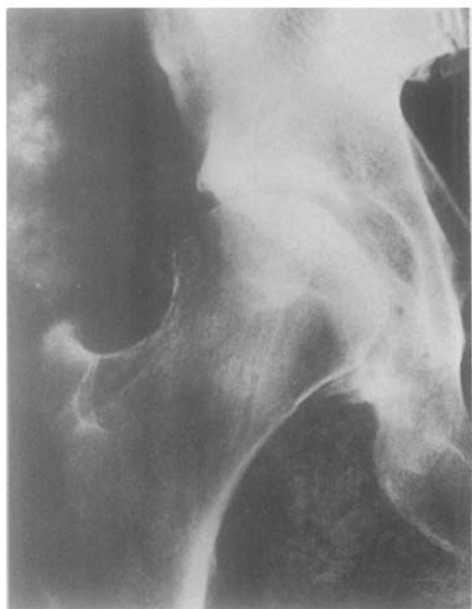


F



A

Fig. 30. 31-year-old male. Traffic accident. Car driver. A: Radiograph at time of injury. Posterior fracture-dislocation Type II. A large posterior fragment dislocated proximally and posteriorly. Conservative treatment with closed reduction of the femoral head followed by immobilization in bed without traction for 10 days. B: Radiograph after 1 day. The femoral head has been reduced. The posterior fragment is still dislocated. C-D: Radiographs at follow-up 11 years and 3 months after injury. AP-view (C) and oblique projection (D). The fragment has healed in a dislocated position. No degenerative changes. Clinical result: excellent. Mobility: 6 points.



B



C



D



A



B



C



D

Fig. 31. 43-year-old male. Fall on the same level. **A:** Radiograph at time of injury. Posterior fracture-dislocation Type III. Surgical treatment with open reduction of the large posterior fragment and fixation with a screw, followed by immobilization in bed for 4 weeks without traction. **B:** Radiograph 1 day postoperatively. The large posterior fragment has been reduced and fixed with a screw. **C–D:** Radiographs 7 years and 2 months after injury. AP-view (**C**). Lateral view standing position (**D**). Ectopic ossification. Osteoarthrosis Grade 1. Clinical result: excellent. Mobility: 6 points.



A



B

C



Fig. 32. 47-year-old male. Traffic accident. Car driver. A: Radiograph at time of injury. Posterior acetabular fracture Type III. Two large posterior fragments dislocated proximally, posteriorly and laterally. The femoral head is not dislocated. Conservative treatment with immobilization in bed without traction for 7 weeks. B–C: Radiographs at follow-up 2 years after injury. AP-view (B) and oblique projection (C). The fragments have healed in unchanged positions. Osteoarthritis Grade I. Clinical result: good. Mobility: 5 points.

Chapter 5

DISCUSSION

Since the earliest description of acetabular fractures with intrapelvic penetration of the femoral head by Callisen 1778 (Schroeder 1909) there has been many reports dealing with these fractures. This injury was uncommon before the onset of serious automobile accidents. During the first 50 years of the 20th century trauma to the hip became more frequent due to the intensified motor traffic. The hip lesion encountered in surgical practice exhibited new features typical of motor-car injuries, the damage as a rule being caused by stronger forces than before. The most common traumatic mechanism producing *central* acetabular fractures is a blow to the trochanteric region and the injury is mostly sustained in connection with traffic accidents, being frequently found among pedestrians. In this material the cause of injury was traffic accident in 45 patients. Twenty-nine of these were pedestrians hit by a car. *Posterior* fractures are often the result of motor-car accidents. The fracture and fracture-dislocation are frequently caused by a blow applied along the long axis of the femur. The mechanism was so often an accompaniment of motor car accidents where the patient's knee struck against the dash-board that the dislocations and fracture-dislocations were given the name of dash-board dislocations (Funsten et al. 1938) and dash-board fractures (Waller 1955). In the present material 29 of 39 posterior acetabular fractures were caused by motor-car accidents, the patient being either driver or passenger in the car.

It is not until the last 20 years that larger series dealing with acetabular fractures have been published, making it possible to evaluate the results of different forms of treatment.

However, fractures of the acetabulum are relatively rare and furthermore individual variations between fractures occur, making it difficult to arrive at a simple classification or to outline the management of these patients. This absence of a uniform method of classification makes comparisons between materials almost impossible. Methods of evaluating results vary greatly, and the radiologic criterias used when evaluating the joint following trauma are not uniform.

Regarding the classification of *central* acetabular fractures some authors classify their fractures depending on the degree of central dislocation of the femoral head (Stewart & Milford 1954, Böhler 1954, Pearson & Hargadon 1962, Eichenholtz & Stark 1964, Lehtonen 1968). Others have found it more important to take account of the fracture lines and which part of the acetabulum that becomes involved (Knight & Smith 1958, Rowe & Lowell 1961, Judet, Judet & Letournel 1964).

Judet, Judet & Letournel (1964) have presented a classification based on radiologic examinations including besides AP view also external and internal oblique views in order to determine the anatomy of these fractures as exactly as possible. Since the therapeutic approach of these authors is strictly surgical, the aim of their classification and radiologic methods has merely been to study the fracture lines in each case to guide them in open reduction. Our approach to the treatment of these fractures has mainly been conservative, and in the present study most cases have not been radiologically examined with oblique projections.

We have chosen a classification similar to that of Stewart & Milford (1954), based on the degree of central dislocation of the femoral head and the involvement of the weight-bearing area, i.e. whether the superior dome was fractured or not.

Different classifications have also been presented for *posterior* acetabular fractures. Many authors include in their series of posterior fracture-dislocations, simple posterior dislocations of the femoral head and posterior dislocations of the femoral head in combination with fractures of the femoral head or the acetabular floor. Posterior fracture-dislocations are divided in groups depending on the size and number of posterior fragment(s), the stability of the joint and if in combination with the posterior dislocation a fracture of the femoral head, or the acetabular floor is present (Thompson & Epstein 1951, Stewart & Milford 1954).

In this material we have not included simple posterior dislocations of the femoral head or posterior dislocations of the femoral head combined with fractures of the femoral neck, but limited the investigation to posterior acetabular fractures with or without posterior dislocation of the femoral head. We have therefore chosen the classification which was presented by Waller in 1955.

Since the cause of injury, the classification, the therapeutic approach and the late results differ between central and posterior acetabular fractures we have in this study chosen to describe these two main groups separately.

Central acetabular fractures

There is great confusion in the literature about the treatment of central fracture-dislocations. There is a better agreement as regards the treatment of central acetabular fractures without central dislocation of the femoral head. This investigation has included central acetabular fractures without central dislocation of the femoral head as well as central fractures with central intrapelvic protrusion of the femoral head.

In order to minimize the examiner's subjective opinion, a point system suggested by d'Aubigné & Postel 1954, later modified by Charnley in 1972, was followed at the assessment of results. A summary of the points for pain and walking has been made to facilitate a comparison with other reported results and between clinical results and radiologic appearance.

Central fractures without central dislocation of the femoral head usually offer no problems. These fractures are generally treated by conservative methods. Some recommend bed rest only (Rowe & Lowell 1961, Judet, Judet & Letournel 1964, Solheim & Skrede 1973) and others a short period of traction (Wechselberger 1956, Pearson & Hargadon 1962, Eichenholtz & Stark 1964). Excellent or good results in 90 to 100 per cent are reported by Rowe & Lowell and Eichenholtz & Stark.

This investigation included 30 patients, all treated conservatively. Twenty-eight were immobilized in bed only and 2 were put into traction. Time for immobilization was 2 weeks. Twenty-seven of 30, i.e. 90 per cent, had excellent or good result, which is well comparable with other reported results. The results for patients with displacement of the acetabular fragment were even better than for those without displacement. All patients with fair or poor result had undisplaced fractures. Only 3 of 29 patients radiologically examined showed signs of osteoarthritis and 2 of these had in addition a necrosis of the femoral head.

It seems that acetabular fractures without central dislocation of the femoral head with or without displacement of the acetabular fragment can best be treated by a short period of immobilization in bed.

While there is general agreement in the treatment of undisplaced central acetabular fractures there is a diversity of opinion on the treatment of *central acetabular fractures with central dislocation of the femoral head*. The surgical treatment of these fractures is difficult (Böhler 1966, Allgöwer 1966) and there are many who advocate a rather strict conservative line of treatment (Eichenholtz & Stark 1964, Nicoll 1966, Böhler 1966, Tipton et al. 1975, Jahna 1976). Others advocate surgical treatment. Armstrong (1948) recommended early arthrodesis, Westerborn (1954) cup arthroplasty and others osteosynthesis with plate and screws (Judet, Judet & Letournel 1964, Letournel 1966, Paleari & Gualtieri 1971). Even primary total hip replacement has been mentioned in the treatment of these fractures (Coventry 1974). Furthermore, some surgeons point out that all central fracture-dislocations should and can best be treated by conservative methods, i.e. longitudinal and lateral traction and perhaps reduction under general anesthesia, and recommend open reduction and osteosynthesis only in fractures engaging the superior dome where closed treatment has failed in reducing both the femoral head and the acetabular roof accurately (Rowe & Lowell 1961, Göthlin & Hindmarsh 1970, Carnsale et al. 1975).

There is, however, a general consensus of opinion that the ultimate aim should be as perfect a restoration of the acetabulum-femoral head relationship as possible (Göthlin & Hindmarsh 1970, Carnsale et al. 1975, Tipton et al. 1975). However, this is a task sometimes difficult to carry out and incongruity between the articulating surfaces becomes accepted as this in many cases does not result in impaired function (Rowe & Lowell 1961, Nicoll 1966, Austin 1971, Tipton et al. 1975).

This follow-up included 36 patients with central acetabular fractures with varying degree of central dislocation of the femoral head. Thirty-one patients were treated conservatively and 5 surgically. As regards the conservative treatment no strict line of treatment was observed, some patients being immobilized in bed only and some being put into traction, which in most cases was applied through the tibial tuberosity. The superior dome was intact in 15 of the 31 patients conservatively treated and 13 of them, i.e. 87 per cent had excellent or good clinical result. No significant difference in clinical results could be observed between those 6 patients who had a good reduction of the femoral head and those 9 who had a less satisfactory reduction. In 11 of these 15 patients the dislocation of the femoral head was moderate, and in 4 it was severe. It is noticeable that those 2 patients who had a severe central dislo-

cation and a less satisfactory reduction of the femoral head both had excellent results. Thirteen of the 15 patients were radiologically examined and 7 of them had osteoarthritis (54 per cent) (2 of the 6 patients with good reduction of the femoral head and 5 of the 7 patients with less satisfactory reduction of the femoral head). Our results are in accordance with the results of Rowe & Lowell (1961), Göthlin & Hindmarsh (1970) and Nerubay et al. (1973) who found 70 to 90 per cent excellent or good results in innerwall fractures treated conservatively. It seems that these fractures can be adequately treated with conservative methods, i.e. longitudinal and lateral traction for 6-8 weeks. If traction fails in reducing the femoral head an attempt during general anesthesia should be performed. It seems that anatomical reduction of the acetabular fragments is of less importance in these fractures. The important thing is to reduce the femoral head under the acetabular roof and keep it there. Like Rowe & Lowell, Eichenholtz & Stark and Austin we found that traction usually had little effect in reducing the acetabular fragments but yet it seemed that nature had filled in the gap between the femoral head and the acetabular fragments, so that a smooth congruent socket had developed.

Sixteen patients of the 31 with central fracture-dislocations treated conservatively had the superior dome fractured. Late results were not so good in this group, and only 38 per cent had excellent or good clinical results. Good reduction of the femoral head (8 patients) gave better results than less satisfactory reduction (8 patients). Worst results were seen in the 9 patients who had a severe central dislocation of the femoral head. Fourteen patients were radiologically examined and 9 of them, i.e. 64 per cent had osteoarthritis (4 of the 8 patients with good reduction and 5 of the 6 patients with less satisfactory reduction). The present results are similar to those of Rowe & Lowell who found 36 per cent excellent or good results in superior dome fractures.

Only 5 patients were treated surgically, all had central fractures with severe central dislocation of the femoral head with the fracture engaging the superior dome. Only one patient achieved a good clinical result. In only 2 patients the femoral head was reduced.

Analysis of the results in the present series show similarities to other reported results. Fractures of the inner wall both with moderate and severe central dislocation of the femoral head gave excellent or good clinical results in the majority of cases with conservative treatment.

Central fracture-dislocations with fractures of the acetabular roof in which the femoral head and the superior dome are satisfactorily reduced by traction or manipulation can be adequately treated by conservative methods. When, however, closed treatment has failed in reducing the femoral head and the acetabular roof accurately, primary open reduction appears to be a rational approach to the problem. It is in line with the modern principles of management of intraarticular fractures, especially in weightbearing joints, because it is aimed at restoring congruity of the weightbearing articular surfaces. However, it is a major undertaking, the technique is difficult and demands considerable surgical experience, and not all patients requiring treatment will be found to be suitable for it. Major associated head and chest injuries, severe chock, severe comminution of the fracture, and advanced age may all contraindicate this form of treatment. Apart from these limitations on the use of open reduction as a standard method of treatment there are other points that should not be forgotten.

It is never possible to make an accurate assessment of the damage of the articular cartilage possibly caused by the injury. Because such damage may be a major contributory factor in determining the development of later osteoarthritis or femoral head necrosis, simple restoration of the anatomy of the acetabulum may not be adequate. Furtheron Porter (1973) and Batra (1976) have stated that for technical reasons accurate reduction at operation is not always possible and therefore joint congruity may not be achieved in a proportion of patients. Letourne! (1966) in his series of 170 operated patients (including 42 posterior fractures) described perfect reduction of the acetabular fragments in 62 per cent and perfect reduction of the femoral head in 85 per cent.

It is difficult to state categorically the indications for open reduction and each case must be considered on its own merits. However, we agree with Carnsale et al. (1975) and Batra (1976) that in relatively young patients who have displaced fractures with involvement of the roof, without undue comminution, this line of treatment may be considered desirable in the hope of reducing displacement and preventing deformity and such premature degeneration in the hip joint as may result solely from uncorrected deformity.

Posterior fractures

While there is confusion about the treatment of central fracture-dislocations, there seems to be greater unity regarding the treatment of posterior fracture-dislocations. The posterior part of the acetabulum has not a weightbearing function but has merely a stabilizing effect on the joint. Most authors agree that a posterior dislocation of the femoral head should be regarded as an emergency and the dislocation should be reduced acute (Stewart & Milford 1954, Waller 1955, Brav 1962, Epstein 1974, Ender 1976). Posterior acetabular fractures without posterior dislocation of the femoral head and without displacement of the acetabular fragment(s) are generally treated by conservative methods, i.e. immobilization in bed or traction for a few weeks (Waller 1955, Nicoll 1966). In posterior fracture-dislocations the important thing is that the dislocated femoral head is reduced to its normal position and is kept there. There is an absolute indication for operation when the femoral head cannot be brought to its normal position by conservative methods, i.e. manipulation during general anesthesia or when there is an involvement of the sciatic nerve (Waller 1955, Rowe & Lowell 1961, Brav 1962, Nicoll 1966, Epstein 1974, Ender 1976). Most authors agree that instability of the joint after reduction of the femoral head requires surgical exploration and osteosynthesis of the acetabular fragment (Rowe & Lowell 1961, Brav 1962, Stewart et al. 1975, Ender 1976). The instability is demonstrated at the time of reducing the dislocation (Nicoll 1966, Ender 1976). If the joint is regarded as stable after reduction of the femoral head, but a posterior fragment remains displaced, some advocate surgical treatment (Waller 1955, Epstein 1974, Ender 1976) and others conservative treatment (Böhler 1954, Brav 1962, Nicoll 1966).

In this material 3 patients had posterior fractures with a small to moderate undisplaced fragment. All were treated conservatively with immobilization in bed for 1-2 weeks and all had excellent clinical results. It appears that these fractures can best be treated by immobilization in bed for 1-2 weeks.

Thirty-two patients had posterior fractures classified as Type II or III; 14 were treated conservatively, 18 surgically. Our indications for surgery have been:

1. Remaining displacement of the acetabular fragment(s). (Reports from the patient records regarding stability or instability have not been obtained.) Most of the patients were operated upon within 1 week.
2. Redislocation of the femoral head.
3. Unsuccessful closed reduction.
4. Sciatic nerve involvement.

Postoperatively some were put into traction and others were immobilized in bed only. Time for immobilization was 4-6 weeks. The conservative treatment has included closed reduction of the femoral head under general anesthesia and immobilization in bed with or without traction for 3-5 weeks. Of the patients treated conservatively, 79 per cent had excellent or good clinical results and of the patients treated surgically, 67 per cent had excellent or good results. (Type II treated conservatively: 100 per cent excellent or good; Type II treated surgically: 70 per cent excellent or good; Type III treated conservatively: 67 per cent excellent or good; Type III treated surgically: 63 per cent excellent or good.)

In 8 patients the posterior acetabular fragment remained displaced after reduction of the femoral head. The clinical results were as good for these patients as for the others treated conservatively. Thirty-two patients with posterior fracture-dislocations of Type II or III were included in the radiologic follow-up study. Osteoarthritis and femoral head necrosis were more frequently seen in the patients who had been operated upon (Tables 30 and 31).

The clinical results in this series are in accordance with other reports. The results for patients treated conservatively are similar to those of Brav (1962), Nerubay et al. (1973) and Stewart et al. (1975) who found 60 to 80 per cent excellent or good long term results after conservative treatment of these fractures. The results for patients treated surgically are similar to those of Waller (1955), Rowe & Lowell (1961), Brav (1962), Solheim & Skrede (1973) and Stewart et al. (1975) who found 60 to 75 per cent excellent or good long term results after surgical treatment.

Most important in posterior fracture-dislocations seems to be the reduction of the femoral head and the stability of the joint. If these demands can be fulfilled and there is no sciatic nerve palsy the prognosis for these fractures seems to be independent of whether they are treated conservatively or surgically. The bad results obtained both after conservative and surgical treatment often depend on the above demands not having been fulfilled. For example:

1. The posterior dislocation has been missed and the femoral head has not been reduced until after 24 hours. In some cases there has been no reduction at all.
2. Repeated unsuccessful attempts with closed reduction have been made.
3. Redislocation of the femoral head has occurred due to instability.

Waller (1955) had only 21 per cent excellent or good results in his patients with Type II- and III-fractures who had been treated conservatively.

Epstein (1974) had even less good results for patients treated conservatively, namely 14 per cent, whereas he had 44 per cent good results for patients treated by closed reduction of the femoral head followed by open reduction and osteosynthesis of the acetabular fragment. In his material 50 per cent of the patients treated conservatively had unfavourable features of the kind mentioned above. However, Nicoll (1966) points out that excellent results should be attainable in all posterior fracture-dislocations and only 1/3 will require operation either to restore stability or to remove obstructing fragments. Stewart et al. (1975) reported on 57 patients with conservatively treated posterior acetabular fractures (Type II - III) and 39 (68 per cent) had excellent or good results. In 44 patients the posterior dislocation was reduced within 12 hours and this group of patients included all those who had excellent or good results. In the present series 8 patients had poor results and 5 of these had unfavourable features, i.e. redislocation of the femoral head, unreduced dislocation or combination with a central fracture.

Osteoarthritis and femoral head necrosis are sequelae which as a rule result in impaired function and it cannot be excluded that the fate of the fracture is decided at the time of injury. Most authors agree that the cause of avascular necrosis is a disturbed circulation due to injury to the ligament of the femoral head and to the joint capsule in fracture-dislocations (Waller 1955, Elliott 1956, Stewart et al. 1975). When the head of the femur becomes dislocated out of the joint cavity the ligamentum teres always ruptures totally which was proved experimentally by Waller (1955). Even if only some of the vessels in the posterior part of the capsule are divided when the femoral head dislocates the circulation in the tightly stretched out capsule is endangered as surviving vessels tend to become compressed and thrombotic. Early reduction of the dislocation is of the greatest importance for these reasons (Waller 1955, Elliott 1956). However, necrosis of the femoral head and arthrotic changes sometimes develop after trauma in which the hip has not been dislocated – indeed it may even develop without any known injury. Consequently it is possible that avascular necrosis after fracture dislocation of the hip is not always caused by destruction of the circulation through the ligamentum teres and the posterior part of the capsule. Stewart & Milford (1954) suggested that the force of the injury may be important in determining whether avascular necrosis develops. In this type of injury it is reasonable to believe that both the head of the femur and the acetabulum itself sustain damage. Radiologically and clinically the head of the femur does not usually show damage unless a piece of bone has been fractured off the head which occurs rarely (Elliott 1956). However, a force resulting in an impact to the femoral head may perhaps cause intracellular molecular changes resulting in necrosis of bone as suggested by Stewart & Milford (1954).

CONCLUSION

It is difficult to state categorically the line of treatment for these fractures. Age and associated injuries have to be considered when deciding about treatment. However, the following general conclusions can be made based on this study and on the study of the literature.

Central acetabular fractures

1. For a detailed analysis of these fractures the radiologic examination should include besides AP views even oblique views.
2. Central acetabular fractures without central dislocation of the femoral head can be adequately treated by a short period of immobilization in bed.
3. Central acetabular fractures with central dislocation of the femoral head, but without fracture of the superior dome can be treated conservatively with traction through the tibial tuberosity, possibly in combination with lateral traction applied through the proximal femur. If traction fails in reducing the femoral head under the intact acetabular roof an attempt during general anesthesia should be made. The traction is continued for 6-8 weeks.
4. In central acetabular fractures with central dislocation of the femoral head and fracture of the superior dome an attempt at conservative treatment with traction should be made. General anesthesia may be required for reduction. If conservative treatment fails in reducing the femoral head and the acetabular roof accurately, open reduction and osteosynthesis can be considered especially in young patients without undue comminution of the fracture.

Posterior acetabular fractures

1. A posterior dislocation of the femoral head should be treated as an emergency and acute reduction should be performed.
2. After reduction the radiologic examination should include AP, lateral and oblique projections.
3. When closed reduction fails in reducing the femoral head open reduction of the femoral head and osteosynthesis of the acetabular fragment should be made.
4. If instability can be demonstrated at the time of closed reduction of the femoral head the acetabular fragment should be fixed.

5. If the joint is regarded as stable after closed reduction of the femoral head but a moderate to large fragment is still dislocated and there are signs of sciatic nerve involvement, open reduction and osteosynthesis should be performed. If, however, there is no sign of nerve injury the prognosis is probably not determined of whether these fractures are operated or not.
6. If the femoral head has not been dislocated posteriorly and the fragment remains in its place, conservative treatment with immobilization in bed for a short period is adequate.

PART TWO
AN EXPERIMENTAL STUDY

by
Olle Lansinger and Bertil Romanus

INTRODUCTION

The knowledge of the fracture mechanism of central acetabular fractures is mainly based on clinical observations.

Some experimental studies have been made on cadavers, violent forces being directed to the trochanteric region by hammers, falling weights or a pendulum. The position of the femoral neck in relation to the acetabulum has not been registered. Analysis of this position and its possible importance in the production of varying types of acetabular fractures has thus not been possible.

The purpose of this investigation has been to design an experimental model by which central acetabular fractures can be produced on cadaver pelvis and to determine the conditions (energy and position of the hip joint) under which various types of central acetabular fractures can be produced (fractures of the posterior column, transverse fractures and fractures of the anterior column).

Fracture mechanism

Theories based on clinical materials

Central acetabular fractures are believed to result from a direct blow to the trochanteric region as occurs e.g. when pedestrians become knocked down by a car or in falls from heights.

The fracture mechanism has been analysed by Cauchoix & Truchet (1951), Wollmar & Wachtler (1956), Judet et al. (1964) and Judet & Letournel (1974).

Cauchoix & Truchet (1951) suggested that depending on the degree of rotation of the femur with this in extension fractures arise either anteriorly or posteriorly in the acetabulum when a force is directed to the greater trochanter. Excluding the view on the importance of the rotation of the femur Wollmar & Wachtler (1956) pointed to the importance of the force being transmitted via the femoral neck and the importance of the femoral head being well centered in the acetabulum.

Judet et al. (1964) and Judet & Letournel (1974) described the theoretical background for posterior rim fractures, fractures of the posterior and anterior column, and transverse fractures. With a force directed to the trochanteric region of the extended hip transverse and posterior fractures were calculated to arise when the femoral neck was internally rotated 50° ; transverse fractures when it was internally rotated $0 - 50^\circ$; fractures of the anterior column when it was externally rotated $0 - 25^\circ$ and fractures of the anterior lip when it was externally rotated 50° . With the hip joint flexed 90° and with the force acting along the femur, fractures would arise in the posterior rim, posterior lip or the posterior column, or transverse fractures would arise depending on the degree of abduction and adduction.

Previous experimental studies on acetabular fractures

Central acetabular fractures have been produced by Virveaux (1899), Thévenot (1904), Schroeder (1909), Cottalorda (1922), Romani (1928), Cauchoix & Truchet (1951), Creyssel & Schnepf (1961) and Pearson & Hargadon (1962) (Table 35).

Table 35. Earlier experimental works on central acetabular fractures

Author	Reported experiments	Reported acetabular fractures	Fractures of the femoral neck or shaft
Virveaux - 1899	17	4	4
Schroeder - 1909	14	4	8
Cottalorda - 1922	7	4	
Romani - 1928	22	1	11
Creyssel & Schnepf - 1961	12	5	
Pearson & Hargadon - 1962	11	11	

Cauchoix & Truchet (1951) stated that it was necessary with a violent force and a solid femoral neck to produce experimental acetabular fractures. They suggested that different degrees of rotation of the femur resulted in different types of fractures when blows were directed to the trochanteric region.

A blow has been directed to the trochanteric region of whole cadavers with a hammer or a wooden club (Virveaux 1899, Schroeder 1909, Cottalorda 1922, Romani 1928), with a falling weight (Creysse & Schnepf 1961), or with a pendulum (Pearson & Hargadon 1962). Attempts have not been made to produce these fractures by blows in the direction of the femoral neck axis. The exact point for the hit has not been registered and the position of the hip joint at the moment of the blow and the importance of this position for the production of various fracture types have not been analysed.

Posterior acetabular fractures have been produced on cadavers by Waller (1955). In 160 experiments he produced 108 posterior "dashboard" fractures by a falling weight (60 kg from 2 meters) against the knee with the hip and the knee in flexion. He described the conditions under which these fractures could be produced.

Table 36. Pelvic specimens (*F* = female, *M* = male).

Specimen	Experiment	Age and sex	Height cm	Weight kg	Cause of death
1	1	59 F	—	—	Circulatory insuff.
2	2	56 F	—	—	Liver insuff.
3	3	49 M	183	72	Circulatory insuff.
4	4 + 5	66 F	165	53	Circulatory insuff.
5	6 + 7	61 F	162	49	Circulatory insuff.
6	8	78 F	166	42	Circulatory insuff.
7	9 + 10	—	—	—	—
8	11 + 12	—	—	—	—
9	13 + 14	—	—	—	—
10	15 + 16	76 F	158	49	Circulatory insuff.
11	17 + 18	—	—	—	—
12	19 + 20	—	—	—	—
13	21 + 22	—	—	—	—
14	23 + 24	—	—	—	—
15	25 + 26	27 M	184	73	Chron. glomerulonephritis
16	27 + 28	85 M	—	—	Circulatory insuff.
17	29 + 30	77 M	194	97	Cancer of the colon
18	31 + 32	57 M	175	64	Circulatory insuff.
19	33 + 34	60 M	—	—	Cancer of the lung
20	35 + 36	72 M	179	83	Circulatory insuff.
21	37 + 38	59 F	160	50	Cancer of the lung
22	39 + 40	79 F	154	47	Circulatory insuff.
23	41 + 42	60 F	—	—	Circulatory insuff.
24	43 + 44	74 M	—	—	Circulatory insuff.

— / Information missing

Material

Twenty-four cadaver pelves were used (Table 36). They consisted of the pelvic ring with the fifth lumbar vertebra and the proximal 15 – 20 centimeters of both femora. The specimens were roughly cleaned from soft tissues except for the ligaments which were left intact. The cadaver pelves were all from individuals who had died from non-skeletal diseases, mainly cardiovascular. There was osteoarthritis in two hips, one of which had been operated with an osteotomy. The remaining pelves were all radiographically normal. The known age distribution of the individuals was 27 – 85 years. It was not possible in all to establish the exact duration of premortal bed-rest or the height and weight from the medical records.

The specimens were either used on the day of preparation or stored in a deep-freeze (-20°C) and thawed at room temperature 12 – 24 hours prior to the experiment.

Method

The specimens were divided into two parts in a sagittal plane through the middle of the vertebra L 5, the sacrum and the coccyx. Anteriorly the division was carried through the symphysis. The resected surfaces were fixed in a metal box (31 x 18 x 4 centimeters) with epoxy resin (Plastic Padding[®]). The metal box was screwed onto a stand which was adjustable (Figs. 33 and 34).

One object of these experiments has been to transmit the force of the pendulum along the femoral neck axis. Another has been to define the degrees of rotation, abduction and adduction of the femur for each individual test. To achieve this, adjustments of the position of the specimen had to be done and the exactness was determined by radiologic examination of the specimen set-up in 2 perpendicular planes prior to each experiment.

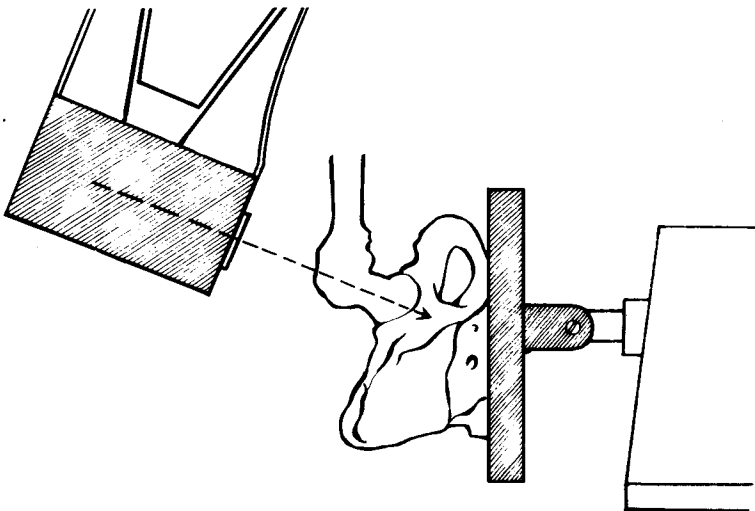


Fig. 33. Experimental set-up in experiments with the femur in extension (left hip).

Energy

The greater trochanter was subjected to a blow by a pendulum with its centre in the ceiling and with a radius of 225 centimeters and a weight of 35 kilos. The fall varied from 45 – 140 centimeters corresponding to an energy of 155 – 480 Nm.

A total of 44 experiments was performed, the first 32 with the femur in extension and the last 12 with the femur in 60 – 90° flexion. With extension we mean that the femoral shaft is parallel to a plane through the anterior superior iliac spine and the pubic crest (Boyd et al. 1958).

Definitions

Measurements of the position of the femur, the striking point of the pendulum and the direction of its force were done on radiographs; 3 perpendicular planes were used: sagittal, frontal, and transverse. The metal box acted as a sagittal plane.

The femoral neck axis: The centre of the femoral head has been determined by concentric circles. A line has been drawn from the centre of the femoral head to the midpoint of the border between the femoral head and neck. This line has been called the femoral neck axis (Figs. 35 and 36).

The longitudinal axis of the femur: This has been determined on radiographs by drawing a line through the centre of the femoral shaft.

Radiologic determination of the position of femur

The angle of anteversion of the femoral neck is estimated at between 12 – 14° (Rydell 1966). The individual variation is great (–13 to 55°) (Backman 1957). To determine the angle of anteversion it is necessary to have the complete femur. For this study, however, the degree of rotation of the femoral neck has been determined by the degree the femoral neck axis

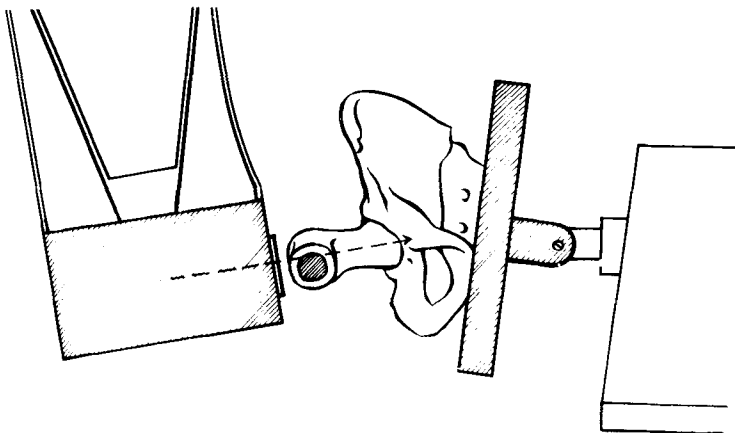


Fig. 34. Experimental set-up in experiments with the femur in flexion (right hip).

formed in relation to the frontal plane (in experiments with the femur in extension) and to the transverse plane (with the femur in 90° flexion).

The position of the femur has been defined in the following projections:

Experiments with the femur in extension

In the *vertical view* of the specimen (Fig. 35) the angle between the axis of the femoral neck and a frontal plane was determined:

+: indicates that the femoral neck axis forms an angle posterior to the frontal plane, "external rotation" (Fig. 35 A).

-: indicates that the femoral neck axis forms an angle anterior to the frontal plane, "internal rotation" (Fig. 35 B).

In the *AP (anteroposterior) view* of the specimen the degree of abduction and adduction in relation to the sagittal plane was determined (Fig. 33).

Experiments with the femur in flexion

In the *AP view* of the specimen (Fig. 34) the angle between the femoral neck axis and a transverse plane was determined (Fig. 36):

+: indicates that the femoral neck axis forms an angle inferior to the transverse plane, "ex-

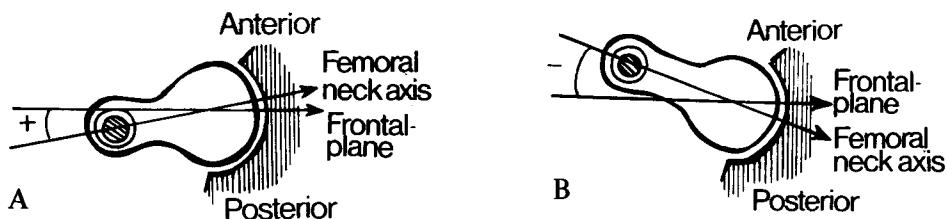


Fig. 35. Vertical view of the right hip with the femur in extension (perpendicular to the paper plane). A: + indicates that the femoral neck axis forms an angle posterior to the frontal plane ("external rotation"). B: - indicates that the femoral neck axis forms an angle anterior to the frontal plane ("internal rotation").

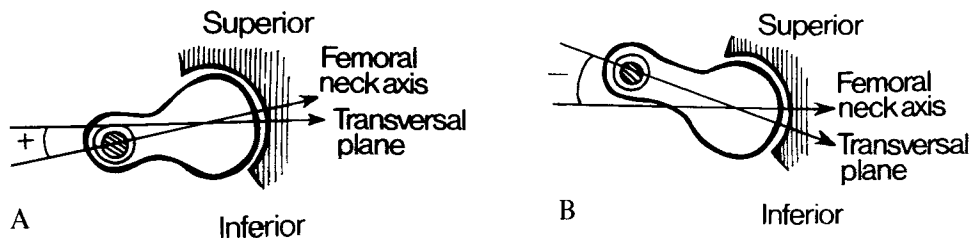


Fig. 36. AP-view of right hip with the femur in 90° flexion (perpendicular to the paper plane). A: + indicates that the femoral neck axis forms an angle inferior to the transverse plane ("external rotation"). B: - indicates that the femoral neck axis forms an angle superior to the transverse plane ("internal rotation").

ternal rotation" (Fig. 36 A).

—: indicates that the femoral neck axis forms an angle superior to the transverse plane, "internal rotation" (Fig. 36 B).

In the *vertical view* of the specimen the degree of abduction and adduction in relation to the sagittal plane was determined.

Position of the femur (Tables 37, 38 and 40)

In 32 experiments the femur was positioned in extension; the degree of combined external or internal rotation was varied. In 12 experiments the femur was positioned in flexion; the degree of combined abduction or adduction was varied. In 7 of these experiments the degree of flexion was $85 - 90^\circ$ and in 5 $60 - 75^\circ$.

Preliminary study

Based on the reports of previous experimental work and on the theories of the fracture mechanism in central acetabular fractures a preliminary study of 12 experiments was carried out (experiments 1 – 12) (Table 37).

Set-up of specimen: The pelvic specimen was placed on the stand upside down with the hip joint extended (Fig. 33). In the first 8 experiments the pendulum hit the greater trochanter at the lowest point of the pendulum course. In the following 4 experiments the blow was directed to the trochanter before the lowest point of the pendulum course as it in this way was easier to obtain the force along the femoral neck axis. The energy, the direction of force and the position of the hip joint varied (Table 37).

Results of the preliminary study (Table 37)

In experiments 1, 3, 6, and 7 the blow hit the trochanter with the force directed inferior to the femoral neck axis resulting in a valgus effect. This resulted in pertrochanteric fractures in experiments 1, 6, and 7. In experiments 6 and 7 transverse acetabular fractures were also achieved and in experiment 3, a posterior column fracture was obtained. In experiment 4 the blow hit the trochanter with the force posterior to the femoral neck axis and a femoral neck fracture and an anterior column fracture were produced. In experiments 5, 8, and 9 the force was transmitted ideally as checked in the AP and vertical projections: in experiment 5 a T-fracture was produced, in experiment 8 a transverse fracture and in experiment 9 a posterior column fracture. In specimen 6 (experiment 8) an intertrochanteric osteotomy according to Wainwright had been carried out. In this case there was a coxa vara which facilitated the blow in the direction of the femoral neck axis. In this experiment an axial compression fracture of the femoral neck was also produced.

In experiment 9 an attempt was made to stabilize the hip joint by a Kirschner wire passed along the femoral neck axis into the acetabulum. After the pendulum hit it was noted that an abduction of 35° had occurred as indicated by bending of the wire. In experiments 10, 11, and 12 we tried to stabilize the hip joint by not thawing the specimens completely. The force was in these experiments transmitted ideally along the femoral neck axis. A pertrochanteric

Table 37. Experimental acetabular fractures – hip in extension. Preliminary study.

Ex-periment	Energy (Nm)	Position of femur		Result		Remarks
		Abduction (Abd) or adduction (Add) degrees	Rotation degrees	Acetabular fracture	Femoral neck or pertrochanteric fracture	
1	155	–	–	–	Pertrochanteric	
2	258	–	–	Vertical fracture-line anteriorly	–	
3	430	–	–	Posterior column	–	
4	430	Abd 4	+ 10	Anterior column	Femoral neck	
5	430	Add 4	+ 17	T-fracture	–	
6	430	Abd 5	– 10	Transverse	Pertrochanteric	
7	430	Add 10	– 10	Transverse	Pertrochanteric	
8	430	Add 6	+ 15	Transverse	Femoral neck	osteoarthrosis
9	430	Add 10	+ 8	Posterior column	–	
10	310	Add 18	+ 16	–	–	not fully thawed
11	310	Add 10	+ 9	–	Pertrochanteric	not fully thawed
12	310	Add 20	+ 4	Vertical fracture-line posteriorly	–	not fully thawed

compression fracture was produced in one experiment (11) and a vertical fracture-line posteriorly in the acetabulum in another (12). There were no other fractures in the acetabulum or pelvis probably owing to a change of the physical properties (e.g. stiffness of the soft tissues).

Nine fractures were produced in 12 experiments in this preliminary study. Three were transverse fractures with only a fracture-line through the middle of the acetabulum. One was a T-fracture through the anterior and posterior columns. Two were anterior fractures, one of which was a fracture of the anterior column and the other only a vertical fracture-line anteriorly. Three were fractures posteriorly, in 2 of which the posterior column was fractured. In one there was only a fracture-line posteriorly. The femoral head was not dislocated centrally in any experiment.

Conclusion of the preliminary study

This preliminary study gave the conditions necessary for the best position of the specimen to produce an acetabular fracture with the pendulum hitting the trochanter with the hip joint in extension. It was found necessary to strike the femoral neck in an axial direction to avoid pertrochanteric and femoral neck fractures. The femur had in these 12 preliminary experiments been fixed with silk sutures in the soft tissues in experiments 1 – 8, been transfixed by a Kirschner wire in experiment 9 and been half thawed in experiments 10 – 12. To obtain a better centering of the femoral head and also a stabilization of the femur in the further experiments, strings were threaded through canals drilled in the femur and the iliac wing and through the obturator foramen in directions corresponding to normal muscles.

Experimental series

Experiments with the femur in extension

Special set-up was done according to the conclusions in the preliminary study. The pelvis was upside down and the femur extended. The femoral shaft was stabilized to the pelvis. The pendulum hit the trochanter before the lowest point of its course.

Results (Table 38)

The first 4 experiments (13 – 16) in this series were carried out with lower energy than previously, as in the preliminary study the best position of the specimen had been determined and it was thought that maximum force would be concentrated to the acetabulum without much being lost in the femoral neck or other tissues. In one experiment (13) a transverse fracture was produced through both columns. In the other 3 no fracture was obtained.

Table 38. Experimental acetabular fractures – Hip in extension.

Ex- peri- ment	Energy (Nm)	Position of femur		Result		Remarks
		Abduction (Abd) or Adduction (Add) degrees	Rotation degrees	Type of fracture	Femoral neck or peritrochanteric fracture	
13	325	± 0	- 4	Transverse	-	
14	258	Add 15	- 12 [☆]	-	-	
15	258	Abd 2	+ 35 ^{☆☆}	-	-	
16	258	Add 5	+ 15	-	-	
17	480	Add 18	+ 10	Transverse	-	
18	480	± 0	+ 38 ^{☆☆}	Anterior column	-	
19	480	Add 18	± 0	Transverse	-	
20	480	Add 18	- 10 [☆]	Transverse	-	
21	480	Add 14	+ 13	Transverse	-	
22	480	Add 10	+ 18	Vertical fracture- line posteriorly	-	osteoarthritis
23	480	Add 15	- 16 [☆]	Transverse	-	
24	480	Add 7	- 7 [☆]	Transverse	-	
25	480	Add 7	+ 28	Transverse	-	
26	480	Add 2	+ 12	Transverse	-	
27	480	± 0	- 2	Transverse	-	
28	480	± 0	+ 12	Transverse	-	
29	480	Add 7	- 8 [☆]	-	-	
30	480	± 0	- 6 [☆]	Anterior column	-	☆☆☆
31	480	Add 10	+ 18	-	-	☆☆☆
32	480	Add 10	- 4 [☆]	Anterior column	-	☆☆☆

☆ = Femur maximal internal rotated, ☆☆ = Femur maximal external rotated, ☆☆☆ = symphysis and sacrum independently fixed.

The energy was then increased to 480 Nm in experiments 17 – 29. In all of these the blow was ideal (with the force along the femoral neck) with the degree of rotation varying from maximal external to maximal internal. In 10 experiments transverse fractures were obtained, in one an anterior column fracture and in one a vertical fracture-line posteriorly. In one experiment (29) no fracture was produced despite ideal position. A possible explanation is that the pelvis was from a strong individual (Table 36) and the energy used was not enough to create a fracture. A summary of experiments 17 – 29 is given in Table 39 in which it is demonstrated that the degree of rotation has not influenced the localization of the fracture. The degree of adduction in these experiments varied between 0 – 18°.

Ten transverse fractures were produced in experiments 17 – 29. In 8 of these both columns were fractured with a displacement between the acetabular fragments of 1 – 1.5 centimeters. In 2 experiments there was only a horizontal fracture-line through the acetabulum. In one experiment there was an anterior column fracture and in one a vertical fracture-line posteriorly.

In experiments 1 – 29 a central dislocation of the femoral head occurred only once. This was interpreted as a result of both the symphysis and the sacrum being stably fixed in the epoxy resin without possibility of individual movement. In experiments 30 – 44 these structures were fixed separately offering the possibility to move in the sagittal plane. In 3 experiments (30 – 32) with unchanged energy and blow on the extended hip joint the degree of rotation was varied from maximal internal (–6°) to "external rotation" (+18°). Two anterior column fractures were produced without dislocation of the femoral head (30 and 32) and one extra-articular fracture through the ramus superior ossis pubis (31).

Comment. In the experiments with the femur in extension this was maximal internally rotated in 7. The measured angles between the femoral neck axis and the frontal plane varied between –4 to –16°. Three transverse fractures and 2 fractures of the anterior column were produced. In 2 experiments the femur was maximal externally rotated and this resulted in a fracture through the anterior column in one experiment.

A study was made to obtain an idea of the rotation in the hip joint with the femur in extension. Both hips in 3 complete pelvic specimens were radiologically examined with the femur in maximal external and internal rotation respectively. The combined external and internal rotation in the 6 hips varied between 20 – 40°. Maximal internal rotation varied from +15 to –15° and maximal external rotation from +20 to 44°.

Table 39. Position (rotation) of the femur in 13 experiments (17–29) and type of acetabular fracture.

Rotation/ degrees	Transverse	Anterior	Posterior	No fracture	Total
+ 38 → + 10	5	1	1	–	7
0 → – 16	5	–	–	1	6
Total	10	1	1	1	13

Experiments with the femur in flexion

On the extended hip joint no difficulties had been encountered in producing transverse or anterior fractures irrespective of the degree of rotation. To try to produce posterior column fractures experiments were carried out on flexed hip joint. In these the degree of abduction and adduction was varied. By adduction of the femur we wanted to concentrate the energy to the posterior column.

Table 40. Experimental acetabular fractures – Hip in flexion

Ex-periment	Energy (Nm)	Position of femur			Result		Remarks
		Abduction (Abd) or Adduction (Add) degrees	Rotation degrees	Flexion degrees	Type of fracture	Femoral neck or pertrochanteric fracture	
33	480	Abd 10	+ 16	90	–	–	Prelim. experim.
34	480	± 0	+ 13	85	–	–	Prelim. experim.
35	480	± 0	+ 10	90	Transverse	–	
36	480	Add 25	+ 40 ^{☆☆}	85	–	–	
37	480	Add 23	+ 20	90	–	–	
38	480	Abd 10	– 10	90	Transverse	–	
39	480	Abd 16	☆☆☆	60	T-fracture	–	
40	480	Add 40	☆☆☆	70	–	Pertrochanteric	
41	480	Abd 25	☆☆☆	70	Transverse	–	
42	480	Add 30	☆☆☆	75	–	–	
43	480	Abd 30	+ 10	85	Transverse	–	
44	480	Abd 28	☆☆☆	75	–	–	

☆ = Femur maximal internal rotated, ☆☆ = Femur maximal external rotated, ☆☆☆ = Measurements on radiographs were not possible depending on the degree of flexion. (The femur was put in neutral position in experiments 39, 40 and 44 and external rotated in experiments 41 and 42).

Results (Table 40)

After 2 preliminary experiments (33 and 34) ideal experimental conditions were obtained. With the hip joint flexed $60 - 90^\circ$ a blow could be directed with almost optimal force concentration along the femoral neck axis.

Ten experiments (35 - 44) were carried out. In 4 of these with the femur in $23 - 40^\circ$ adduction no acetabular fracture was produced. In one experiment with the femur in neutral position a transverse fracture was produced. In 5 experiments with abduction $10 - 30^\circ$ a transverse fracture was produced in 3 and a T-fracture in one (Table 41).

Of 5 fractures produced in this series 4 were transverse and one a T-fracture. The transverse fractures were all fractures through both the posterior and anterior columns. In 2, the femoral head was dislocated centrally 3 - 4 centimeters and in one of them the superior dome was fractured. In 2, the femoral head was not dislocated and in one of them the superior dome was fractured. In one experiment a T-fracture through both columns was produced. The femoral head was not dislocated and the superior dome was intact.

Table 41. Position (abduction - adduction) of the femur in 10 experiments (35 - 44) and type of acetabular fracture.

Position of femur					
Abduction/adduction degrees	Transverse	Anterior	Posterior	No fracture	Total
Adduction $23 - 40$	—	—	—	4	4
± 0	1	—	—	—	1
Abduction $10 - 30$	4 [☆]	—	—	1	5
	5			5	10

☆ = T-fracture in one experiment.



A

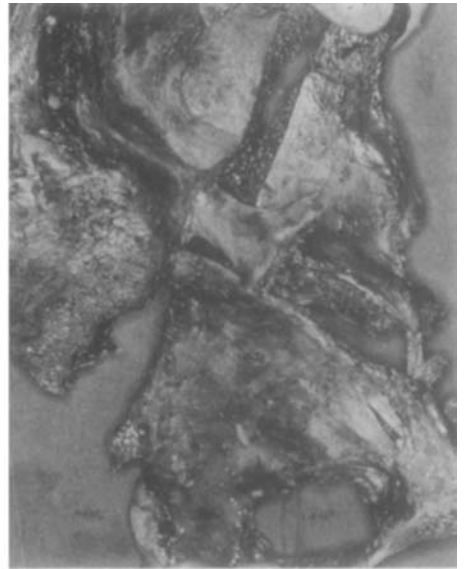


B

Fig. 37. Experiment 18. Fracture of the anterior column. A: External and B: Internal aspect of the specimen. Arrows indicate the fracture through the anterior column.



A



B

Fig. 38. Experiment 20. Transverse fractures have separated a fragment that includes part of the weight-bearing surface: the superior dome. A: External and B: Internal aspect of the specimen. Arrows indicate the loose fragment.



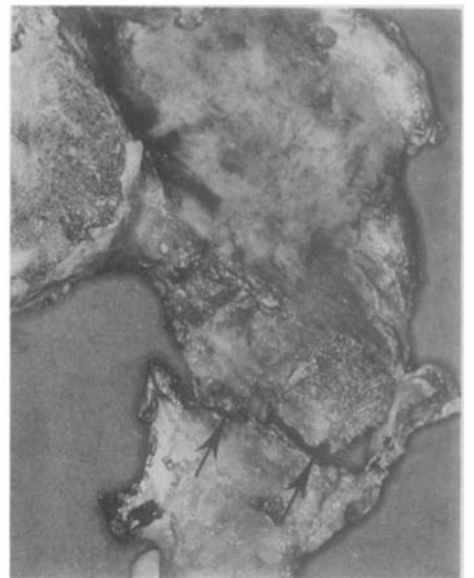
A



B



C



D

Fig. 39. Experiment 17. Transverse fracture. A: AP-view. B: Alar view which clearly demonstrates the fracture through the posterior column. C: External and D: Internal aspect of the specimen. Arrows indicate the fracture.



A



B



C

Fig. 40. Experiment 26. Transverse fracture. A: AP-view. B: Foramen obturator view and C: Alar view which demonstrate the fracture through the anterior and posterior columns. D: External and E: Internal aspect of the specimen. Arrows indicate the fracture.



D



E



A



B

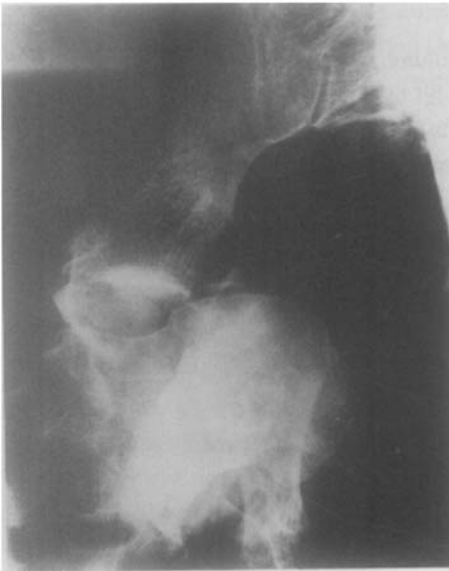


C



D

Fig. 41. Experiment 27. Transverse fracture through the middle of the acetabulum. A: AP-view. B: Alar view which demonstrates the fracture through the posterior column. C: External and D: Internal view of the specimen. Arrow points at the femoral head.



A



B



C



D

Fig. 42. Experiment 35. Transverse fracture with central dislocation of the femoral head. The superior dome is intact. A: AP-view. B: A lateral view. C: Internal aspect of the specimen. Arrows indicate the displaced medial wall. D: External aspect demonstrating the fracture. The superior dome is intact.

DISCUSSION

Various types of acetabular fractures (anterior column, transverse and posterior column) are calculated to arise when the trochanteric region is hit by a force with the femur in extension and varying degree of rotation, or when the force is applied along the axis of the femur with the hip joint in flexion and varying degree of abduction or adduction (Cauchoix & Truchet 1951, Judet et al. 1964, Judet & Letournel 1974). With this concept of the fracture mechanism as a background we have tried to produce experimental acetabular fractures of various types. One problem has been to find an optimal experimental set-up. The difficulties to produce other unusual fractures experimentally have learned us the necessity to concentrate the energy to the actual bone and to avoid non-axial energy transmission in the bones that are supposed to act as impact bodies (Peterson et al. 1976). To determine the pendulum hit point and the degree of rotation and abduction or adduction of the femur in the experiments it was necessary to x-ray the specimen set-up before each experiment. Adjustments could then be made.

After a preliminary study the optimal experimental set-up could be defined. The difficulties to achieve this even under controlled laboratory conditions may explain the rareness of the acetabular fracture clinically as compared to the frequent occurrence of pertrochanteric and femoral neck fractures and fractures through the pelvic rami as the result of a trauma to the trochanteric region.

In the first 29 experiments only one central dislocation of the femoral head was achieved. This was interpreted as a possible result of both the symphysis and the sacrum being stably fixed in the same epoxy resin. In the following experiments these structures were fixed separately, offered the possibility to move in the sagittal plane. In 7 acetabular fractures 2 resulted in a severe central dislocation of the femoral head.

Only a few isolated posterior column fractures could be produced although the force was transmitted through the femoral neck in maximal internal rotation in several experiments. It was noticed that the possible maximal internal rotation that could be performed in the specimen hip joints was far from that calculated necessary for producing these fractures.

Different amount of energy was used to find the lowest necessary to produce these fractures. The preliminary study showed that all 7 experiments with 430 Nm resulted in acetabular fractures. Out of 9 (in all series) with lower energy only 3 resulted in acetabular fractures. Fourteen of 16 experiments with 480 Nm resulted in acetabular fractures on an extended hip joint. In the experiments with the hip joint in flexion the same energy was used in all. This seemed to be sufficient to produce transverse fractures with the femur in abduction or neutral position but insufficient in the 4 experiments with the femur in adduction. The posterior column seemed to withstand this energy. It is possible that the posterior column fractures are a result of a blow to the knee with the femur in abduction and flexion. It is also possible that the energy used in this series was too low. Waller (1955) used an energy of 1200 Nm in producing posterior acetabular fractures on flexed hip. Creyssel & Schnepf (1961) used 500 Nm on producing central acetabular fractures on whole cadavers.

During this experimental investigation it was noticed that it was difficult to detect fractures with no displacement between the acetabular fragments at the radiologic examination. When the joint was opened at the dissection the fractures were obvious. It was also noticed that oblique projections were necessary to determine the fracture-lines.

CONCLUSIONS

The following conclusions of the experiments can be made:

1. It is possible to produce central acetabular fractures by an impact to the trochanteric region.
2. It is important to hit the trochanter so that the force is transmitted axially through the femoral neck and to stabilize the femoral shaft in order to concentrate the energy and to avoid pertrochanteric or femoral neck fractures.
3. The degree of rotation of the femur with this in extension does not seem to influence on the type of acetabular fracture produced.
4. An energy of 430 Nm was sufficient to produce acetabular fractures.

SUMMARY

Part one

There are discrepancies in reported series regarding treatment and late results of fractures of the acetabulum. The purpose of this investigation has been to perform a study of these fractures with reference to frequency, classification, radiologic appearance, cause of injury, associated injuries, treatment and late results.

I. During 1963-1973, 123 patients with 124 acetabular fractures were admitted to the Departments of Orthopaedic Surgery at Sahlgren Hospital in Göteborg. The study has included central acetabular fractures with and without central dislocation of the femoral head and posterior acetabular fractures with or without posterior dislocation of the femoral head. Of the 124 acetabular fractures, 85 were central and 39 posterior.

Central acetabular fractures were classified depending on the degree of central dislocation of the femoral head and the involvement of the weightbearing area, i.e. whether the superior dome was fractured or not.

Posterior acetabular fractures were classified depending on the degree of displacement and comminution of the posterior acetabular rim (Waller 1955).

Of 85 patients with *central acetabular fractures* 80 were treated conservatively with immobilization in bed only or with traction through the tibial tuberosity, in some cases in combination with lateral traction through the proximal femur. Five patients were treated surgically.

Of 39 patients with *posterior acetabular fractures* 19 were treated conservatively with immobilization in bed only or with traction through the tibial tuberosity. Twenty patients were treated surgically with open reduction of the acetabular fragment and osteosynthesis.

II. Onehundred patients with 101 fractures were followed up clinically after 1 1/2 - 12 years, with a mean time for follow-up of 6.1 years.

Central fractures

The follow-up comprised 66 patients with central acetabular fractures; 61 of these were treated conservatively, 5 surgically.

Conservative treatment: Results were excellent or good in 75 per cent of the 61 patients conservatively treated. Thirty patients without central dislocation of the femoral head had excellent or good results in 90 per cent.

Fifteen patients with central dislocation of the femoral head without fracture of the superior dome had excellent or good results in 87 per cent.

Sixteen patients with central dislocation of the femoral head with fracture of the superior dome had excellent or good results in 38 per cent.

Surgical treatment: Five patients were treated surgically and one patient had good result and 4 fair.

Posterior fractures

Thirty-five patients with posterior acetabular fractures were followed up; 17 were treated conservatively and 18 surgically.

Conservative treatment: The fracture was classified as Type I in 3 patients, as Type II in 5 patients and as Type III in 9 patients. The results were excellent or good in 82 per cent (Type I: 100 per cent; Type II: 100 per cent; Type III: 67 per cent).

Surgical treatment: The fracture was classified as Type II in 10 patients and as Type III in 8 patients. The results were excellent or good in 67 per cent (Type II: 70 per cent; Type III: 63 per cent).

Sciatic nerve injury

Weakness of the foot extensors was registered in 8 patients. Seven of these had a posterior acetabular fracture in combination with a posterior dislocation of the femoral head. One patient had a central acetabular fracture without central dislocation of the femoral head. At follow-up the paresis remained in 5 patients.

III. Ninety-three patients with 94 acetabular fractures were followed up radiologically (61 patients with central acetabular fractures and 33 with posterior acetabular fractures).

Osteoarthritis was found in 23 of 61 patients with central acetabular fractures (38 per cent) and in 14 of 33 patients with posterior acetabular fractures (42 per cent).

Avascular necrosis of the femoral head was found in 8 patients, 5 with central acetabular fractures and 3 with posterior acetabular fractures.

Ectopic ossification was noticed in 13 of 99 patients (13 per cent) who were examined radiologically for more than 1 year.

Part two

Based on the reports of previous experimental work and on the theories of fracture mechanism in central acetabular fractures an experimental study of these fractures has been performed. The purpose was to design an experimental model by which central acetabular fractures could be produced on cadaver pelves and to determine the conditions (position of hip joint, and energy) under which various types of central acetabular fractures could be produced.

A preliminary study comprising 12 experiments was performed which gave the optimal specimen set-up.

Two experimental series, one with the femur in extension (20 experiments) and one with the femur in flexion (12 experiments) were then performed. In these two series 20 acetabular fractures were produced.

We found it important to hit the trochanter so the force was transmitted directly through the femoral neck and to stabilize the femur in order to avoid pertrochanteric or femoral neck fractures. The degree of rotation of the femur with this in extension did not seem to influence on the type of fracture produced. When a force was applied to the trochanteric region with the femur in flexion and abduction an energy of 480 Nm was sufficient to produce transverse fractures.

With the same energy applied to the trochanteric region, with the femur in flexion and abduction we did not obtain acetabular fractures, probably owing to insufficient energy.

In a total of 44 experiments 29 acetabular fractures of various types could be produced.

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CORRECTIONS

Pages 8 and 91. It says Ender (1976). It should be read Ender (1975).

Page 26. Under the paragraph with the second comment. Four lines below it says No difference It should be read A difference

Pages 38 and 89. It says Jahna (1976). It should be read Jahna (1975).

Page 54. Under the paragraph Summary of results in pain and walking. Seven lines below it says seventy-three per cent It should be read seventy-two per cent

Page 71. The top figure to the left. The letter A should be corrected to the letter B.

Page 84. The two lower illustrations. The letter C should be corrected to the letter D and the letter D should be corrected to the letter C.

Page 120. The last line but one. Abduction should be corrected to adduction.