SEMICONSTRAINED ELBOW REPLACEMENT FOR DISTAL HUMERAL NONUNION

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We have reviewed 36 of 39 consecutive patients with an average age of 68 years who had semiconstrained elbow replacement for distal humeral nonunion at an average follow-up of 50.4 months (24 to 127). Of these, 31 (86%) had satisfactory results, three (8%) had fair, and two (6%) had poor results; 32 patients (88%) had moderate or severe pain before and 91% had no or only mild discomfort after the procedure. Motion had improved from a mean arc of 29° to 103° before operation to 16° to 127° after surgery. All five flail extremities were stable at last assessment.

There were seven complications (18%); two patients had deep infection, two had particulate synovitis, two had ulnar neuropathy and one had worn polyethylene bushes. Five of these seven, excluding the two with transient neuropathy, required reoperation (13%).

Joint replacement arthroplasty can be a safe and reliable treatment for this difficult clinical condition, seen most commonly in elderly patients. This is a significant advance, since repeated osteosynthesis has been shown to be ineffective in most patients.

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Nonunion is seen in about 5% of patients after distal humeral fractures (Sim 1985) and is known to occur more often in elderly women (Mitsunaga, Bryan and Linscheid 1982; Ackerman and Jupiter 1988). Two reports on treatment by secondary osteosynthesis have recorded unsatisfactory results in about 65% of cases (Mitsunaga et al 1982; Ackerman and Jupiter 1988). This incidence of poor outcome makes it reasonable to consider resection of the distal fragment and replacement of the elbow with a prosthesis device.

Early reports of this option using a tightly constrained or a custom joint replacement in small numbers of patients have shown disappointing results and high complication rates (Mitsunaga et al 1982; Figgie et al 1989). There appears to be no reliable solution to the problem, and little information is available about management.

Since 1982, we have used non-custom elbow replacement with the semiconstrained, modified Coonrad design (Zimmer Corp, Warsaw, Indiana) to treat patients with distal humeral nonunion. We now report our eight-year experience.

PATIENTS AND METHODS

The Coonrad semiconstrained elbow replacement device was developed in 1978. It is made of a titanium alloy with stems designed for cemented fixation in both humerus and ulna. The articulation is of UHMWPE with a cobalt-chrome pin secured with a split ring. It allows 7° to 10° of varus-valgus laxity at the captive articulation. In 1981, an anterior flange was added to provide extraosseous cortical fixation which resists posterior displacement and external rotation stresses on the humeral component. The flange of the prosthesis was designed to rest against the proximal part of the coronoid fossa (Fig. 1), and it was recognised that it could be used to manage distal humeral nonunion without the need of a customised device (Morrey 1985).

Our indication for replacement for distal humeral nonunion from its first use in 1982, was for patients over the age of 60 years and at least four months after injury. Consistently satisfactory results have allowed us to expand the indications, and we now include younger patients who are not suitable for secondary osteosynthesis because of the small size and osteoporotic nature of the ununited fragment.

From 1982 to 1990, 39 consecutive patients with distal humeral nonunion were treated by joint replacement. There were 34 women and 5 men and their mean age was 67.4 years (40 to 89). The nonunions were ten intercondylar (26%), four condylar (10%), four transcondylar (10%) and 21 supracondylar (54%). The average time from the original fracture to joint replacement was 21 months (4 to 70). Thirty-three of the 39 patients had had previous surgery the average being 1.6 procedures. Three of the patients (8%) had had a history of open drainage at some time during the treatment for the initial injury before referral to us. The possibility of infection associated with previous surgery was assessed by aspiration in these three patients and in five others with previous clinical courses suggestive of
The current Coonrad/Morrey elbow replacement prosthesis (a). Model of the distal humerus to show the position of the humeral component with removal of the condyles at the level of the typical fracture nonunion (b). The anterior flange rests over the roof of the coronoid fossa (c).

Operative technique. The patient is supine on the operating table with a bolster under the scapula. A tourniquet is applied and the arm is brought across the chest. A posterior skin incision is preferred but if an incision has been previously used to fix the fracture, this scar is reopened. The ulnar nerve is identified at the triceps in every case, and dissected sufficiently to allow it to be protected throughout the operation.

The triceps is left intact, and the exposure continues medially to release the flexors, pronator teres and medial collateral ligament from the medial epicondyle of the fractured fragment (Fig. 3a). All hardware is removed from the medial aspect of the distal humerus and Kocher’s interval is identified and entered. Triceps is elevated from the posterior and the lateral aspects of the humerus, and any other fixation devices are removed. The extensor origin and the lateral collateral ligament complex are then elevated and removed from the lateral epicondyle of the ununited fragment (Fig. 3b).

The fracture fragment or fragments are then removed either from the medial or the lateral aspect of the triceps (Fig. 3c). This provides excellent exposure of the distal humerus and good access for preparation for the insertion of the humeral component (see Fig. 1a). The ulnar notch is exposed by rotating the forearm, usually from a lateral to a medial direction. The ulnar canal is then prepared.

The ulnar component is inserted first. A portion of bone is taken from the ununited segment and placed behind the flange of the humeral implant as this is inserted down the canal. After the humeral implant has been inserted and the cement has cured, the joint is articulated. This technique preserves the triceps mechanism and allows immediate use of the joint.

Assessment. Of the 39 patients, three had died at 4, 12, and 17 months after surgery from unrelated causes, but all had a functioning replacement at the time of death. The average follow-up for the remaining 36 was 50.4 months (24 to 127). Of these, 24 returned to the Mayo Clinic for review, four were assessed by local physicians, and eight responded...
to a questionnaire. All had radiographs at least two years after surgery, and evaluation was by the functional, clinical and radiographic standards which we have previously described (Morrey and Adams 1992), and which are outlined below.

**Pain.** Pain was rated as none, mild, moderate or severe and scored from a maximum of 45 points.

**Motion.** Range of motion was measured with a hand-held goniometer, pronation and supination being measured with the elbow at 90°. Scoring gave a maximum of 15 points for the flexion arc and five points for the rotation arc.

**Instability.** Instability was recorded as none, modest or severe. Modest instability was over 5° but less than 20° of varus-valgus excursion. Stability was given a maximum of 10 points.

**Function.** We recorded five specific activities of daily living and personal care both before and after surgery (Morrey et al 1981; Broberg and Morrey 1987). These included combing hair, feeding, hygiene, buttoning a shirt, and tying shoe laces; these were selected because they require a spectrum of motion and position and were recorded as possible or impossible, awarding five points for each.

**Performance index.** An overall performance index was obtained by addition: 90 points or better were considered an excellent result; 70 to 89 points were good; 50 to 69 points fair; and less than 50 points poor. Excellent or good outcomes were considered satisfactory. This rating index is the refinement of several prior attempts to describe and summarise elbow function accurately (Broberg and Morrey 1987; Morrey 1990; Morrey and Adams 1992) and is felt to be a precise reflection of the functional status of the arm.

**Statistical analysis.** Differences in continuous variables were analysed by a single two-sample t-test. The relationship between discrete variables was determined by the Wilcoxon signed-rank test. Differences with less than a 5% probability of chance were considered significant.

**RESULTS**

Of the 36 surviving patients, 24 (67%) had excellent results after the initial replacement procedure and seven (19%) had good results, giving satisfactory results in 86%. Three (8%) had fair and two (6%) poor outcomes. Seven patients had significant complications. These and the five reoperations are discussed later.

**Pain.** Before surgery, 32 of 36 (89%) had moderate or severe pain. Excluding two with deep infection, after surgery 31 of 34 (91%) had no or only mild discomfort (Table I). Most pain before surgery was associated with activity; after surgery, pain was generalised and poorly localised. These differences are statistically significant (p < 0.001).

**Motion.** The average arc of motion before surgery was 29° (0 to 60) of extension to 103° (60 to 140) of flexion. After surgery the mean extension was 16° (0 to 60) and mean flexion was 127° (95 to 150) (Figs 4 and 5). The mean arc of pronation was 47° (0 to 90) and of supination 57° (0 to 93). After surgery these arcs were 61° (40 to 90) and 72° (60 to 90) respectively. These improvements after surgery are statistically significant for both flexion (p < 0.001) and forearm rotation (p < 0.01).

**Instability.** Before surgery, moderate or severe instability was present in 12 (32%). After surgery, as noted below, two patients underwent resection arthroplasty after which one has moderate and the other gross instability. The remaining 34 of 36 (94%) with implants in place have no objective or subjective evidence of joint instability.

**Function.** The effect of the nonunion and of the joint replacement on function is shown in Table II. Before
Radiographs showing T-Y condylar nonunion in a 68-year-old woman. (a) Six years after replacement, the patient is painfree with motion from 20° to 135°. (b) There is maturation of the bone graft and good cement-bone interfaces.

Supracondylar nonunion with gross instability (a). Five years after joint replacement the patient has minimal pain, a stable arc of motion from 25° to 130° and all five daily functions are being performed (b). The cement-bone interface is good.

surgery the mean number of the five activities performed by the patients was 1.1; after surgery this was 4.8. This improvement in function may be considered a composite expression of pain, motion and stability and is highly significant statistically (p < 0.001).

Performance index. The distribution of the performance index is shown in Table III: the mean index changed from 51 points (47 to 70) to 92 (65 to 100) (p < 0.001).

Radiography. Two patients with deep infection and two who were revised for particulate debris were excluded. The mean radiographic follow-up in the remaining 32 was 44 months (24 to 72). Of these, two had an inadequate cement technique, not extending past the tip of the humeral component. None had progressive radiolucency. Two components had non-progressive, incomplete lucent lines around the proximal half of the humeral component measuring less than 2 mm. One ulnar component had a 1 mm non-progressive lucent line about the proximal one-third of the component. No patient had a mechanically loose implant. Of the 32 reviewed, 27 (84%) showed radiographic incorporation of the bone graft between the anterior prosthetic flange and the distal humeral cortex.

Complications. Seven patients (18%) in the overall group of 39 patients had complications. Two had deep infection and two developed particulate synovitis. There was ulnar nerve palsy in two: one had moderate motor impairment
Another patient had aggressive debridement and replacement of the polyethylene bushes. This implant remains in place but has become painful at four years; radiographs reveal osteolysis and implant removal has been recommended. The fifth reoperation was the replacement of worn bushes as noted above; at operation the implant was securely fixed and not loose as was suggested by the radiographs.

Two of the reoperations have restored satisfactory elbow function. The overall results therefore are 25 excellent (69%), eight good (22%), one fair (3%), and two poor (6%). Thus, 91% of the surviving patients have a satisfactory result at latest review.

DISCUSSION

There is little information on the management of patients who develop nonunion after distal humeral fracture (Mitsunaga et al 1982; Ackerman and Jupiter 1988; Helfet and Rosen 1989; Jupiter and Goodman 1992). The problem is difficult because most such patients are elderly, the fragment is osteoporotic and scarring tends to involve the articulating surfaces.

Two previous studies of the results of osteosynthesis for this condition have reported a very low incidence of satisfactory results. Mitsunaga et al (1982) reviewed 25 patients whose average range of motion at follow-up was 71°, with complications in 13 (52%) and requirement for additional procedures in ten (40%). These operations were for persisting nonunion in six, infection in two and nerve complications in two. Ackerman and Jupiter (1988) reported a satisfactory result in only seven of 20 patients. Both series report eventual union but residual pain and limited motion adversely influenced the final result.

Jupiter and Goodman (1992) describe a technically demanding but improved technique of osteosynthesis used in six patients with a mean age of 68 years. The arcs of motion were not as good as those obtained with replace-

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<th>Table II. Function before and after replacement of the elbow for distal humeral nonunion (see text)</th>
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<th>Table III. Performance indices before and after initial replacement</th>
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and the other sensory loss with greater than 10 mm two-point discrimination. One patient returned to heavy labour lifting 110 kg logs against repeated advice to the contrary; he required replacement of worn polyethylene bushes after 50 months (Fig. 6).

Reoperation. Five patients (13%) required reoperation. One of the patients with deep infection had a successful debridement and has remained free from infection after 30 months; the other had a resection arthroplasty. One patient with severe particulate synovitis was also treated by resection.

**Fig. 6a**
Condylar nonunion of six years' duration (a). Four years after replacement the patient noticed a 'grinding', after regular manual work lifting logs up to 110 kg. The bushes had worn but the cement-bone junction was intact (b). Revision surgery required simple debridement and replacement of the bushes (c).
ment, but satisfactory results were obtained in five (84%). They attribute the improvement to effective rigid fixation and the aggressive and complete release of contracted soft tissue, which is a consistent feature of distal humeral nonunion. They also emphasised the need to expose and protect the ulnar nerve.

The problems of residual pain and limited motion after osteosynthesis make joint replacement arthroplasty a reasonable option. Mitsunaga et al (1982) first reported its effectiveness, with good relief of pain and restoration of motion in all of their seven patients, but two developed early loosening and these authors did not encourage the use of first-generation, constrained, elbow replacements.

Figgie et al (1989) reported 14 replacements for this indication, using several different implants, including some which were custom-designed. They obtained a mean arc of flexion of 100° and excellent relief of pain in their 70% of successful cases. There were seven major complications (50%), although the infection rate (7%) was roughly comparable to the 5% which we report. Their failure rate of approximately 30% was considerably greater than ours.

These high complication rates are not surprising. The typical patient has had previous operations which increase the likelihood of a low-grade infection (Mitsunaga et al 1982; Figgie et al 1989). The presence of one or several old incisions should alert the surgeon to potential problems with wound healing; Figgie et al (1989) had wound complications in 21%. Our extensile exposure requires that potential skin problems be identified before surgery. In one of our cases the skin margins were dusky at three days, and a previously planned delayed latissimus dorsi flap was successful. Microvascular and other soft-tissue cover techniques may be needed as an integral part of the treatment.

Jupiter and Goodman (1992) point out and emphasise the vulnerability of the ulnar nerve. We had ulnar-nerve complications in two patients (5%) and one (7%) was reported after arthroplasty by Mitsunaga et al (1982). Both direct injury and post-traumatic scarring have been reported (Bryan and Bickel 1971; Ackerman and Jupiter 1988; Helfet and Rosen 1989; Sanders and Sackett 1990; Jupiter and Goodman 1992). We now identify and translocate the ulnar nerve when performing this or any elbow replacement.

We report a lower complication rate and better functional outcomes than those of previous authors, and consider that relief from pain is much more predictable than after osteosynthesis. No patient required revision for mechanical loosening, and this seems to justify the increased but cautious use of prosthetic replacement for this condition. Leaving the triceps in continuity is a specific advance in surgical technique since 1989: this allows immediate active joint motion without fear of disruption of a repair.

Resection and joint replacement should generally be reserved for patients over the age of 60 years (Morrey, Adams and Bryan 1991). For younger patients with no complicating factors we continue to use osteosynthesis with capsular release (Morrey 1990), as has been well described by Jupiter and Goodman (1992). With our technique of arthroplasty, the rapid recovery is of considerable value for the elderly patient, and advances in design and technique have made this a reliable procedure. Age, activity and the size of the fractured fragment are the three most important considerations in selecting the procedure, with due regard for potential complications. As always, results with either treatment improve with greater expertise.

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REFERENCES


