Two-level reconstruction of comminuted posterior-wall fractures of the acetabulum

Our aim was to evaluate the efficacy of a two-level reconstruction technique using subchondral miniscrews for the stabilisation of comminuted posterior-wall marginal acetabular fragments before applying lag screws and a buttress plate to the main overlying posterior fragment. Between 1995 and 2003, 29 consecutive patients with acute comminuted displaced posterior-wall fractures of the acetabulum were treated operatively using this technique.

The quality of reduction measured from three standard plain radiographs was graded as anatomical in all 29 hips. The clinical outcome at a mean follow-up of 35 months (24 to 90) was considered to be excellent in five patients (17%), very good in 16 (55%), good in six (21%) and poor in two (7%). The use of the two-level reconstruction technique appears to provide stable fixation and is associated with favourable results in terms of the incidence of post-traumatic osteoarthritis and the clinical outcome. However, poor results may occur in patients over the age of 55 years.

Fractures of the posterior wall of the acetabulum comprise one-fourth to one-third of all acetabular fractures and represent the most common pattern of fracture of the acetabulum. The pioneering observations of Judet, Judet and Letournel set the foundation for the operative management of displaced fractures of the acetabulum by means of open anatomical reduction of the articular surface combined with rigid internal fixation and early mobilisation. This approach has become the standard treatment for these injuries and has led to a reduction in the incidence of post-traumatic arthritis and an improvement in the overall outcome.

However, many investigators have found a relatively high incidence of unsatisfactory outcome of approximately 30%, Commi- nuted fractures of the posterior wall are challenging cases. Maintaining reduction of the fracture fragments until solid union takes place is difficult. Indeed, the most crucial determinant of clinical success is the accuracy of the reduction and the avoidance of increased contact pressure due to steps and gaps.

The traditional sequential approach to the operative treatment of posterior-wall fractures consists of elevating depressed osteoarticular fragments and bone grafting impacted areas. The femoral head is used as a template to orientate and to reduce the different articular fragments. In cases of extensive comminution it is more difficult to maintain anatomical reduction unless additional support is provided for intercalary osteochondral fragments. Furthermore, as the overlying posterior-wall component is reduced, shifting of the potentially mobile interposed osteochondral fragments may occur. This loss of reduction is not usually perceived, either by intra-operative fluoroscopy or by direct visualisation through a standard posterior surgical approach. Therefore, in fractures with intra-articular comminution and intercalary osteochondral fragments, we have used small subchondral screws to maintain the anatomical reduction of these articular fragments before subsequent reduction and fixation of the overlying posterior-wall fragment by lag screws and a buttress plate. Our aim in this study was to evaluate the efficacy of this two-level method of treatment.

Patients and Methods

Demographic data and types of fracture. Between January 1995 and December 2003, we treated 29 consecutive patients with acute comminuted displaced posterior-wall fractures of the acetabulum using the described technique. During the same time period 98 acetabular fractures were treated surgically in both our institutions. All the fractures included in our study were isolated posterior-wall fractures. Patients with associated...
Acetabular fracture patterns or combined pelvic and acetabular injuries were excluded. In each patient the two-level reconstruction technique was used, namely open reduction and internal fixation of a comminuted acetabular fracture using small subchondral screws to maintain anatomical reduction of intercalary osteochondral fragments before reduction and fixation of the overlying posterior-wall fragment by lag screws and a buttress plate.

There were 26 men and three women with a mean age of 42 years (19 to 79). Of these, eight were 55 years of age or older. Road-traffic accidents accounted for 28 of the injuries and sport for one. All fractures were unilateral on the right side in 13 hips and on the left in 16. In 27 cases, the patient initially presented with a dislocated hip which required reduction; 25 had a successful closed reduction within 12 hours of the injury; one was reduced at more than 12 but less than 24 hours after injury, and another at more than 24 hours after injury. Those with dislocation had femoral skeletal traction after reduction while awaiting surgery, in order to prevent redislocation or wear of the femoral head. Six patients had incomplete palsy of the sciatic nerve. In three, the injury was limited to a sensory deficit presenting as dysesthesia. Three patients presented with motor weakness (graded as Medical Research Council (MRC)13 power 3/5) in the ankle or toe dorsiflexors. A total motor weakness (graded as Medical Research Council score14) for this group was 10 (9 to 18). The mean time from injury to operation was six days (0 to 18) and the mean hospitalisation time 10.6 days (9 to 19).

The Advanced Trauma Life Support15 evaluation protocol was followed during the patients’ admission. The initial assessment included a meticulous physical examination focusing on a complete neurological assessment of the lower limb and evaluation of the soft tissues in the trochanteric and gluteal regions. All patients were initially evaluated using an anteroposterior radiograph and two 45° oblique radiographs of the pelvis. CT with 2 mm to 3 mm sections through the affected area was performed allowing a more accurate characterisation of the fracture.16

The indication for surgery was instability of the hip. Patients with fractures and gross instability who were examined after closed reduction were treated operatively. Fractures shown by two-dimensional CT to involve more than 50% of the posterior wall were also considered to be unstable.17-19 For all other fractures, dynamic fluoroscopic stress examination of the hip was performed with the patient under general anaesthesia to identify those with occult instability requiring surgical treatment.20

Operative technique. The patients were positioned either lateral or prone on a radiolucent fracture table capable of providing traction for the assistance of reduction and joint inspection. Skeletal traction through a distal femoral traction pin was often used. All the procedures were performed with the patient under general anaesthesia and with muscle paralysis if hip subluxation was required for joint debridement and for reduction.

The standard Kocher-Langenbeck approach was used in all cases.21,22 Soft-tissue stripping was limited to the periphery of the fractures. Neurodiagnostic monitoring was not used. Osteotomy of the greater trochanter in an attempt to improve access was not required. The joint was meticulously inspected for marginal impaction, damage to the femoral head and intra-articular fragments. Fracture reduction was performed by direct manipulation of the bone with standard pelvic reduction instruments.

When marginal impaction was present, the small osteochondral fragments were elevated and rotated into an anatomical position with an elevator, using the located femoral head as a template. Stable fixation of the fragments was achieved by using an appropriate number of 1.5 mm or 2 mm fully-threaded cortical mini screws inserted in a subchondral location, sparing the articular cartilage. The number of screws used ranged from one to four depending on the number and size of the intercalary osteochondral fragments. Subsequently, the overlying posterior-wall fragment was stabilised by 3.5 mm lag screws (wall to column). The overall posterior-wall fixation construct was then buttressed by the application of a reconstruction-type plate, appropriately contoured to accommodate the shape of the posterior wall and column. Intra-operative fluoroscopic imaging was used in all patients to assess reduction and location of the implant.8,23

The operating time ranged from one hour and 45 minutes to three hours (mean 2 hours). Prophylactic cefalosporin and aminoglycoside antibiotics were used in the peri-operative period. Closed suction drains were used routinely and antibiotics were continued post-operatively until removal of the drain. Routine prophylaxis against heterotopic bone formation was not used in one institution in which the patients were treated. However, treatment with oral indometacin (25 mg three times day), beginning within 24 hours of surgery and continuing for six weeks post-operatively, was routinely used at the other centre on 14 patients. Low-molecular-weight subcutaneous heparin preparations were instituted peri-operatively for prophylaxis against thromboembolic disease and continued until the patient regained full walking ability.

Post-operative assessment and follow-up. Post-operatively, the patients were mobilised as soon as medically possible under the supervision of a qualified physiotherapist and subsequently began formal physiotherapy for muscle strengthening. Active exercises of the hip, with progressive resistance of the adductors, quadriiceps, and hamstrings were encouraged. In general, partial, toe-touch weight-bearing with crutches or a walker was begun between six and 12 weeks after the procedure, depending on the degree of comminution and the stability of the fracture, as subjectively assessed by the treating physician. Physiotherapy was continued until the muscle strength and range of movement were regained or a plateau was reached. Post-operatively, and before discharge from hospital, three standard radiographs of the pelvis and a two-dimensional CT scan were
obtained at the same time, usually within one week of surgery, to assess the reduction. A total of 25 patients had post-operative CT scan. The CT scan was graded as imperfect if there was any gap or offset of 2 mm or greater.

Clinical and radiological examinations were performed and data recorded at 6 and 12 weeks, and 12 and 24 months. Thereafter, they were performed annually. Not all the patients were examined at every follow-up interval, but all were seen at the final follow-up. The mean follow-up was 35 months (24 to 90).

The outcome was evaluated using the clinical grading system developed by Merle d’Aubigné and Postel and modified by Letournel and Judet and subsequently by Matta. The modification involved a stricter grading of the score for the range of movement of the hip, which was determined by comparison of the total score for the injured side with that for the uninjured side. Flexion, abduction and adduction were assessed with the patient supine, and rotation with the patient prone. The clinical outcome was categorised as excellent, very good, good, fair or poor, depending on the scores in three subset categories of pain, walking and range of movement (Table I).

Heterotopic ossification was assessed using the modification of Moed and Smith of the technique of Brooker et al which uses anteroposterior, iliac and obturator oblique views of the pelvis. In this system, classes 0, I and II are consistent with essentially normal movements of the hip and classes III and IV are associated with functional loss of movement. Therefore, classes III and IV were deemed to be...

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Points</th>
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<tbody>
<tr>
<td>Pain</td>
<td></td>
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<tr>
<td>None</td>
<td>6</td>
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<tr>
<td>Slight or intermittent</td>
<td>5</td>
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<td>After walking but resolves</td>
<td>4</td>
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<tr>
<td>Moderately severe but patient is able to walk</td>
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<tr>
<td>Severe, prevents walking</td>
<td>2</td>
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<tr>
<td>Walking</td>
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<tr>
<td>Normal</td>
<td>6</td>
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<tr>
<td>No walking aid but slight limp</td>
<td>5</td>
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<tr>
<td>Long distance with walking aid</td>
<td>4</td>
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<tr>
<td>Limited even with support</td>
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<tr>
<td>Very limited</td>
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<td>Unable to walk</td>
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<td>Range of movement (percentage of value obtained for normal contralateral hip)</td>
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<td>95 to 100</td>
<td>6</td>
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<tr>
<td>80 to 94</td>
<td>5</td>
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<tr>
<td>70 to 79</td>
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<td>60 to 69</td>
<td>3</td>
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<td>50 to 59</td>
<td>2</td>
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<tr>
<td>&lt; 50</td>
<td>1</td>
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<tr>
<td>Clinical score (sum of points for pain, walking and range of movement)</td>
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<tr>
<td>Excellent</td>
<td>18</td>
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<tr>
<td>Very good</td>
<td>17</td>
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<td>Good</td>
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<td>Fair</td>
<td>13 or 14</td>
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<td>Poor</td>
<td>&lt; 13</td>
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indicative of severe heterotopic ossification. Osteonecrosis was diagnosed only when the radiological findings provided a clear differentiation from wear of the femoral head.8

Statistical analysis. This was provided by an independent biostatistician who was not directly involved with the study and who used SPSS software version 11.5 (SPSS Inc., Chicago, Illinois). For the purpose of risk-factor analysis, the clinical outcome scores were divided into two categories, good-to-excellent and fair-to-poor. For all statistical tests, a p-value < 0.05 indicated significance. The association between clinical outcome and final radiological grade was statistically evaluated using the kappa statistic. In order to accomplish this task, the five clinical outcome groups were reduced to four corresponding categories (excellent, good, fair and poor) with the clinical outcome grade of very good being combined with excellent.16 A kappa value > 0.70 was accepted as indicating good agreement between the groups.

Results
The operative findings showed intra-articular free fragments to be present in 25 patients (86%), injury to the femoral head in three (10%), acetabular articular impaction (marginal impaction) injury in 11 (38%) and severe fracture comminution in 21 (72%). Bone grafting was used in nine (31%) to fill a void after reduction of an impacted intra-articular fragment. The quality of the reduction measured from the three standard plain radiographs of the pelvis was graded as anatomical in all 29 hips. The quality of reduction assessed on post-operative CT showed that there was a fracture gap (negative defect in the acetabular surface) of 2 mm or more in seven patients (24%) and fracture offset (change in alignment of the fracture fragment in reference to the femoral head) of greater than 2 mm in one (3%). In no case was the gap width > 10 mm (Fig. 1).

The clinical outcome was graded as excellent in five patients (17%), very good in 16 (55%), good in six (21%) and poor in two (7%), giving a good-to-excellent result in 27 patients (93%). The radiological outcome was graded as excellent in 19 patients (66%), good in six (21%), fair in one (3%) and poor in three (10%), giving a good-to-excellent result in 25 (86%). All the outcome scores were based on the final assessment. There was good agreement between the clinical outcome and radiological grade (kappa = 0.71).

Two patients required total hip replacement (THR) within two years of injury, in both due to post-traumatic osteoarthritis. The first was 67 years of age and had sustained a severely comminuted fracture. Post-operative CT revealed a maximal fracture gap width of 6 mm with a gap area of 18 mm² and fracture offset of 2 mm. The other patient was 65 years of age and his hip had remained dislocated for more than 24 hours before reduction. Post-traumatic arthritis was the presumptive diagnosis, but osteonecrosis could not be completely ruled out as a causative factor. In this patient, the reduction was within 2 mm as evaluated on post-operative CT. Another patient with a history of prolonged dislocation of the hip before reduction (more than 12 but less than 24 hours after injury) developed radiological signs of osteonecrosis of the femoral head at two years after injury. At the final follow-up three years after injury, this patient had a Merle d’Aubigné score of 16 (good) with a radiological grade of poor. Heterotopic ossification was documented in 11 patients (38%), class I in six (21%) and class II in five (17%). No patient developed a wound infection or deep-vein thrombosis. There were no iatrogenic nerve injuries. In all 29 patients, a congruent reduction was achieved followed by union of the fracture and return to full weight-bearing on the affected limb within three months. Five of the six patients with an incomplete pre-operative palsy of the sciatic nerve made a complete recovery. The sixth patient had residual sensory symptoms, consisting of occasional dysaesthesia. An age > 55 years was found to be a risk factor for a clinical result of less than good (Fisher’s one-sided exact test, p = 0.03).

The patient numbers were otherwise too small to give a sound statistical analysis of other variables.

Discussion
The operative management of acetabular fractures is technically demanding and has many potential complications.1,7,8 The goal of surgery is to restore accurately the anatomical configuration and stability of the hip, while avoiding complications. The results after surgery correlate most closely with the quality of the reduction.8,11,16 However, there is no doubt that other prognostic variables are involved in addition to the variables identified in our study.2,8,11,16

Despite the relatively simple appearance of posterior-wall fractures, the clinical results after surgical treatment have been variable.2,3,8,9,11,27 In a series of 262 acute acetabular fractures followed for two to 14 years, Matta8 reported that 22 had posterior-wall fractures. Despite an anatomical reduction as determined by plain radiography in all 22, a good-to-excellent clinical result was obtained in only 15 (68%), with a poor result in the remaining seven (32%). Saterbak et al9 reported the outcome in types of fracture which included a posterior-wall fracture as part of the injury pattern. A total of 42 fractures were evaluated with 20 isolated to the posterior wall. Of these 20, seven (35%) had complete loss of the joint space within one year of surgery.9 Aho et al10 undertook a follow-up over five years of 20 patients who had undergone open reduction and internal fixation of a posterior-wall fracture using screws;10 14 (70%) had good or moderate results.

Larger series have provided somewhat different results. Letournel and Judet2 have provided the greatest source of information on the operative treatment of acetabular fractures. In their series of 117 posterior-wall fractures followed for one to 33 years, 82% had a good-to-excellent result, despite a perfect reduction in 94%.2 The occurrence
A 45-year-old man who had been involved in a motor-vehicle accident sustained a posterior fracture/dislocation of the left hip. a) Initial anteroposterior and 45° oblique radiographs, b) CT scan showing a dislocated hip and a comminuted posterior-wall fracture with marginal impaction, c) intra-operative photograph showing the intercalary osteochondral fragment which became free after elevation from its marginally impacted position. For orientation, the patient is in the prone position with the head to the left, d) intra-operative photograph showing reduction and fixation of the fragment using a miniscrew, e) post-operative anteroposterior and 45° oblique radiographs. The reduction was graded as anatomical, f) post-operative CT scan showing restoration of the articular surface and subchondral placement of a miniscrew. The fracture gap was < 2 mm without any fracture offset, g) anteroposterior and 45° oblique radiographs obtained two years after injury. The radiological grade was excellent and the clinical grade very good (17 of 18).
of osteonecrosis and the fact that reconstruction of severely comminuted fractures was difficult to perform were noted as contributors to the less-than-good results. In a larger follow-up study of 890 acetabular fractures Matta reported that 88% of the posterior-wall fracture group had a good-to-excellent clinical result.

Moed et al. reported similar favourable results for a recent large series after a mean follow-up period of five years, with good-to-excellent results in 89 of 100 (89%) posterior-wall fractures treated by open reduction and internal fixation. They emphasised that long-term good-to-excellent results can be expected after anatomical reduction and internal fixation. Identified risk factors for an unsatisfactory clinical result included delay in the time to reduction of an associated dislocation of the hip of > 12 hours, age 55 years or older at the time of injury, intra-articular comminution (defined as three or more separate fragments) and the presence of osteonecrosis. Bhandari et al. reviewed 109 patients with fractures of the acetabulum and posterior dislocation of the hip. Using multivariable analysis, the quality of reduction of the fracture was identified as the only significant predictor of radiological grade, clinical function and the development of post-traumatic arthritis. All patients lacking anatomical reduction developed arthritis, whereas only 23.5% (24) with an anatomical reduction did so (p = 0.05). By contrast, Kreder et al. recently reported that anatomical reduction alone was not sufficient to restore function. They found that the fracture pattern, marginal impaction and residual displacement of > 2 mm were associated with the development of arthritis which correlated with poor function and the need for hip replacement. Furthermore, they concluded that it might be appropriate to consider immediate total hip replacement for patients older than 50 years with marginal impaction and comminution of the wall; seven of 13 patients in this age group required early hip replacement.

In a separate study using CT analysis of 67 operatively-treated posterior-wall fractures, Moed et al. identified additional risk factors for an unsatisfactory clinical result including marginal impaction and fracture gaps of > 10 mm and an estimated gap area of > 35 mm². With a minimum follow-up of two years the clinical results were graded as excellent in 31 patients (46%), very good in 20 (30%), good in eight (12%) and poor in eight (12%). One, with a delay in reduction of the hip progressed to osteonecrosis of the femoral head and there were two elderly patients with comminuted fractures. Eight patients were aged 55 years or older. Using the described two-level reconstruction technique, satisfactory reduction (by plain radiological and CT criteria) was obtained in all. Poor clinical and/or radiological results were seen in only three patients (10%). One, with a delay in reduction of the hip progressed to osteonecrosis of the femoral head and there were two elderly patients with comminuted fractures. Good-to-excellent clinical results were obtained in 27 patients (93%). These clinical results are very favourable when compared with other series which have included less complicated fractures.

The established assessment methods used in our study were in accordance with those used by most other authors. The performance of THR after previous stabilisation of an acetabular fracture poses intra-operative technical problems. However, in both of our patients who proceeded to hip replacement, our previous fracture fixation technique did not add any further technical obstacles. The subchondral screws were easily removed once uncovered by the reaming process.

We feel that, as supported by post-operative CT findings, this fixation technique provides the best opportunity for maintaining intra-operative reduction of the articular fragments in patients with highly comminuted intra-articular posterior-wall fractures. However, poor results may occur in patients over the age of 55 years.

No benefits have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References
TWO-LEVEL RECONSTRUCTION OF COMMINUTED POSTERIOR-WALL FRACTURES OF THE ACETABULUM


