We treated 31 intra-articular fractures of the distal radius by arthroscopically-assisted reduction and percutaneous fixation with Kirschner (K-) wires. Tears of the triangular fibrocartilage (58%), scapholunate (85%) and lunotriquetral (61%) instability and osteochondral lesions (19%) were also treated. A total of 26 patients was independently reviewed at an average of 19 months. The mean pain score was 1.3/10, the range of movement 79% and the grip strength 90% of the contralateral wrist. Using the New York Orthopaedic Hospital score, 88% were graded excellent to good. On follow-up radiographs, 65% had no step and 31% had a step of ≤1 mm. Pain was significantly related to the size of the step. There was a significant difference in the incidence of persistent scapholunate diastasis and the Leibovic and Geissler grade (p < 0.01): I (0%), II (0%), III (42%) and IV (100%). We recommend anatomical reduction and acceptance of a step of <1 mm since the size of the step is related to the incidence of pain.

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Failure to reduce intra-articular fractures of the distal radius predisposes to pain, restricted movement and degenerative arthritis.1-5 Malposition is related to the radial height, radial angle, volar tilt and the accuracy of intra-articular reduction.1,2,6

Knirk and Jupiter1 found that radiological arthritis developed in 91% of wrists which had any degree of articular step and in all of those with a step greater than 2 mm. This has been confirmed by other authors.8,9

Open reduction and internal fixation of comminuted intra-articular fractures of the distal radius has been recommended, but this can be difficult since a dorsal and volar approach may be required.8,9 Exposure of the fracture strips the soft tissues with devascularisation of the bony fragments. Further capsular and ligamentous dissection is required to provide adequate exposure of the articular surface. This produces additional soft-tissue injury and may lead to postoperative stiffness or radiocarpal instability.2,8,10-12 Some surgeons have advocated limited open reduction which gives selective exposure of displaced articular fragments.8,11,12 Even with these techniques, complete visualisation of the articular surface is difficult. There have been many reports of the use of arthroscopy in the management of intra-articular fractures of the distal radius.8,11,12,14-18 It is less invasive and allows a magnified view of the articular surface as well as assessment of the triangular fibrocartilage (TFC), the scapholunate and the lunotriquetral ligaments. A high incidence of associated ligamentous injuries has been found in all studies. Culp and Osterman12 reported 27 patients who had been treated by arthroscopically-assisted reduction. There were ten excellent and 12 good results using the classification of Gartland and Werley.19 Pain, satisfaction and complications were not reported. Wolfe et al8 stated that six of their seven patients had an excellent result using the Gartland and Werley score, but did not mention whether any concomitant intracarpal injuries were present. Hanker15 described 77 patients in whom this method had improved the outcome in complex intra-articular fractures of the distal radius, but did not report any objective results. Other authors who reported arthroscopically-assisted reduction gave no objective results.11,15,18

Patients and Methods
We reviewed a consecutive series of 31 patients with intra-articular fractures of the distal radius which had been managed by arthroscopically-assisted reduction carried out by a single surgeon (GIB) between 1994 and 1996. A total of 25
patients, 9 men and 16 women (26 wrists) was available for review. Their mean age was 55 years (21 to 76) and the mean duration of follow-up was 19 months (8 to 27). There were 14 left and 12 right (1 bilateral) fractures. The dominant arm was involved in 16 patients. A low-energy injury, such as a simple fall, accounted for 13 fractures and a high-energy injury for 13. The mean time from injury to surgery was three days (0 to 10). The findings at operative arthroscopy were collected on standardised forms.

Operative technique

Arthroscopy. Arthroscopy of the wrist was carried out under general anaesthesia with a 2.7 mm 30° angle arthroscope using a standard technique by the 3-4, 6R, portals in the radiocarpal joint. The haematoma was evacuated from the joint using lavage and a motorised resector. The fractures and the soft-tissue injuries were assessed.

After distraction and closed reduction, fluoroscopy invariably revealed a small intra-articular step. Despite this, the degree of joint incongruity demonstrated at arthroscopy was surprising. It was not uncommon to find that the fragments were tilted in the sagittal plain, but this was not appreciated on lateral fluoroscopy because of the overlap of the ulna, scaphoid and lunate fossae.

Reduction of the fracture. The fracture was reduced using a five-level algorithm:

First-order technique, traction and closed manipulation. We found, at arthroscopy, that articular reduction was not achieved by these techniques alone.

Second-order technique, percutaneous K-wire manipulation. The Kapandji (intrafocal) technique uses K-wires placed into the fracture under fluoroscopy. These wires elevate, reduce and buttress the distal fragment. K-wires driven into larger fragments such as the radial styloid act as joysticks. In both of these techniques the wires are positioned under fluoroscopy, then manipulated as the distal articular surface of the radius is arthroscopically assessed (Fig. 1). The wires are advanced once anatomical reduction is obtained.

The ‘London technique’ was used in comminuted intra-articular fractures. K-wires were advanced through the distal ulna into the subchondral distal radius and withdrawn from the radial aspect so that they did not encroach on the distal radioulnar joint (Fig. 2). For the impacted fracture, placement of two K-wires, with fluoroscopic guidance, beneath the fragment to manipulate it free was usually successful.

Third-order technique, arthroscopic manipulation. An arthroscopic probe can be used to manipulate bony fragments, particularly those involving the lunate fossa. Alternatively, the K-wire is inserted into the joint and through the articular surface of the sigmoid notch, after debridement of the torn TFC, and withdrawn from the radial side of the wrist until it is invisible from the joint.

Fourth-order technique, limited open techniques. These are required if the above procedures are unsuccessful or are potentially unsafe. Occasionally, a limited open reduction will be required and an elevator introduced under the depressed fragment. Arthroscopically-assisted reduction can then be carried out on the elevated fragment.

In patients who had a large volar fragment, a limited anterolateral and/or anteromedial incision was made over the distal radius. On the ulnar aspect, the plane of dissection was between the ulnar neurovascular bundle and the flexor tendons of the fingers. On the radial aspect the approach was through the bed of the flexor carpi radialis tendon. The exposure required had to be large enough to insert safely two K-wires into the fragment. Under arthroscopic vision, one K-wire joystick was manipulated until an anatomical reduction was obtained. The other wire was then advanced into the shaft of the radius. Both wires were then withdrawn from the dorsal aspect so that none remained on the volar aspect of the wrist (Fig. 3).

Fifth-order technique, open procedures. If all of the above techniques proved futile then an open reduction was required.

Fluoroscopy. Fluoroscopy was valuable to ensure satisfactory insertion and positioning of the K-wires. It is used to confirm the metaphyseal reduction, restoration of radial height, volar tilt and the radial angle but, in our experience, has not been accurate enough to assess the articular reduction. Assessment of the stability of the fixation was carried out dynamically by gentle manipulation of the fracture under fluoroscopic control in two planes. Extra fixation, either percutaneous or external, was used if required.

Methods of fixation. Often more than one technique was used to obtain stability. Fixation using percutaneous K-wires employed the trans-styloid technique of Mah and Atkinson (5 wrists), the Kapandji intrafocal method (12 wrists) or a hybrid of both of these procedures (5 wrists). The volar pinning approach (8 wrists) and the London technique (3 wrists) were used in conjunction with other methods. An external fixator was used as a neutralising device in 13 patients. Others were fitted with a moulded below-elbow plaster slab. Fixation of the ulnar styloid was undertaken in one patient. No bone grafts were used.

Management of intracarpal injuries

Radiocarpal arthroscopy. Findings at radiocarpal arthroscopy included tears of the TFC complex in 15 patients (58%), which were graded using Palmer’s classification.

There were 12 class-1D acute tears, with avulsion from the radius (80%), one class-1A tear (acute tear, with a central perforation), one class-1B tear (acute tear, with ulnar avulsion) and one combined class-1B and class-1D lesion. Nine tears were debrided and the class-1B tear was sutured using an arthroscopically-assisted technique with an epidural needle. Small tears, which were not unstable to probing, were not debrided or sutured.

Midcarpal arthroscopy. Using midcarpal arthroscopy, scapholunate and lunotriquetral instability was graded using the arthroscopic classification of Leibovic and Geissler. The scapholunate joint there were two cases of grade I, one of grade II, 19 of grade III and one of grade IV, and for
K-wires positioned into or below the bony fragments are manipulated under arthroscopy.

Figures 2a and 2b – For the ‘London technique’ K-wires are advanced through the distal ulna into the subchondral distal radius and withdrawn from the radial aspect so that they do not encroach on the distal radioulnar joint.
the lunotriquetral joint the numbers were 5, 1, 10 and 0, respectively. Patients with instability were treated by arthroscopically-assisted reduction and percutaneous pinning of these joints using two 1.6 mm K-wires (Fig. 4). Scapholunate pinning was undertaken in 19 patients and lunotriquetral fixation in ten.

Osteochondral lesions of the capitate (4) and hamate (1) were arthroscopically debrided. Plain radiographs did not show these injuries.

Postoperative management. This consisted of a supervised programme of mobilisation. The fixators and the K-wires were usually removed six weeks after operation, but

Figures 3a and 3b – The volar pinning technique uses a limited volar approach. K-wires are placed in the fragment and manipulated under arthroscopy. Once the reduction is obtained the wire is withdrawn from the dorsal aspect.

Joystick K-wires in the scaphoid and lunate are manipulated to reduce the scapholunate interval under arthroscopic vision. Prepositioned K-wires in the scaphoid are advanced into the lunate.
delayed until eight weeks in patients with more complex fractures (mean 7.14 weeks).

**Postoperative evaluation**

**Clinical.** At the final follow-up an independent functional, clinical and radiological assessment was completed by one of the authors (JAM). The patients were asked about satisfaction and function. The pain score was measured on a visual analogue scale in which zero indicated no pain and ten the worst conceivable pain. The median, ulnar and the superficial cutaneous branches of the radial nerve were examined.

Movement at the wrist was measured with a goniometer. Grip strength was recorded using the Jamar grip dynamometer at the second position and pinch strength using the baseline pinch dynamometer.

The results were graded using the New York Orthopaedic Hospital (NYOH) score and the system of Gartland and Werley.

**Radiological.** Radiographs taken before operation and at follow-up were examined independently for the height and angle of the radius and articular incongruity compared with the contralateral wrist. The fractures were classified using the Frykman and the AO systems. The final films were assessed for articular incongruity and arthritis, as described by Knirk and Jupiter. Articular incongruity was graded as: 0, no step; 1, 1 to 2 mm step-off; 2, 2 to 3 mm step-off; and 4, >3 mm step-off. We subclassified grade 0 into no step or a step of ≤1 mm.

Arthritis was graded as: 0, none; 1, slight narrowing of the joint space; 2, marked narrowing; and 3, bone on bone and formation of osteophytes and cysts.

**Statistical analysis.** The correlation between the categorical outcomes as judged by the scoring systems and the categorical predictors of intracarpal injuries was determined by Fisher’s exact test. We used the Kruskal-Wallis test to correlate the categorical outcomes with abnormally distributed predictors, such as radiological assessment, and abnormally distributed outcomes including grip, range of movement and pain. Spearman rank correlations were used for abnormally distributed outcomes and predictors.

**Results**

**Preoperative radiography.** All patients had a preoperative intra-articular step of more than 2 mm. Two patients had >10° of volar angulation and 14 had >10° dorsal angulation. The remaining patients had a ‘burst’ pattern of the fracture in which the fragments were splayed out in the transverse plane, usually in a dorsoradial direction. In this pattern, the proximal extent of the fracture is close to the articular surface, with all the force having been dissipated on to the articular surface and distal metaphysis. Arthroscopy usually revealed the four-part fracture described by Melone. The ‘burst’ pattern should not be confused with the ‘dye-punch’ fracture of the lunate fossa.

There were 13 Frykman type-VII fractures and 13 type VIII. All cases therefore had involvement of the sigmoid fossa. The fractures classified by the AO system are shown in Table I.

<table>
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<tr>
<th>AO classification</th>
<th>NYOH classification</th>
<th>Gartland and Werley classification</th>
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<td>1 excellent</td>
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**Outcome.** A total of 23 of the 25 patients (92%) was satisfied with their results. The mean residual pain score was 1.3 on a visual analogue scale of 0 to 10. Most patients had no pain and in some it was intermittent.

The mean active range of movement in the affected wrists was: supination 84° (88% of the opposite side), pronation 78° (89%), flexion 57° (74%), extension 56° (78%), radial deviation 14° (71%) and ulnar deviation 26° (78%). All patients had full flexion at the metacarpophalangeal and the interphalangeal joints. There was a significant decrease in the final rotation of the forearm with increased preoperative dorsal angulation (p < 0.05). The mean grip strength was 36 kg (90%). The mean cumulative grip strength (grip plus pinch grip) was 87% of the contralateral side, and the cumulative pinch strength (precision, key and chuck grips) averaged 88%.

Using the NYOH score, excellent to good results were obtained in 88% of the patients. In the Frykman-VII fractures the score was 100% and in Frykman-VIII fractures 77%.

Using the Gartland and Werley score, excellent to good results were obtained in 70% of the patients. In Frykman-VII fractures the score was 85% and in Frykman-VIII fractures 54%.

**Postoperative radiography.** In 17 wrists (65%) there was no intra-articular radiocarpal step (Fig. 5), in eight (31%) there was a step ≤1 mm, and in one a step between 1 mm and 2 mm. The last patient had a poor result on both wrists.
grading systems and was the only one with severe pain. There was a significant difference (p < 0.05) in the incidence of pain (VAS > 2) for the patients with no step (18%), ≤1 mm step (38%) and >1 mm step (100%).

There were five patients who had slight narrowing of the joint space but no patient had marked narrowing, bone-on-bone or formation of osteophytes or cysts. The narrowing of the joint space occurred without articular incongruity and is likely to reflect the severe articular injury which occurred at the time of the fracture.

Compared with contralateral radiographs, three patients had a volar tilt of ≥10°, two had a dorsal tilt of >10° and all other patients had a normal volar tilt to within 10°. All but one patient had correction of the radial height to within 2 mm. These radiological variables were not significantly related to outcome.

There was no instability at the distal radioulnar joint. There were 12 fractures of the ulnar styloid of which seven developed nonunion. Seven also had tears of the TFCC, of which six were radial and one was central. One patient had a comminuted fracture of the distal ulna.

Of the 19 patients with scapholunate instability managed by K-wire fixation, nine had a residual diastasis of ≥3 mm. There was a significant difference in the incidence of persistent diastasis and the Leibovic and Geissler classification (p < 0.01); grade I (0%), II (0%), III (42%) and IV (100%).

Complications. Before the development of our technique of volar pinning, one patient had loss of reduction due to comminution of the volar cortex which was managed by open reduction and application of a volar buttress plate. One patient developed acute postoperative compression of the median nerve which was treated by prompt release. No patient developed a forearm compartment syndrome.

Seven patients with external fixators had infection of the proximal pin sites. This high incidence of infection may be related to movement of the soft tissues over the pins as part of the aggressive rehabilitation undertaken. We now no longer use this and have noticed a decreased incidence in these infections. Four patients had paraesthesiae of the superficial branch of the radial nerve. This may be due to neurapraxia related to the insertion of the K-wires, since all external fixators were applied with an open technique to the forearm and second metacarpal. At the final review, there was no evidence of residual infection or paraesthesiae.

A radioulnar synostosis developed in one patient who had a comminuted fracture of the distal radius (AO C3.3) and of the distal ulna which extended to the diaphysis (Fernandez type 3). Porter and Tillman reported two similar cases in their series.

Discussion

In 1814 Abraham Colles stated “that the limb will at some remote period again enjoy perfect freedom in all its motions, and be completely exempt from pain.” In 1986, Knirk and Jupiter demonstrated that articular incongruity of more than 2 mm leads to an incidence of osteoarthritis of the radiocarpal joint of 100%. Melone reported that articular separation of fragments of as little as 2 mm gave rise to persistent and progressive incongruity of the joint with a high probability and often rapid development of degenerative arthritis. Other authors have also echoed the importance of restoration of articular congruity to avoid osteoarthritis.

The work of Knirk and Jupiter and Melone has resulted in acceptance of a step in the articular surface up to 2 mm. We have demonstrated that the incidence of pain is significantly related to the size of the step. Patients with no step, ≤1 mm step and >1 mm step had an incidence of pain of 18%, 38% and 100%, respectively. We believe that the principal aim of managing intra-articular fractures should be to restore the normal anatomy, aim at articular congruity and accept only a step of <1 mm. These goals were achieved in

Fig. 5a

Radiographs showing a) the intra-articular fracture of the distal radius and b) postoperative anatomical reduction.
all but one patient in our study, using arthroscopy and fluoroscopy.

Fluoroscopy complements arthroscopy so that the intra-articular fractures can be reduced with percutaneous or minimally invasive techniques. Our experience is that most are four-part fractures as described by Melone, and an understanding of this helps when carrying out reduction. The five-level algorithm enables these fractures to be managed with the least possible additional soft-tissue injury.

The advantages of arthroscopy are that it provides a magnified view of the articular fragments, which can then be reduced with precision to obtain an anatomical reduction, allows the intra-articular ligaments to be assessed and managed arthroscopically, and is minimally invasive.

Operative fluoroscopy should be considered as an adjunct to the operative management which, with arthroscopy, has extended the scope of surgery. Fluoroscopy enables accurate placement and manipulation of joysticks, assessment of the radiological variables of reduction (radial height, volar tilt, radial angle, scaphoid and lunate orientation) and internal fixation, and assessment of the stability of the fracture and carpus.

Fluoroscopy, by itself, has been reported to be misleading in the interpretation of the reduction of intra-articular fractures, and this has also been our experience.

Over the past decade the presence of intracarpal injuries with distal fractures of the radius has been increasingly recognised (Table II). In our study, tears of the TFC complex (58%) and scapholunate (85%) and lunotriquetral instability (61%) were common. The number of patients was too small to be able to identify a statistically significant difference in outcome in those patients who sustained these additional injuries. It is too simplistic to think of intra-articular fractures of the distal radius merely as a skeletal injury, and the contribution of the ligamentous lesions towards the final outcome may ultimately prove to be substantial.

A high incidence of pain in the ulnar side of the wrist has been reported, but we did not find this to be a significant problem. The arthroscopic technique has advantages over conventional treatment. An anatomical reduction of the lunate fossa will indirectly reduce the articular surface of the sigmoid notch which articulates with the distal ulna. Tears of the TFC complex can be debrided or repaired, and lunotriquetral instability can be stabilised.

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