IMMEDIATE MOBILISATION FOLLOWING CORRECTIVE OSTEOTOMY OF DISTAL RADIUS MALUNIONS WITH CANCELLOUS GRAFT AND VOLAR FIXED ANGLE PLATES

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The purpose of the study was to examine the reliability with which a specific technique of corrective osteotomy of malunions of the distal radius combined with early mobilisation could both restore the normal anatomic parameters of the radius and achieve a functional range of motion with good strength. Corrective osteotomy of the distal radius was performed through a volar approach using a fixed angle volar plate and cancellous bone graft from the iliac crest in 19 patients of mean age 50 years with initial malunions with a mean dorsal tilt of 36° and 7 mm of ulnar variance. An immediate mobilisation programme was started. All healed at a mean of less than 12 weeks (including two heavy smoking patients who required repeat cancellous bone grafting to achieve final union) to achieve a total arc of wrist motion around 120°, forearm rotation of 158° and grip strength which was 80% of contralateral. This treatment strategy was judged to be straightforward and effective.

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Malunion of a distal radius fracture produces derangement in carpal kinematics and concentrates articular loads across the distal radioulnar joint (DRUJ), which can lead to loss of motion, pain, weakness and poor function (Fig 1) (Bronstein et al., 1997; George et al., 2004; Park et al., 2002). Malunions of only a limited degree and in lower demand patients may be adequately treated by non-surgical means. If surgical treatment is necessary, osteotomy of the distal radius is commonly performed (Jupiter and Ring, 1996) Others have shortened the ulna in a single, or multiple, stages (Brown and Bell, 1994; El-Karef, 2005; Wada et al., 2004). However, the use of techniques and concepts used in the treatment of complex acute fractures of the distal radius for corrective osteotomy of malunions makes it possible to restore normal anatomic parameters even in severe malunions with a single operation which leaves the ulna untouched (Henry et al., 2001; Orbay and Fernandez, 2002, 2004; Smith and Henry, 2005).

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MATERIALS AND METHODS

Between June 2002 and June 2005, 58 patients underwent corrective osteotomy of the radius for malunion. Inclusion criteria were a metaphyseal, extraarticular osteotomy that created a large gap requiring cancellous bone grafting, which was stabilised by a volar fixed angle plate (Fig 2). After exclusions, 19 patients remained in the study. Eleven were women and 8 were men, with a mean (standard deviation) age of 50 (14) years. These patients had had a total of seven prior surgical interventions. Patients were followed for a mean (standard deviation) of 29 (11) months.

Thirty-nine patients were excluded for the following reasons: 10 had intraarticular osteotomies of the radiocarpal joint surface, 7 also had an ulnar shortening osteotomy, obviating the need for cancellous grafting, 2 in the paediatric age group had K-wire fixation, 14 had an osteotomy at the shaft, rather than metaphyseal level and 6 failed to attend for appropriate follow-up.

Patients were examined pre-operatively and throughout follow-up with goniometer measured wrist flexion and extension, supination and pronation. Grip strength was measured in kilograms on a Jamar dynamometer set at position two and expressed as both the absolute value and as a percentage of the contralateral grip strength.

Digital X-rays were taken pre-operatively and throughout follow-up and tilt, radial inclination and ulnar variance were measured. Tilt is the measured angle between the perpendicular to the neutral axis of the radial shaft and a line drawn between the volar and dorsal articular margins on the lateral X-ray. Positive values indicate volar tilt and negative values indicate dorsal tilt. Radial inclination is the angle between the perpendicular to the neutral axis of the radial shaft and a line drawn from the radial styloid to the distal margin of the sigmoid notch on the posteroanterior X-ray. Ulnar variance is the longitudinal distance, measured in millimetres, between the distal margin of the ulnar head and the subchondral line of the distal radial articular surface where the lunate fossa meets the sigmoid notch on a neutral forearm rotation posteroanterior X-ray.

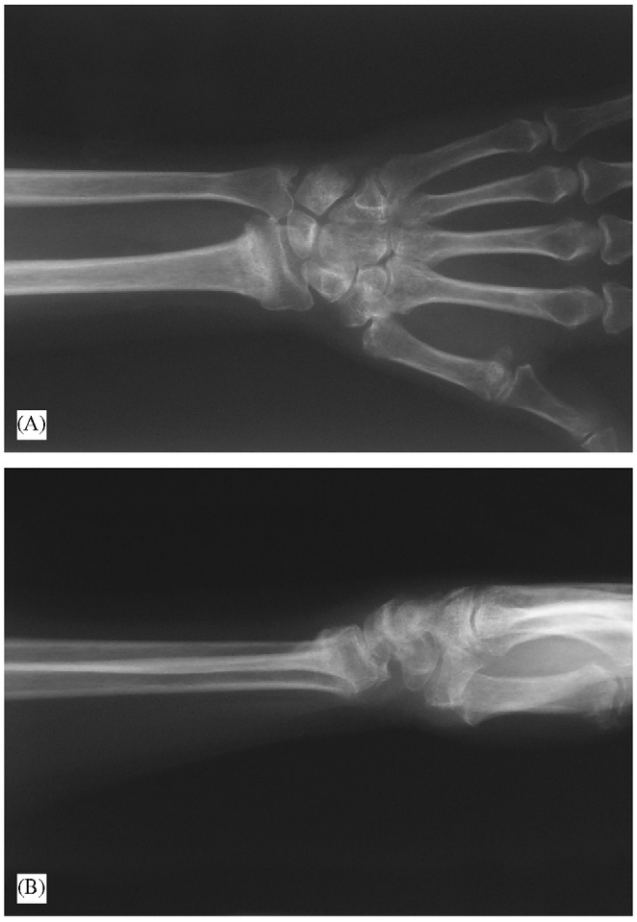

Fig 1 The typical pre-operative deformity includes loss of inclination, loss of tilt, ulnar positive variance and adaptive DISI in the carpus.

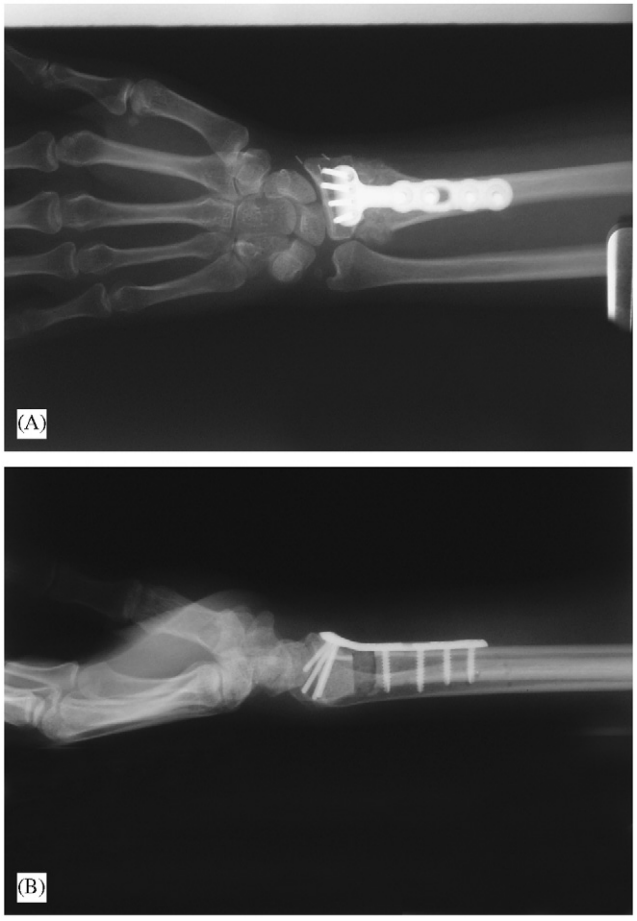

Fig 2 The original deformity is corrected and stabilised with a volar fixed angle plate and the intervening gap is filled with cancellous bone graft from the iliac crest.

Positive values indicate the ulna to be more distal than the radius and negative values indicate the ulna to be more proximal than the radius.

Time to healing was measured by digital X-ray and judged by the criteria of bridging trabeculae oriented parallel to the longitudinal axis of the radius seen continuously from the proximal shaft fragment through the bone graft zone into the distal fragment on all three views (Fig 3). This may give a time to healing that is greater than clinical healing but was used for the purpose of research standardisation.

Surgery was performed under general anaesthesia and tourniquet control through a 6 cm volar incision overlying the flexor carpi radialis (FCR), tendon with a 15 mm ulnar directed back cut in the proximal wrist crease. The FCR sheath was incised along its radial border to avoid the palmar cutaneous branch of the median nerve and then through the floor of the sheath. The deep approach was between the FCR, which was retracted radially toward the radial artery, and the flexor pollicis longus (FPL), retracted ulnarly. The pronator quadratus was incised along its radial and distal borders and retracted in an ulnar direction, exposing the entire distal radius. The prior fracture site and apex of deformity was easily identified by direct inspection and with landmarks confirmed radiographically. The brachioradialis was released from the distal fragment and the wrist and digital extensor tendons were elevated from the dorsal surface of the radius from the radial side with a curved periosteal elevator prior to osteotomy. The osteotomy was then made with an oscillating saw proximal to the distal radioulnar joint and parallel to the articular surface of the distal radius. After making the correction, the sharp edges on the proximal and dorsal border of the distal fragment, adjacent to the extensor tendons, were trimmed. The volar fixed angle plate was attached to the distal fragment and checked radiographically for alignment of the plate and the fragment (DVR-A standard, Hand Innovations LLC, Miami, FL, USA). It is important to separate the malunion first and make the necessary correction to the distal fragment in three-dimensional space before

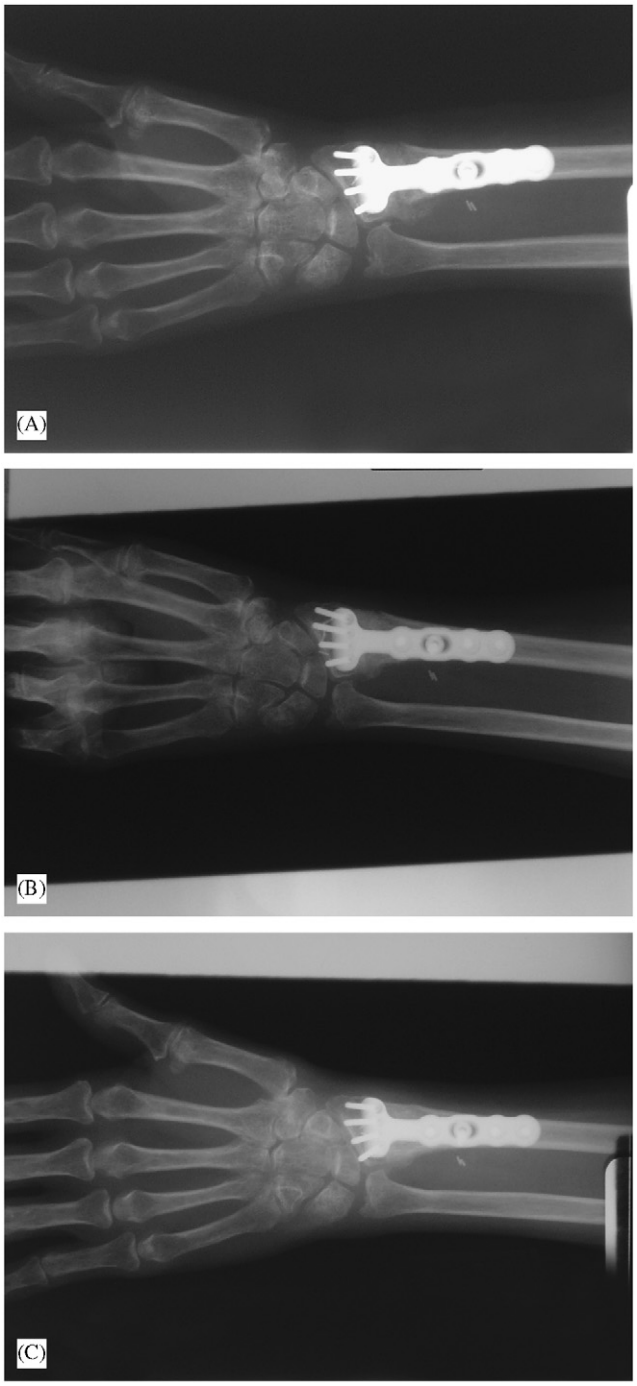

Fig 3 The progressive stages of incorporation of cancellous graft in the osteotomy gap are seen in (A) where abundant graft actually overfills the space, including ulnarly towards the interosseous space, but (B) as it remodels and incorporates the bone outside the pathway of loading resorbs until, (C) ultimately, it forms a clear neo-cortex.

applying any hardware to avoid incomplete correction of the malunion (Malone et al., 2006) The correct position for the distal fragment is judged using intraoperative fluoroscopy examining tilt, inclination, translation, and length. The combined unit of the plate and the distal fragment were then oriented relative to the radial shaft to correct the length, tilt and inclination of the original deformity from a three-dimensional perspective. The plate was fixed to the shaft and the volume of the gap requiring bone graft measured, including the longitudinal measurement, in millimetres, between the two widest osteotomy margins. Pure cancellous bone was harvested from the anterior iliac tubercle region with cylindrical trocars and packed tightly into the osteotomy gap with a tamp. The DRUJ was manually tested and found to be stable post-osteotomy in all cases. The pronator quadratus was closed over the plate and osteotomy gap, followed by skin closure and dressing with a volar splint holding the wrist in 30° extension.

Within a week, the patients began full active and active assisted range of motion exercises of all joints, including full range wrist extension, using a removable orthoplast splint. Sustained passive stretch of wrist flexion and extension under moderate force was initiated by 4 weeks and strengthening against resistance between 6 and 8 weeks.

RESULTS

The mean gap filled with cancellous graft was 15 (4) mm.

All patients eventually achieved union at a mean (standard deviation) time of 12 (4) weeks, including the two smoking patients who required repeat bone grafting.

The mean (standard deviation) changes in the objective measures from pre-operative to postoperative are shown in Table 1. Wrist flexion improved from 28 (17)° pre-operatively to 58 (13)° postoperatively. Wrist extension improved from 43 (32)° pre-operatively to 62 (16)° postoperatively. Supination improved from 46 (21)° pre-operatively to 81 (7)° postoperatively. Pronation improved from 46 (18)° pre-operatively to 78 (10)° postoperatively. Grip strength improved from 10 (7) kg,

Table 1—Preoperative to postoperative changes in objective measures

	Preoperative	*Postoperative*
Volar tilt (deg)	−36 (7)	10 (2)
Radial inclination (deg)	11 (5)	22 (2)
Ulnar positive variance (mm)	7 (3)	0 (2)
Wrist flexion (deg)	28 (17)	58 (13)
Wrist extension (deg)	43 (32)	62 (16)
Supination (deg)	46 (21)	81 (7)
Pronation (deg)	46 (18)	78 (10)
Grip strength (kg)	10 (7)	26 (18)
Grip strength as a percentage of contralateral	33 (22)	79 (17)

Values are given as mean (standard deviation).

33 (22)% of contralateral grip strength, pre-operatively to 26 (18) kg, 79 (17)% of contralateral grip strength, postoperatively. The values for these parameters in the context of the number of patients entered in the study were insufficient to achieve statistical power.

Tilt, on lateral X-ray, improved from 36 (7)° dorsal pre-operatively to 10 (2)° volar postoperatively. Radial inclination, on posteroanterior X-ray, improved from 10 (5)° pre-operatively to 22 (2)° postoperatively. Ulnar variance on a neutral rotation posteroanterior X-ray improved from 7 (3) mm ulnar positive pre-operatively to 0 (2) mm ulnar positive postoperatively.

There were two complications of initial non-union in two men who continued to smoke two packets of cigarettes per day after the initial surgery, despite promising otherwise pre-operatively. Serial X-rays showed the bone graft being resorbed progressively instead of being incorporated. Both patients stopped smoking and returned for repeat cancellous grafting without change of the fixation and, eventually, healed at 16 and 24 weeks.

No hardware removal has been required to date.

DISCUSSION

Malunion of a fracture of the distal radius produces alterations in the normal biomechanics of the carpus and the distal radioulnar joint which are associated with varying degrees of clinical symptoms. Park et al. (2002) demonstrated that carpal bone motions were markedly altered at all positions of dorsal angulation of the distal radius. Bronstein et al. (1997) reported 47% reduction of forearm pronation and 29% reduction of supination with radial shortening of 10 mm. Clinical manifestations of radial malunion include pain, weakness, loss of motion and visible deformity.

The patients in this series had substantial corrections of around 46° tilt and 7 mm ulnar variance (corresponding to dorsal defects of over 14 mm). The result was a mean arc of wrist motion of 120°, evenly balanced between flexion and extension, and a more than doubling of the grip strength. The total arc of forearm rotation after surgery was greater than 158°. These results compare favourably with the results of other reported series (Brown and Bell, 1994; Jupiter and Ring, 1996). Brown and Bell (1994) reported a postoperative total arc of wrist motion of 72° and a total arc of forearm rotation of 106° in 11 patients. Jupiter and Ring (1996) reported a postoperative total arc of motion of 87° and a total arc of forearm rotation of 145° in 10 patients. While it is impossible to state that early mobilisation was the primary factor responsible for the favourable range of motion in this series, improving the ranges of motion was the intended outcome when the protocol was set up to pursue immediate motion following surgery (Smith et al., 2004).

When the degree of malunion and magnitude of clinical symptoms require surgical treatment, corrective osteotomy of the distal radius is the preferred surgical treatment (Jupiter and Ring, 1996) and clinical success is directly related to the accuracy of the correction (Prommersberger et al., 2002). In highly comminuted distal radius fractures, the forces of rehabilitation are borne entirely by the fixation device until healing occurs. Volar fixed angle plate stabilisation of these fractures has proven capable of withstanding immediate rehabilitation of the wrist and the distal radioulnar joint (Henry et al., 2001; Orbay and Fernandez, 2002, 2004; Smith and Henry, 2002, 2005; Smith et al., 2004). The same forces occur at the site of radial osteotomies filled with cancellous graft and the same principles of management can be applied.

The benefits of avoiding scarring and irritation of the extensor tendons, occurring with dorsally placed plates, are realised by using a purely volar approach and a volar fixed angle plate. The traditional structural tricortical wedge graft can be replaced by purely cancellous morselised graft without problems and, possibly, some advantage in healing capacity (Ring et al., 2002). Although Luchetti (2004) reported use of carbonated hydroxyapatite as a substitute for autogenous graft in six patients, the length correction was only a mean of 3 mm and the surgery failed to restore volar tilt. This study gave no indication as to whether this method could be applied to the much larger defects usually occurring following adequate restoration of normal parameters. Given the effectiveness of radial osteotomy and grafting, ulnar shortening procedures synchronously with radial correction seem to be unnecessary (Brown and Bell, 1994; Wada et al., 2004). Staging of interventions is also unnecessary (El-Karef, 2005).

The seven exclusions from this study who had concomitant ulnar osteotomies had different clinical problems from the standard distal radius malunion being discussed in this paper: they required revision after previous extensive forearm mangling injuries from industrial and vehicular trauma.

In conclusion volar locking plates and cancellous bone grafting allow a safe correction of malunited distal radius fractures. The technique has the advantage that extensor tendon irritation is avoided and that the plate does not require removal later. By avoiding tricortical bone graft, donor site morbidity is also reduced.

References

Bronstein AJ, Trumble TE, Tencer AF (1997). The effects of distal radius fracture malalignment on forearm rotation: a cadaveric study. Journal of Hand Surgery, 22A: 258–262.

Brown JN, Bell MJ (1994). Distal radial osteotomy for malunion of wrist fractures in young patients. Journal of Hand Surgery, 19B: 589–593.

El-Karef E (2005). Staged reconstruction for malunited fractures of the distal radius. Journal of Hand Surgery, 30B: 73–78.

George MS, Kiefhaber TR, Stern PJ (2004). The Sauve-Kapandji procedure and the Darrach procedure for distal radio-ulnar joint dysfunction after Colles' fracture. Journal of Hand Surgery, 29B: 608–613.

Henry MH, Griggs SM, Levaro F et al. (2001). Volar approach to dorsal displaced fractures of the distal radius. Techniques in Hand and Upper Extremity Surgery, 5: 31–41.

Jupiter JB, Ring D (1996). A comparison of early and late reconstruction of malunited fractures of the distal end of the radius. Journal of Bone and Joint Surgery, 78A: 739–748.

Luchetti R (2004). Corrective osteotomy of malunited distal radius fractures using carbonated hydroxyapatite as an alternative to autogenous bone grafting. Journal of Hand Surgery, 29A: 825–834.

Malone KJ, Magnell TD, Freeman DC et al. (2006). Surgical correction of dorsally angulated distal radius malunions with fixed angle volar plating: a case series. Journal of Hand Surgery, 31A: 366–372.

Orbay JL, Fernandez DL (2002). Volar fixation for dorsally displaced fractures of the distal radius: a preliminary report. Journal of Hand Surgery, 27A: 205–215.

Orbay JL, Fernandez DL (2004). Volar fixed-angle plate fixation for unstable distal radius fractures in the elderly patient. Journal of Hand Surgery, 27A: 96–102.

Park MJ, Cooney 3rd WP, Hahn ME et al. (2002). The effects of dorsally angulated distal radius fractures on carpal kinematics. Journal of Hand Surgery, 27A: 223–232.

Prommersberger KJ, Van Schoonhoven J, Lanz UB (2002). Outcome after corrective osteotomy for malunited fractures of the distal end of the radius. Journal of Hand Surgery, 27B: 55–60.

Ring D, Roberge C, Morgan T et al. (2002). Osteotomy for malunited fractures of the distal radius: a comparison of structural and nonstructural autogenous bone grafts. Journal of Hand Surgery, 27A: 216–222.

Smith DW, Henry MH (2005). Volar fixed angle plating of the distal radius. Journal of the American Academy of Orthopaedic Surgeons, 13: 28–36.

Smith DW, Henry MH (2002). Comprehensive management of associated soft tissue injuries in distal radius fractures. Journal of the American Society for Surgery of the Hand, 2: 153–164.

Smith DW, Brou KE, Henry MH (2004). Early active rehabilitation for operatively stabilized distal radius fractures. Journal of Hand Therapy, 17: 43–49.

Wada T, Isogai S, Kanaya K et al. (2004). Simultaneous radial closing wedge and ulnar shortening osteotomies for distal radius malunion. Journal of Hand Surgery, 29A: 264–272.

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