A new technique for reconstruction of the proximal humerus after three- and four-part fractures

The results of proximal humeral replacement following trauma are substantially worse than for osteoarthritis or rheumatoid arthritis. The stable reattachment of the lesser and greater tuberosity fragments to the rotator cuff and the restoration of shoulder biomechanics are difficult. In 1992 we developed a prosthesis designed to improve fixation of the tuberosity fragments in comminuted fractures of the proximal humerus. The implant enables fixation of the fragments to the shaft of the prosthesis and the diaphyseal fragment using screws, washers and a special toothed plate. Between 1992 and 2003 we used this technique in 50 of 76 patients referred to our institution for shoulder reconstruction after trauma. In the remaining 26, reconstruction with a prosthesis and nonabsorbable sutures was performed, as the tuberosity fragments were too small and too severely damaged to allow the use of screws and the toothed plate.

The Constant score two years post-operatively was a mean of 12 points better in the acute trauma group and 11 points better in the late post-traumatic group than in the classical suture group.

We recommend this technique in patients where the tuberosity fragments are large enough to allow fixation with screws, washers and a toothed plate.

It is generally accepted that the results of replacement of the proximal humerus are worse following trauma than for osteoarthritis (OA) or rheumatoid arthritis. Difficulties with reconstruction of the rotator cuff and reattachment of the shoulder muscles are thought to be the main cause of these bad results.

The indications for replacement of the proximal humerus in traumatic cases are fractures which cannot be reconstructed, fractures with destruction of the joint surface and fracture dislocation with devitalisation of the head fragment. In these injuries, classified by Neer1 as three- or four-part fractures, the rotator cuff frequently remains attached to a fragment of the greater or lesser tuberosity. Methods of reconstruction usually involve suturing the bone fragments and rotator cuff to the proximal part of the stem of a prosthesis and the metaphysis. However, using these methods it is often difficult to restore the proximal humeral anatomy or to obtain stable fixation for early mobilisation. This is particularly difficult when the fragments of the tuberosity are severely comminuted and only held together by the rotator cuff. When the fragments of the tuberosity are intact, stable fixation to a prosthesis or to the diaphysis with a plate or screws is preferred. We have developed a system which allows the stable fixation of bone fragments using a perforated prosthetic stem, screws and when necessary, a plate to reattach the rotator cuff.

Patients and Methods

The prosthesis. Our aim was to provide stable fixation of the greater and lesser tuberosities to the proximal part of the shaft of the prosthesis and the diaphysis. In 1992 we began using a prosthesis with holes in the stem for screws, in positions based on an anatomical study of the proximal humerus (MMS prosthesis; Prospon Company, Kladno, Czech Republic (Fig. 1a) and M.I.L. Company, Limoges, France (Fig. 1b)). These holes enable the tuberosity fragments to be fixed to the prosthesis, either directly with screws and washers, or with the use of a toothed plate.

Patients. Between 1992 and 2003, the prosthesis was used in 76 consecutive patients, in 43 following acute trauma and in 33 for late post-traumatic indications (Table I). Our department is a specialised unit within the Trauma Centre of Motol Hospital in Prague. The majority of patients referred to us for this type of shoulder surgery are young patients.
capable of satisfactory co-operation during post-operative rehabilitation. There were no patients who were confined to bed, had major social problems or serious medical comorbidities. Glenoid replacement was not performed in any patient in this study.

Of the 43 patients in the acute trauma group, 23 had a three-part and 20 a four-part fracture, as classified by Neer,\(^1\) with displacement of the head fragment. A total of 12 patients had fracture dislocations. All these patients were treated within five weeks of injury. Separation of the main fragments was still possible by careful dissection at this time. Subsequently, however, such separation was impossible and the fragments had to be separated using a chisel or osteotome. The remaining 33 patients presented with pain and had unsatisfactory positioning of the fragments more than five weeks after injury (Table I). They were originally treated conservatively elsewhere and were referred for operative treatment.

The pre-operative evaluation of the displacement and the number of fragments was carried out using standard anteroposterior radiographs. If these did not provide sufficient information, a CT scan with three-dimensional (3D) reconstruction was used.

The decision as to which method of fixation was used depended on the type of fracture and the size and quality of the largest tuberosity fragment attached to the rotator cuff. Where the rotator cuff attachment was destroyed or the size of the largest fragment was less than 2 cm wide, we used the classical technique of suturing with non-absorbable stitches. In patients with larger tuberosity fragments and an intact rotator cuff attachment, we used our method of reconstruction with screws, washers and where necessary a toothed plate. It was, therefore, not possible to randomise the study because of the different indications for fixation.

A non-absorbable suture was used for reconstruction and fixation of the tuberosities in 26 patients, screws alone in 15 and screws with the toothed plate in 35. Our technique of fixation was used in 50 of the 76 patients.

**Surgical technique.** We use a standard procedure for the implantation of the prosthesis. The choice of the size of the head of the component in acute injuries is based on the size of the original humeral head. In late post-traumatic cases, the choice is determined by the tension of the soft tissues in order to achieve free movement of the shoulder joint. We position the prosthesis in the generally accepted position of 15\(^\circ\) to 30\(^\circ\) of retroversion.

If the tuberosity fragments and their attachment to the rotator cuff are not severely damaged we use the following procedure.

We avoid separating the rotator cuff from its bone attachments. Fixation of the greater tuberosity is carried out with a screw and washer or the toothed plate, depending on the size, shape and quality of the bone. The lesser tuberosity is always fixed using a cortical screw passing through the toothed plate, tuberosity fragment, prosthetic stem and diaphyseal cortex (Figs 2c and 2d). The same technique may be used without the plate, providing that the greater tuberosity fragment is large enough to cover the hole in the humeral shaft distally. The fragment of the lesser tuberosity is fixed using a similar technique with a screw and washer.

The reconstruction of the proximal humerus is completed with autograft from the humeral head. In particular, these grafts are used to restore the normal distance between the rotator cuff attachment and the centre of rotation of the shoulder (Fig. 3).
The classical technique of suturing with non-absorbable sutures and autografting is only used when osteosynthesis is not possible because the tuberosity is too severely damaged and only small bone fragments are attached to the tendon.

All our patients were treated for 3 to 12 months after operation by experienced physiotherapists. During the first three months all patients, irrespective of age, received daily physiotherapy.

All patients were followed up by one of two surgeons, neither of whom is an author or the main surgeon. Clinical and radiological evaluation was carried out at 3, 6, and 12 months after surgery, and annually thereafter. No patient was lost to follow-up.

We used the Constant score,\(^2\) without corrections, for the evaluation of functional outcome, to compare the results of the patients treated with our technique with those treated with non-absorbable sutures. We assessed the maximum elevation achieved by both groups. Rotation was measured according to the Constant score.

In the acute trauma group we could only review the post-operative data whereas in the late post-traumatic group the pre-operative and two-year post-operative scores were compared.

**Statistical analysis.** The results are presented as the mean range and standard deviation (SD). All parameters were normally distributed according to the Shapiro-Wilk test. Results between the two groups were compared by statistical software (Statistica; StatSoft Inc., Tulsa, Oklahoma) using the unpaired Student’s-t-test. A value of \(p < 0.05\) was considered to be statistically significant.

**Results**

**Acute trauma group** (Table II). The mean time between the injury and operation was five days (0 to 5). This interval was relatively long because some patients were secondary referrals.

Of the 43 patients in this group, 31 were treated by our technique of reconstruction and each was reviewed two years post-operatively. The mean Constant score in these 31 patients at follow-up was 65 (48 to 86). The maximum elevation was 95˚ (60˚ to 140˚). Eight patients (26%) had no pain and 23 (74%) had moderate pain during physical exertion. Four patients (13%) found their ability to work was limited because of the pain. No patient had pain at rest or during careful moderate movement.

The classical suture method was used in 12 patients and each was reviewed two years post-operatively. The mean Constant score at follow-up was 53 (23 to 75). The maximum elevation was 80˚ (40˚ to 100˚). Three patients (25%) had no pain, eight (67%) had moderate pain and one (8%)
severe pain. In seven patients (58%), pain limited their ability to work.

There was a statistically significant difference in the Constant scores between the two groups (Student’s t-test, p = 0.012), with lower scores for the classical suture group compared with those treated with our method of reconstruction.

Post-traumatic indications group (Table II). Our technique of reconstruction was used in 19 of 33 patients in this group and they were reviewed two years post-operatively. The mean Constant score at follow-up in these 19 patients was 59 (38 to 88) and the mean maximum elevation was 90° (55° to 130°). Seven patients (37%) had no pain, 11 (58%) moderate pain during physical exertion and one (5%) severe pain. Working ability was limited by pain in five patients (26%). In comparison to the pre-operative Constant score a mean improvement of 20 points (8 to 39) was achieved.

The classical suture method of reconstruction was used in 14 patients whose follow-up was at exactly two years. The mean Constant score at follow-up was 48 (20 to 71). The mean maximum elevation was 80° (30° to 110°). Five patients (36%) had no pain, six (43%) moderate pain and three (21%) severe pain. Working ability was limited by pain in eight patients (57%). Compared with the pre-operative Constant score, the post-operative score had improved by a mean of 12 points (6 to 21).

The data from both groups were compared using an unpaired t-test which showed significant variation between both groups (t-test, p = 0.038). The Constant scores of the group treated by the classical method were statistically
lower (t-test, p < 0.038) than those of the group treated by our technique of reconstruction.

Of the 43 patients in the acute injuries group, 34 (79%) returned to their original profession, as did 16 (70%) in the post-traumatic group. In the acute trauma group 23 patients played various sports, such as tennis, basketball and volleyball, non-professionally before the injury, of whom 11 were able to return to sport.

We did not attempt to analyse the difference between the types of reconstruction in these patients as they displayed variable levels of activity prior to their injury.

Between three and five years after operation, five patients in the classical suture group and three in the screw and plate fixation group had died. A further three patients in the classical group and two in the plate group died between five and ten years after operation.

Complications. There was one complication in screw plate fixation (acute trauma) group. The greater tuberosity fractured where it was fixed to the toothed plate during a manipulation under radiological control. The separated fragment was reattached using a transosseous suture.

In the post-traumatic reconstruction group, of 14 patients treated by the classical suture method, one developed anterior subluxation which was treated by strengthening the anterior rotator cuff and using a smaller humeral head to enable a secure soft-tissue repair. There were no infections and no radiological evidence of non-union.

Discussion

Satisfactory function of the shoulder joint after arthroplasty for fracture depends on secure fixation of both tuberosities.3-11 Detachment of the rotator cuff leads to shoulder instability. Moeckel et al.5 analysed the cause of instability in 10 of 236 cases treated by operation and found that rotator cuff failure was a major cause. We therefore believe that a shoulder joint prosthesis should enable easy and secure reconstruction of the rotator cuff and tuberosity fracture fragments, a view emphasised by Boileau and Walch.3 The technique we have described provides favourable conditions for union of the fragments to the diaphyseal fragment, thereby reducing the risk of their later displacement.

The maintenance of the distance between the rotator cuff attachments, the centre of rotation of the shoulder joint, and correct adjustment of the height of the prosthesis is an important technical feature of the reconstruction as has been shown in a biomechanical model.12 In order to restore normal anatomy in these complicated fractures we use cancellous bone graft from the humeral head placed under the greater and lesser tuberosity fragments before their fixation to the implant (Fig. 3).

We found that the Constant score two years after surgery for acute injuries treated with screw and plate fixation was better than for injuries treated by suture. This is similar to the results of other authors (Table III).6,13 During surgery it is clear that screws, with or without a plate, produce more rigid fixation and we believe that as a result, post-operative rehabilitation is both quicker and less painful.

The outcome following treatment of late injuries was worse than after acute injuries. However, the Constant score in this group improved compared with the pre-operative scores. We believe that it is appropriate to treat these severely disabled patients surgically and that, as with acute injuries, if possible, the use of screws, a plate and a perforated stem is the preferred method of fixation.

We did not observe a clear correlation between age and functional outcome. All our patients received extensive post-operative physiotherapy.

There were only two complications, one in the classical suture treatment group and one in the screw and plate fixation group. There was no incidence of mechanical failure or loosening of the implant.

The new technique of rotator cuff reconstruction which we present retains a larger proportion of the rotator cuff attachment to bone. We believe this provides a better opportunity for bony union with the proximal humeral diaphysis. However, in 26 of the 76 patients (34%) the tuberosity fragments were too small and too severely damaged to allow satisfactory fixation and we had to use the classical non-absorbable suture method. We were therefore unable to randomise the study. Another limitation of our study is that although we have compared the results of the two methods, the results may have been biased in favour of our method of reconstruction using screws and where necessary, a plate, because the indications for the treatment methods were different. Nevertheless, we believe that the results for our technique of reconstruction of three- and four-part fractures of the humerus show that when applicable, stable fixation of the fragments to the perforated shaft of the prosthesis can produce better results than the classical method of suture.

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References

Table II. The results of both groups and of the techniques used

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Table III. Constant scores for acute trauma in different studies

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