RECONSTRUCTION AFTER MALUNION AND NONUNION OF INTRA-ARTICULAR FRACTURES OF THE DISTAL HUMERUS

METHODS AND RESULTS IN 13 ADULTS

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We reviewed the results in 13 adults of secondary reconstruction of malunited and ununited intra-articular distal humeral fractures. Their average age was 39.7 years, and preoperatively all had pain, loss of motion and functional disability; the average arc of motion was only 43° and the average flexion contracture was 45°. Nine patients had ulnar neuropathy.

Elbow reconstruction, at an average of 13.4 months after the original injury, included osteotomy for malunion or debridement for nonunion, realignment with stable fixation and autogenous bone grafts, anterior and posterior capsulectomy and ulnar neurolysis. The elbows were mobilised 24 hours postoperatively. There were no early complications and all nonunions and intra-articular osteotomies healed.

After a mean follow-up of 25 months, the average arc of motion was 97° with no progressive radiographic degeneration. Ulnar nerve function improved in all cases and clinical assessment using the Morrey score showed two excellent, eight good and three fair results.

Reconstruction of intra-articular malunion and nonunion of the distal humerus in young active adults is technically challenging, but can improve function by restoring the intrinsic anatomy of the elbow.

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Intra-articular malunion or nonunion after a fracture of the distal humerus may be disabling. Loss of elbow motion is common because of articular deformity, intra- or extra-articular adhesions, or changes in the articular cartilage (Sim 1985; Ackerman and Jupiter 1988; Morrey 1990). There may also be pain, instability, weakness, or ulnar neuritis.

The direct surgical correction of intracapsular nonunion or malunion is difficult because of the complex architecture of the distal humerus, poor soft-tissue attachments to the articular surface, associated capsular contractures and the lack of space for internal fixation. Alternative methods of reconstruction, particularly in young or active patients may also be unsatisfactory (Beckenbaugh 1983; Rashkoff and Burkhalter 1986). The use of total elbow arthroplasty carries risks of loosening, dislocation and infection; this has limited its application to post-traumatic conditions, especially in active patients (Inglis and Pellicci 1980; Morrey et al 1981; Figgie et al 1989). Distraction and resurfacing arthroplasties have high complication rates and are technically demanding; preservation of the patient’s own joint is better (Morrey 1990).

We have reviewed our experience with the surgical correction of intra-articular nonunion or malunion of the distal humerus. Our aims have been realignment and stable fixation, but we regard elbow capsulectomy, ulnar nerve neurolysis (when required) and functional rehabilitation as being of equal importance.

PATIENTS AND METHODS

We have studied 13 patients with intra-articular malunion or nonunion of the distal humerus which required operative correction of the intracapsular deformity (Table I). Patients were selected for this treatment when they had sufficient bone stock for internal fixation, reversible articular pathology or capsular contracture, and were thought to be capable of undertaking vigorous post-operative rehabilitation. We excluded patients for reasons of advanced age, limited activity, bone loss, or irreversible...
Table I. Details of 13 patients with intra-articular malunion or nonunion of the distal humerus

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Side</th>
<th>Injury</th>
<th>Fracture type*</th>
<th>Initial treatment</th>
<th>Pre-op range of motion (degrees)</th>
<th>Ulnar neuropathy</th>
<th>Delay (mth)</th>
<th>Intra-articular pathology</th>
<th>Procedure</th>
<th>Bone graft</th>
<th>Follow-up (mth)</th>
<th>Post-op range of motion (degrees)</th>
<th>Elbow score</th>
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<tr>
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<td>34</td>
<td>M</td>
<td>R</td>
<td>Bicycle</td>
<td>B2</td>
<td>MUAt Cast</td>
<td>80 to 105</td>
<td>+</td>
<td>+</td>
<td>Malunion</td>
<td>Osteotomy</td>
<td>–</td>
<td>30</td>
<td>45 to 100</td>
<td>60</td>
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<tr>
<td>2</td>
<td>27</td>
<td>M</td>
<td>R</td>
<td>Fall</td>
<td>C1</td>
<td>ORIF† Cast</td>
<td>25 to 110</td>
<td>–</td>
<td>–</td>
<td>Nonunion</td>
<td>Medial and lateral plates</td>
<td>+</td>
<td>30</td>
<td>40 to 135</td>
<td>78</td>
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<tr>
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<td>25</td>
<td>M</td>
<td>L</td>
<td>Fall</td>
<td>C2</td>
<td>ORIF</td>
<td>5 to 120</td>
<td>–</td>
<td>–</td>
<td>Nonunion</td>
<td>Medial and lateral plates</td>
<td>+</td>
<td>30</td>
<td>20 to 135</td>
<td>89</td>
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<tr>
<td>4</td>
<td>50</td>
<td>F</td>
<td>L</td>
<td>MVA§</td>
<td>C1</td>
<td>ORIF</td>
<td>60 to 110</td>
<td>–</td>
<td>–</td>
<td>Nonunion</td>
<td>Medial and lateral plates</td>
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<td>48</td>
<td>15 to 130</td>
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<td>5</td>
<td>21</td>
<td>M</td>
<td>R</td>
<td>Hang-glider</td>
<td>C2</td>
<td>MUA Cast</td>
<td>40 to 45</td>
<td>+</td>
<td>+</td>
<td>Malunion</td>
<td>Osteotomy Plate</td>
<td>+</td>
<td>60</td>
<td>40 to 130</td>
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<td>6</td>
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<td>F</td>
<td>L</td>
<td>Fall</td>
<td>C1</td>
<td>ORIF Cast</td>
<td>60 to 110</td>
<td>–</td>
<td>+</td>
<td>Malunion</td>
<td>Osteotomy Plate</td>
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<td>L</td>
<td>Fall</td>
<td>B3</td>
<td>Cast</td>
<td>40 to 85</td>
<td>–</td>
<td>–</td>
<td>Malunion</td>
<td>Osteotomy Screws</td>
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<td>16</td>
<td>10 to 120</td>
<td>95</td>
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<tr>
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<td>F</td>
<td>R</td>
<td>MVA</td>
<td>C3</td>
<td>ORIF Cast</td>
<td>20 to 100</td>
<td>+</td>
<td>+</td>
<td>Malunion</td>
<td>Osteotomy Plates</td>
<td>+</td>
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<td>5 to 130</td>
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<td>9</td>
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<td>F</td>
<td>L</td>
<td>Fall</td>
<td>B3</td>
<td>ORIF Cast</td>
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<td>+</td>
<td>+</td>
<td>Malunion</td>
<td>Osteotomy Plates</td>
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<td>F</td>
<td>L</td>
<td>Snowmobile</td>
<td>C3</td>
<td>ORIF Cast</td>
<td>60 to 75</td>
<td>–</td>
<td>+</td>
<td>Lateral malunion</td>
<td>Osteotomy Plates</td>
<td>+</td>
<td>14</td>
<td>35 to 100</td>
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<td>62</td>
<td>F</td>
<td>L</td>
<td>MVA</td>
<td>C3</td>
<td>ORIF Cast</td>
<td>30 to 60</td>
<td>–</td>
<td>+</td>
<td>Medial nonunion</td>
<td>Medial and lateral plates</td>
<td>+</td>
<td>12</td>
<td>25 to 125</td>
<td>97</td>
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<tr>
<td>12</td>
<td>36</td>
<td>M</td>
<td>L</td>
<td>Fall</td>
<td>C2</td>
<td>ORIF Cast</td>
<td>45 to 90</td>
<td>+</td>
<td>+</td>
<td>Lateral malunion</td>
<td>Osteotomy Plates</td>
<td>+</td>
<td>12</td>
<td>30 to 140</td>
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<tr>
<td>13</td>
<td>55</td>
<td>F</td>
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<td>ORIF Cast</td>
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<td>+</td>
<td>+</td>
<td>Nonunion</td>
<td>Medial and lateral plates</td>
<td>+</td>
<td>12</td>
<td>30 to 110</td>
<td>85</td>
</tr>
</tbody>
</table>

† manipulation under anaesthesia
‡ open reduction, internal fixation
§ motor-vehicle accident
articular damage; they were treated by either total elbow arthroplasty or a distraction/resurfacing arthroplasty.

There were seven women and six men with an average age of 39.7 years (17 to 62); the dominant arm was involved in seven. Their occupations included office work (6), manual labour (4), further education (2) and engineering (1). Six of the original fractures resulted from a fall, three from a motor-vehicle accident and one each from hang-gliding, skiing, bicycling and snowmobile accidents. Ten were type C-complete articular fractures (three C1, three C2, four C3) on the AO/ASIF classification (Müller et al 1987); three were type B-partial articular fractures (one B2 and two B3). Three of the original fractures were open. Initial management had been by open reduction and internal fixation in ten and nonoperative treatment in three. Eight of the ten patients treated operatively had been immobilised in an above-elbow cast for an average of six weeks postoperatively.

The patients were referred to one of our centres at an average time of 13.4 months after their injury (3 to 60). Five had intra-articular nonunion, six had intra-articular malunion and two had a combination of malunion and nonunion (Table I). All 13 complained of pain and disability, mainly due to limited arcs of motion and nine had altered sensibility in the ulnar nerve distribution.

Six patients had varus or valgus deformity. The average arc of elbow motion was 43° (5 to 115) and the average elbow flexion was 88° (45 to 120). All had flexion contractures; the average was 45° (5 to 80). Six had elbow instability. Nine showed loss of light touch discrimination in the ulnar nerve distribution using the Semmes-Weinstein monofilament test, and six of these had weakness of the intrinsic muscles of the hand and of flexor digitorum profundus to the little finger. Ulnar nerve dysfunction at or above the level of the cubital tunnel was confirmed by EMG and nerve-conduction velocity measurements in all nine. Preoperative ulnar neuropathy was noted in two of three who had been treated conservatively, and seven who had had primary operative treatment. Heterotopic bone formation was seen radiographically in eight patients, two of three treated conservatively and six of ten treated operatively. This was mild, had not produced bony ankylosis, did not correlate with reduced elbow motion, and never influenced the operative plan.

Operative technique. The procedure combined extensile exposure, anterior and posterior capsulectomy, and reconstruction of intra-articular pathology, with mobilisation and neurolysis of the ulnar nerve when this was indicated.

A lateral decubitus position was used, with the affected side up and a tourniquet on the upper arm. The posterior skin incision incorporated previous skin incisions whenever possible. In 11 cases, we used a transolecranon approach, and in two with lateral column damage we used an extensile lateral approach. Olecranon osteotomy was made in a chevron fashion, with care to preserve the ulnar attachments of the medial and lateral collateral ligaments.

The ulnar nerve was then isolated, usually by identifying it proximally where it appeared beneath the edge of the triceps. In all cases, it was encased in the periarticular fibrosis. Nine patients required external neurolysis, using loupe or microscopic magnification. The nerve was dissected distally for about 6 to 8 cm in the flexor/pronator muscles, taking care to identify and protect the branches to the flexor carpi ulnaris. At the end of the operation, the nerve was placed in a tension-free, subcutaneous position.

Posterior periarticular adhesions were excised together with the fibrotic posterior capsule. Access to the anterior capsule was gained by mobilising the soft tissues along the lateral aspect of the distal humerus, while identifying and preserving the lateral collateral ligament complex. In some cases with intra-articular nonunion, the anterior capsule could be approached through the nonunion site.

The skeletal deformity was then delineated by dissection of soft tissues, with removal of any retained hardware. The exact anatomy of the intra-articular nonunion could only be defined after debridement of all synovial tissue. Intra-articular malunions were osteotomised through the original fracture lines, the fragments reduced to more anatomical alignment, and provisionally fixed with Kirschner wires. The distortion of the distal humerus made it necessary to use malleable templates to determine the best position for the plates. In the four cases in which malunion or nonunion involved only one column (two medial and two lateral), fixation with one or two plates was confined to that column. In one case the osteotomy of a malunited articular shear fracture was fixed with screws alone. Eight patients required two plates, one medial and one lateral; by choice, the first was placed on the posterior aspect of the lateral column extending distally to the posterior margin of the capitellum. The second plate could then be placed at right angles to the first, and bent distally to extend around the medial epicondyle. Screws were placed in several directions in the distal articular fragments to provide an interlocking network. One patient required the addition of a third plate along the lateral column. In 11 of the 13 cases, autogenous bone graft from the ipsilateral iliac crest was placed in the osteotomy or nonunion sites.

Before repair of the olecranon osteotomy, the elbow was tested for range of motion and stability of fixation; we aimed at a functional range from 30° to 130° before closing. The olecranon osteotomy was then fixed with two oblique Kirschner wires or 4.0 mm, partially threaded, cancellous screws and a figure-of-eight tension band wire.

After tourniquet release, haemostasis was achieved by electrocautery before closure in layers over a drain. Well-padded posterior splints were used for 24 hours before rehabilitation started. Each patient had carefully supervised physiotherapy including active flexion, gentle passive flexion and gravity-assisted extension from the first postoperative day. Active extension was started at

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approximately three weeks. Patients were reviewed weekly and turnbuckle splints were used to improve flexion and extension in selected cases once bone union had occurred.

Final evaluation was by the senior authors (JJ, CC) and included range of motion, strength and stability testing of the elbow and motor and sensory testing of the ulnar nerve. Anteroposterior, lateral, and oblique radiographs were obtained to assess bone union, and any evidence of avascular necrosis or post-traumatic arthritis. The results were recorded on the elbow functional evaluation scale of Morrey and Bryan (1985), which includes pain, strength, stability, function and patient satisfaction. On this scale a score of 95 to 100 is excellent; 80 to 95 is good; 50 to 80 fair; and 50 points or less is recorded as a poor result.

RESULTS
The average follow-up was 25 months (12 to 60). All 13 patients had union of intra-articular osteotomies or nonunions: no patient required any further procedure to obtain union. All 11 olecranon osteotomies united. There were no early postoperative complications but one patient required outpatient removal of prominent Kirschner wires from the olecranon.

All patients felt that they had gained some improvement. Six were painfree, four had discomfort on exertion but did not require medication, and three occasionally required analgesics after activity. No patient had pain at night or at rest. The nine patients with preoperative ulnar dysfunction all had some improvement. Light touch discrimination by the Semmes-Weinstein monofilament test was improved in all as was strength in the intrinsic muscles of the hand and flexor digitorum profundus to the little finger.

Range of motion at the elbow had improved by an average of 54° to an average arc of 97° (55 to 125). The average postoperative flexion was 124° (100 to 135), and the average flexion contracture was 27° (5 to 45). Forearm rotation was normal in all except one who had an ipsilateral ulnar malunion and lacked 45° of pronation. There was no deterioration in range of motion during follow-up. No patient had any subjective instability, nor could any medial or lateral instability be detected.

All patients were able to return to their previous occupations, including the three manual labourers. Nine patients returned to previous recreational activities which included canoeing, tennis and golf; the other four reduced their level of activity because of discomfort after exertion.

One patient who had an intra-articular osteotomy for malunion showed radiographic changes consistent with avascular necrosis in part of the trochlea, but this did not progress over a two-year follow-up. Three patients had evidence of mild pre-existing post-traumatic arthrosis, but there was no evidence of progressive joint degeneration in any of the follow-up radiographs.

On the elbow rating scale of Morrey and Bryan (1985) the elbow score ranged from 60 to 97 with an average of 83, a 'good' clinical result. There were two excellent, eight good and three fair results.

ILLUSTRATIVE CASES
Case 7. A 17-year-old man injured his left non-dominant arm in a fall, sustaining an intra-articular fracture of the distal humerus. He was treated elsewhere in a long-arm cast for six weeks followed by prolonged physiotherapy.

On referral after six months his total arc of motion was 45° (40 to 85), and radiographs showed malunion of an intra-articular shear fracture that included the capitellum and a portion of the trochlea (Figs 1a and 1b). The fragment had been displaced proximally and rotated laterally.

Through an extended lateral incision, soft tissues were stripped subperiosteally both anteriorly and posteriorly. The lateral collateral ligamentous complex was detached and tagged for reattachment. A thin saw blade was used to cut through the original fracture line; the articular fragment, which was devoid of soft-tissue attachment, was replaced into its anatomical position and held with two intra-articular Herbert screws and a 3.5 mm screw. Iliac-crest bone graft was added. Intraoperative radiographs confirmed the good position, and the intraoperative range of motion was from 0° to approximately 130°. The lateral ligamentous complex was reattached by suture through drill holes.

A well-padded posterior splint was removed at 24 hours and physiotherapy started.

At 16 months the range of motion was from 10° to 120° with full forearm rotation, and the elbow rating was 95, confirming an excellent clinical result. Radiographs show maintenance of the reduction with no evidence of avascular necrosis or arthritis (Figs 1c and 1d).

Case 9. A 54-year-old woman fell on her left non-dominant arm sustaining an intra-articular distal humeral fracture, which was treated by open reduction and internal fixation followed by an above-elbow cast for four weeks. At six months she had a 60° flexion contracture with only 20° flexion. She also had ulnar nerve dysfunction. Radiographs showed intra-articular malunion of the lateral column (Figs 2a and 2b).

Through the scar of the old posterior incision, the ulnar nerve was dissected free of dense scar tissue using loupe magnification, then transposed into the anterior soft tissues. Lateral subperiosteal dissection allowed the lateral collateral ligament to be detached from the humerus and tagged. Extensive resection of intra- and periarticular adhesions, both anteriorly and posteriorly, was required and the tip of the olecranon was excised to improve motion.

The malunion site showed a 6 mm intra-articular displacement through the lateral trochlea. Old hardware was removed, and an oscillating saw used to make an
oblique intra-articular osteotomy starting at the articular surface and exiting through the lateral column to recreate the original fracture line (Fig. 2c). Reduction was stabilised with two 3.5 mm pelvic reconstruction plates, one laterally and one posteriorly and several screws. Excellent stability was achieved, giving an intraoperative range of motion of 20° to 130°. The lateral collateral ligament was reattached through drill holes. Active range of motion exercises began at 24 hours, with the use of knuckle-duster splints for the hand. At eight weeks, after osteotomy union, turnbuckle bracing was used to improve extension.

Ulnar nerve function improved over three months with diminution of pain, improvement of pinch and grip strength and return of normal sensation. At 18 months the patient has returned to work and has motion from 25° to 120°. Her elbow score is 83, a 'good' clinical result. Radiographs show healing of the osteotomy in good anatomical alignment (Figs 2d and 2e).

Case 5. A 21-year-old man injured his dominant right arm in a hang-gliding accident, sustaining an intra-articular C2 distal humeral fracture. An associated brachial artery injury was repaired and a closed reduction was followed by wearing of a cast for 12 weeks.

Four months after the injury the elbow was very stiff, with only a 5° arc of motion. An associated ulnar neuropathy caused numbness on the ulnar side of the hand and intrinsic muscle weakness. Radiographs showed severe intra-articular malunion (Figs 3a and 3b).

Through a posterior approach the ulnar nerve was

A 17-year-old man had malunion of an intra-articular shearing fracture which limited elbow motion. Figures 1a and 1b – Radiographs showing the malunion; a double line (arrow) reveals the displacement of the trochlea. Figures 1c and 1d – At 16 months after osteotomy and screw fixation, anatomical alignment has allowed full functional recovery.
A 54-year-old woman had an intra-articular fracture of the humerus. Figures 2a and 2b – Radiographs show malunion involving primarily the lateral column with valgus angulation of the elbow. Figure 2c – An operative photograph showing the intra-articular osteotomy (arrow). Figures 2d and 2e – At 18 months radiographs show union of the osteotomy with maintenance of anatomical alignment.

freed of dense adhesions involving the medial intermuscular septum and the fascia over flexor carpi ulnaris, and then transposed to a tension-free position anteriorly. A chevron olecranon osteotomy allowed extensive adhesions to be removed and the malunion site to be identified. There were two main components of the malunion, with posterior displacement of the extra-articular portion and rotation of the capitellum and trochlea towards each other, severely compromising elbow motion. Extensive periarticular adhesions were excised and the extra-articular malunion was osteotomised first and provisionally fixed with Kirschner wires. Intra-articular osteotomy was then performed to restore the relationship between the trochlea and the capitellum; this osteotomy was secured with 3.5 mm lag screws placed through two 3.5 mm pelvic reconstruction plates, one posterolaterally and one medially. Iliac-crest bone graft was placed at the osteotomy sites. The olecranon osteotomy was closed with two 4.0 cm screws and a figure-of-eight tension band wire. Recovery was uneventful and the patient returned to work as an industrial chemist. His range of motion was 40° to 130° and his elbow score was 77 points. There had been no decrease in elbow motion at 60 months and no degenerative changes (Figs 3c and 3d).

DISCUSSION
Nonunion or malunion of the articular surface of the distal humerus not only distorts this complex articulation, but also causes severe periarticular fibrosis and in many cases compromises ulnar nerve function. Our therapeutic approach aimed to address each of these problems and restore functional capacity (Mitsunaga, Bryan and Linscheid 1982). The potential advantages of reconstruc-
A 21-year-old man sustained a comminuted, intra-articular fracture associated with a brachial artery injury. The fracture was treated by manipulation under anaesthesia and a long-arm cast. Figures 3a and 3b—Radiographs at the time of referral four months later show redisplacement and both intra-articular and extra-articular malunion, allowing only 5° of motion. Figures 3c and 3d—After stable internal fixation with restoration of both intra-articular and extra-articular alignment and iliac-crest bone grafting of the osteotomy sites.

Nine of our patients had clinical dysfunction of the ulnar nerve, with significant disability. Most authors recommend elevation of the nerve from the cubital tunnel at the time of surgery for fractures of the distal humerus (Müller et al 1979; Mehne and Jupiter 1992), but failure to mobilise the nerve fully, both proximally and distally, risks the development of fibrosis, especially when the elbow is immobilised postoperatively or fails to regain a functional arc of motion. It is therefore important to perform extensive mobilisation, from the medial antebrachial fascia proximally to the fascia of the flexor carpi ulnaris as far as 6 cm distal to the cubital tunnel (Jupiter and Goodman 1992). We found an encouraging quality of recovery of both sensory and, in some cases, motor function after neurolysis. This means that the surgeon must be prepared for a tedious and complex dissection. Surgical magnification and microsurgical instruments are essential, since some cases will require an internal neurolysis before normal fascicular patterns can be identified (Dellon 1989).

The substantial improvement in the arc of elbow motion was largely due to excision of periarticular fibrosis. We took special care to maintain the medial soft-
tissue attachments to the distal humerus and to reattach the lateral collateral ligament complex where detachment had been necessary to provide surgical access to the anterior capsule (Morrey 1990). There have been no studies which have specifically evaluated the contribution of the osseous architecture of the distal humerus (King, Morrey and An 1993), but the inherent stability of the elbow depends both on the articular congruity of the joint, and on its associated soft-tissue restraints, especially the medial and lateral ligamentous complexes (Morrey et al 1981).

Accurate restoration of the shape of the ulnotrochlear and radiocapitellar joints gives primary resistance to translational forces, and rotatory forces on the ulna are dissipated primarily by the coronoid against the anterior portion of the trochlea. Valgus stresses are resisted by the medial collateral ligament, and, to a less extent, the radial head. Varus stress is dissipated by articular congruity, the lateral collateral ligament and the capsule (King et al 1993). The restoration of soft-tissue restraints and accurate reconstruction of the trochlea in relation to the olecranon, restore a large degree of intrinsic stability, and we consider this to be primarily responsible for the continued excellent function and lack of radiographic degeneration in our group of patients. The improved range of motion also decreases the leverage placed by a stiff elbow on the nonunion or osteotomy sites during flexion and extension, which enhances early bony union (Müller et al 1979).

Our choice of internal fixation was tailored to meet the unique requirements of each case, but the general plan depended on advances in the understanding of complex articular trauma involving the distal humerus (Ackerman and Jupiter 1988). The metaphyseal bone of the distal humerus can provide excellent purchase for screws, even in chronic cases, and with the predictable purchase obtainable in the lateral and medial bony columns offers a number of options for placement of internal fixation. The Herbert screw was particularly useful in several cases to provide secure fixation of articular fragments.

Despite the extensive soft-tissue dissection required for the anterior and posterior capsulotomies and osteotomies, which sometimes yield articular fragments virtually devoid of soft tissue, we saw the development of avascular necrosis in only one patient (case 8) and this had not progressed after a two-year follow-up. Devascularised cortical bone usually suffers extensive necrosis, but this may not apply to metaphyseal bone, while cancellous bone recovers more quickly. This is possibly due to increased cellularity and faster revascularisation which result in the early formation of immature, woven bone (Schenk 1992).

Stable internal fixation allowed early, controlled motion in all our patients within 24 hours of surgery, contributing to the improved range of motion (Waddell, Hatch and Richards 1988). Case selection is vital because the patient must tolerate structured inpatient rehabilitation followed by supervised outpatient physiotherapy. Regular clinical review identifies patients who fail to make adequate progress, and turnbuckle splints were extremely effective in gaining flexion or extension in resistant cases (Morrey 1990).

Conclusions. Intra-articular malunion or nonunion of the distal humerus can be well treated by restoration of the articular anatomy when this is technically feasible. This can give elbow stability, relieve pain, improve motion and in many cases restore ulnar nerve function.

Our results suggest that careful preoperative planning and meticulous technique can give articular congruity and delay and possibly prevent the development of post-traumatic arthritis, while restoring a functional arc of motion.

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

REFERENCES


