Influence of the design of the prosthesis on the outcome after hemiarthroplasty of the shoulder in displaced fractures of the head of the humerus

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We reviewed 39 patients with displaced three- and four-part fractures of the humerus. In 21 patients (group A) we had used an anatomical prosthesis for the humeral head and in 18 (group B) an implant designed for fractures.

When followed up at a mean of 29.3 months after surgery the overall Constant score was 51.9 points; in group A it was 51.5 and in group B 52.4 points. The subjective satisfaction of the patients was assessed using a numerical rating scale and was similar in both groups. In group A complete healing of the tuberosities was found in 29% and 50% in group B. Partial integration was seen in 29% of group A and in only one patient in group B, while resorption was noted in 43% of group A and 44% of group B. The functional outcome was significantly better in patients with complete or partial healing of the tuberosities (p = 0.022). The specific trauma prosthesis did not lead to better healing of the tuberosities. The difference in clinical outcome obtained by the two designs did not reach statistical significance.

In complex fractures of the proximal humerus there is still debate about the indications for open reduction and internal fixation (ORIF) and primary hemiarthroplasty. The risk of secondary displacement of the fragments and necrosis of the head of the humerus after open reduction and internal fixation, especially in elderly patients, led Neer to popularise primary prosthetic replacement of the head.1 The indications for hemiarthroplasty include comminuted three- and four-part fractures with dislocation of the head, and fractures which split the head with involvement of more than 40% of the articular surface.2 The results of primary hemiarthroplasty vary from satisfactory1,3-6 to disappointing.7-12

In their early clinical series, Neer1 and Cofield3 reported relief from pain in over 90% of patients and a virtually free range of movement in two-thirds of patients with a hemiarthroplasty for proximal fractures of the humerus. However, other studies reported restriction of movement after joint replacement in comminuted three- and four-part fractures.9,10 Movin et al12 described unsatisfactory results, with persisting symptoms and restricted movement. Several other authors observed primary malposition and secondary migration of the tuberosities12 or deficient osseous integration13-15 as a complication after the use of a prosthesis for the treatment of proximal humeral fractures, leading to a poor functional outcome.

Advances in surgical techniques and the use of modular prostheses and designs developed specifically for the treatment of fractures have extended the indications for hemiarthroplasty after displaced fractures of the head of the humerus.

Kralinger et al16 compared the results obtained with several prostheses of the first, second and third generations of design in the treatment of these fractures. Integration of the tuberosities was found to differ with the type of prosthesis, and the number of such procedures undertaken by a surgeon per year seemed to have an impact on the functional outcome.

We are not aware of any studies which have compared the results obtained with prostheses of the third generation with implants designed specifically for fractures. This prospective study has examined the results obtained with hemiarthroplasty for the treatment of displaced fractures of the head of the humerus, with special reference to whether a more advanced design influences healing of the tuberosities or the functional results.

Patients and Methods

Since 1997 we have performed hemiarthroplasty on 77 patients with fractures of the head of the humerus. Anteroposterior and axillary radiographs were taken in order to classify the fractures according to the number and the degree
Fig. 1a
Radiographs showing a) a dislocated four-part fracture and b) at two and c) at five years after implantation of a standard shoulder prosthesis. There is complete integration of the tuberosities.

Fig. 2a
Radiographs showing a) a trauma prosthesis with open stem and b) complete osseous integration three years after surgery.
of dislocation of the fragments. When classification was difficult, additional CT scans were analysed. Only patients with displaced three- or four-part fractures, or with fractures which had split the head, were enrolled in this study. Because of the uncertain reliability of the common classification systems no further categorisation of the fractures was undertaken.

A total of 47 patients was treated by hemiarthroplasty between 1997 and 2002 and followed up for a minimum of 12 months. Subsequently, three patients died, two moved away without leaving forwarding addresses, two experienced deterioration in their general condition making them unable to take part in the study, and in one the prosthesis had to be revised 2.5 years after implantation because of a late infection. This left 39 patients in the study.

Two different types of prosthesis were used. Between 1997 and 1999, 21 patients (group A) received a standard third-generation anatomical prosthesis (Aequalis; Tornier, Grenoble, France). This design had anterior and posterior rims to prevent rotation and a rib with two holes for fixation of the tuberosities (Fig. 1). In all cases an inclination angle of 130˚ was used.

From 1999 onwards a further 18 patients (group B) had a more refined version of this prosthesis. This model was designed especially for trauma (Aequalis Fracture; Tornier) and had a laterally flattened neck for better positioning of the tuberosities and a metaphysseally medialised, hydroxyapatite-coated open stem in order to improve osseous integration, with an angle of inclination of 130˚ (Fig. 2).

All patients were followed up at six and 12 months after operation. For this study they were seen more than 24 months after surgery. In addition to the Constant and Murley score the patients assessed their own results subjectively using a numerical rating scale (1, very good; 2, good; 3, satisfactory; 4, adequate; 5, inadequate; and 6, poor).

At each follow-up anteroposterior and axillary radiographs were taken to assess the healing of the tuberosities. Complete integration was confirmed when the position and shape of the re-attached tuberosities had not changed (Fig. 1). Partial healing was noted when the radiological appearance indicated union of 50% and major resorption was recorded when less than 50% of the tuberosities remained. The radiographs were also examined for the presence of radiolucent lines around the stem and possible tilt or subsidence of the prosthesis itself.

In the 39 patients the fractures involved the right shoulder in 21 and the left in 18. The mean time between fracture and operation was eight days (1 to 39). The operation was performed within six days after the accident in 22 patients. In 19 operations delays were caused by referral of patients from other hospitals. Nine patients had already undergone operative treatment of their fractures in other hospitals, Kirschner (K)-wire fixation in six and intramedullary nailing in three, with secondary displacement of the fracture.

The clinical details of both groups were similar. In group A, 17 patients were female and four male and in group B, 13 were female and five male. The mean age at the time of surgery in group A was 74.1 years (65 to 83). Seventeen patients had four-part and four had three-part fractures, and the mean time of surgery was 9.9 days after trauma. The mean operating time was 117 minutes (80 to 210). In group B the mean age was 70.0 years (54 to 88). There were 16 four-part and two three-part fractures. The mean time to surgery was 6.4 days after the trauma, and the mean operating time was 99 minutes (70 to 143). All the operations were either performed or assisted by the first author (ML).

**Operative technique.** During the operation the insertions of the tendons of the rotator cuff into the tuberosities were preserved as far as possible and attached to the metaphyseal part of the prosthesis in an anatomical position with non-resorbable multiple sutures (Ethibond Polyester 1 mm diameter, non-resorbable, 1.5 mm diameter, Ethicon, Hamburg, Germany), using the fin and the open stem for fixation to ensure a stable and anatomical adaptation. The size of the head of the prosthesis matched the diameter of the head fragment in order to allow reconstruction of the centre of rotation. The prosthesis was positioned in approximately 20˚ of retroversion. The height of implantation was determined by the size of the displaced greater tuberosity and the metaphyseal calcar. The metaphyseal defects were filled with cancellous bone taken from the head and in group B placed around the stem. In all cases tenotomy of the long tendon of biceps was performed.

All patients had a standard rehabilitation programme. The arm was placed in a 45˚ abduction splint for four weeks. After five days the shoulder was treated by active assisted exercises with limitation of abduction and flexion to 60˚ with no external rotation for four weeks. After this free passive and active movement was allowed.

**Statistical analysis.** The mean, SD and range were calculated for continuous variables and for quasimetric satisfaction notes (patients own subjective assessment of results; 1, very good; 6, poor). An unpaired t-test was applied in order to determine whether the differences between both groups were significantly different. Associations between discrete variables were tested by the chi-squared test. A two-tailed p value equal to or less than 0.05 was considered to be significant. Because of the exploratory design of our study all tests were performed without alpha adjustment. Analysis of data was performed by SPSS for Windows 12.0 (SPSS, Chicago, Illinois).

**Results**

No relevant complications were encountered during surgery. In one patient in group A wound healing was impaired, requiring a superficial revision. One female patient in group B sustained a periprosthetic fracture 13 months after operation in a fall at home. Because resorption of the tuberosities had by then already occurred, revision was undertaken using a reversed prosthetic implant.

A female patient in group B already had irritation of the brachial plexus before the operation which was attribut-
able to previous internal fixation with K-wires carried out elsewhere. This persisted at all attendances for follow-up.

At six months the mean Constant score was 43.2 (19 to 70) points and 62% in the age- and gender-adapted score.\textsuperscript{17} The mean score in group A was 41.9 (19 to 70) points (62%) and in group B 44.6 (22 to 67) points (62%).\textsuperscript{17} Statistical evaluation by an unpaired \textit{t}-test showed no significant difference (\(p = 0.571\)) (Table I). The pain score was 8.0 points for group A and 9.5 points for group B (\(p = 0.369\)). The mean subjective assessment of the outcome corresponding to the numerical rating scale was 3.0 (1 to 5), 3.1 in group A and 2.9 in group B (\(p = 0.663\)).

Overall, active abduction was 78.9˚ (30˚ to 130˚). In group A the mean abduction attained was 83.6˚ and in group B 73.3˚. The mean active flexion was 81˚ (10˚ to 140˚) for all patients, being 76.9˚ in group A and 84.7˚ in group B. The mean external rotation was 13.8˚ (0˚ to 50˚), 13.8˚ in group A and 13.9˚ in group B. In patients who had been treated within six days of sustaining the injury the mean Constant score was 42 points, while in those whose treatment was delayed for more than six days the score was 45 points. However, because of the small numbers, this difference also failed to reach statistical significance (\(p = 0.472\)).

At a mean of 12 months after surgery the Constant score was 52.5 points (74%) in group A, while in group B it was 54.1 points (75%). The patients’ subjective assessment of the outcome of surgery (group A, 2.8; group B, 2.8) was also similar in both groups (\(p = 0.832\)).

The final assessment was carried out at a mean of 29.3 (12 to 88) months after operation (30.7 months in group A, 27.6 months in group B). At this time the overall Constant score was 51.9 (18 to 77) points (74.7%). Group A scored 51.5 (30 to 76) points (74%) and group B 52.4 (18 to 77) points (75%) (\(p = 0.854\)) (Table II). Pain had improved to 9.8 points in group A and 10.3 points in group B (\(p = 0.730\)).

The mean subjective satisfaction was 2.8 (1 to 5), 2.8 in group A and 2.8 in group B (\(p = 0.823\)). The mean active flexion was 91.8˚ (40˚ to 180˚), 86.0˚ (40˚ to 130˚) in group A and 100.0˚ (40˚ to 180˚) in group B. The mean range of active abduction was 88.1˚ (40˚ to 180˚), 80.7˚ (40˚ to 125˚) in group A and 96.7˚ (40˚ to 180˚) in group B. The mean external rotation was 17.2˚ (-10˚ to +65˚), 17.6˚ (-10˚ to +65˚) in group A and 15.3˚ (0˚ to 50˚) in group B. Comparison of the groups by means of an unpaired \textit{t}-test showed no significant differences (Table II).

Radiological examination at the last review showed complete healing and anatomical integration of the tuberosities in 15 patients (38%), partial integration in seven (18%) and major resorption in 17 (44%). In group A complete

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**Table I.** The mean (SD) shoulder function and subjective assessment six months after hemiarthroplasty of the shoulder

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>(p) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abduction (˚)</td>
<td>83.6 (28.8)</td>
<td>73.3 (20.6)</td>
<td>0.216</td>
</tr>
<tr>
<td>Flexion (˚)</td>
<td>76.9 (33.0)</td>
<td>84.7 (28.0)</td>
<td>0.434</td>
</tr>
<tr>
<td>External rotation (˚)</td>
<td>13.8 (12.0)</td>
<td>13.9 (12.9)</td>
<td>0.984</td>
</tr>
<tr>
<td>Constant score (points)</td>
<td>41.9 (14.6)</td>
<td>44.6 (13.7)</td>
<td>0.571</td>
</tr>
<tr>
<td>Subjective assessment (grades 1 to 6)</td>
<td>3.1 (1.2)</td>
<td>2.8 (1.1)</td>
<td>0.663</td>
</tr>
</tbody>
</table>

**Table II.** The mean (SD) shoulder function and subjective assessment at a mean of 29.3 months after hemiarthroplasty of the shoulder

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>(p) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abduction (˚)</td>
<td>80.7 (24.5)</td>
<td>96.7 (44.5)</td>
<td>0.187</td>
</tr>
<tr>
<td>Flexion (˚)</td>
<td>86.0 (29.2)</td>
<td>100.0 (45.1)</td>
<td>0.249</td>
</tr>
<tr>
<td>External rotation (˚)</td>
<td>17.6 (16.8)</td>
<td>15.3 (16.3)</td>
<td>0.872</td>
</tr>
<tr>
<td>Constant score (points)</td>
<td>51.5 (14.2)</td>
<td>52.4 (17.5)</td>
<td>0.854</td>
</tr>
<tr>
<td>Subjective assessment (grades 1 to 6)</td>
<td>2.8 (1.2)</td>
<td>2.8 (1.0)</td>
<td>0.823</td>
</tr>
</tbody>
</table>

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Fig. 3

Radiograph showing resorption of the tuberosities and superior migration after implantation of a standard prosthesis.
healing was found in six patients (29%), partial integration in six (29%) and resorption of the tuberosities in nine (43%). In group B complete healing was observed in nine patients (50%) and resorption of the tuberosities in eight (44%). In one patient partial integration was noted (p = 0.134). Secondary dislocation of the fragments was not seen. There were no radiolucent lines around the shaft or changes in the position of the prosthesis. One patient in group A with resorption of the tuberosities showed superior migration of the humeral head (Fig. 3) relative to the glenoid. In group B superior migration was not seen but in one patient there was anterior subluxation with the prosthesis supported on the coracoid process. On clinical examination this patient was not found to be substantially restricted. In six patients minor heterotopic ossification was seen around the prosthesis, but this had no significant clinical implications.

Discussion

The treatment of fracture-dislocation of the head of the humerus is challenging and likely to involve complications. In operations to preserve the head there is a high risk of dislocation of the fragments, pseudarthrosis and post-traumatic necrosis of the head. However, after primary hemiarthroplasty a low rate of complications and revision has been described.² The functional results seen after prosthetic replacement vary widely. The published results suggest that the outcome obtained by elective shoulder arthroplasty, for example in the case of primary arthritis or avascular necrosis, cannot be matched by replacement of the head for the treatment of a complex fracture. However, patients with displaced fractures of the proximal humerus can expect a good level of relief from pain and satisfactory function.¹⁻³,¹⁶

The only long-term follow-up of a large population (138 patients) with hemiarthroplasty after trauma has been by Robinson et al.² They found an overall survival rate for the prosthesis of 93.9% after ten years. A major negative factor predicting outcome was radiological evidence of displacement of one or more tuberosities. In a recent series of Boileau et al¹³ detachment of tuberosities and migration were noted in 23%. Malposition occurred in 50% and correlated with unsatisfactory results and superior migration of the prosthesis.

In terms of the functional result, successful re-attachment of the tuberosities is vital. The design of modern prostheses allows better fixation and more stable integration of the fractured tuberosities at the proximal end of the prosthesis, with consequent restoration of function of the rotator cuff. The results have been anticipated following biomechanical studies on the kinematics of the shoulder after anatomical and non-anatomical reconstruction of the tuberosities.²⁰ Clinical studies have shown that healing of the tuberosities in their anatomical position is the most important influence on the eventual functional outcome.¹⁴⁻¹⁶ Even slight dislocation of the tuberosities will produce results which are only marginally better than those seen after absorption of the tuberosities. Primary fixation in a non-anatomical position led to poor results in all cases. Kralinger et al¹⁶ found healing of the tuberosities in 37% of patients with prostheses of conventional design.

It has been suggested that delay in undertaking surgery after trauma¹⁴ or the time of post-operative immobilisation¹⁹ may influence healing of the tuberosities. In our study these factors did not play a significant role in healing of the tuberosities or in the functional outcome.

In our series complete integration of the tuberosities was seen more frequently in group B (50%) than in group A (29%) but the difference was not significant (p = 0.134). Partial healing of the tuberosities was found in another 29% in group A and in only one patient in group B. The Constant score was significantly better in the presence of either complete or partial healing of the tuberosities than when they had been resorbed (Table III).

In the whole series, superior or anterior migration of the hemiarthroplasty was seen in only two patients which was similar to that in elective arthroplasties with an intact rotator cuff.²¹

Clinically, in terms of active abduction and flexion the prosthesis designed for use following trauma in group B tended to be superior to the conventional design in group A at the later reviews (Table II). However, the overall Constant score did not differ between both groups and comparisons using an unpaired t-test did not reach statistical significance (p < 0.05). This may be explained by the relatively small number of patients in our study.²²

An additional factor which may have influenced the results was the experience of the surgeon (ML) and the unit, which usually improves with time. The length of the operation was shorter in the later patients in group B.

Analysis of the results at the first, second and final reviews in both groups showed very small differences in the active range of movement between the groups initially, but an increase in both flexion and abduction in time. In group A the overall improvement in flexion from 76.9° to 86.0° between the first and last review is small and abduction deteriorated from 83.6° to 80.7°. However, in group B there was an improvement from 84.7° to 100.0° in flexion and from 73.3° to 96.7° in abduction.

The overall Constant score was 43.2 points (62%) after six months and 51.9 points (74.7%) after 29 months, similar to observations made in previous studies.²⁻⁹,¹⁶ The improvement in function over time may be attributable to the exer-
exercise therapy carried out after surgery, with consequent strengthening following bony healing of the tuberosities.

A detailed comparison of the outcomes in the literature is very difficult, as most authors do not give accurate scores but just report ‘very good’, ‘good’ and ‘satisfactory’ results. The various systems of evaluation in use and differences in the patient populations make comparison of the results impossible.

In our study, 62% of the patients in group A and 72% of those in group B assessed the result of their surgery as very good to satisfactory at the time of the first review. Using a numerical rating scale which corresponded to the German-language marking system as an additional method for patient assessment, we found this to be very reliable. Other observations, with 78% of good results, show a similar level of patient satisfaction.15

The clinical outcome of shoulder arthroplasty after four-part fractures is satisfying. The functional result is significantly better when healing of the tuberosities is achieved than when this does not occur (p = 0.022). The prosthesis which was specially designed for fractures does not lead to improved osseous integration of the tuberosities. The overall results obtained by the standard and trauma prostheses were very similar.

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References


