■ UPPER LIMB

Correction of dorsally-malunited extra-articular distal radial fractures using volar locked plates without bone grafting

M. Mahmoud,
S. El Shafie,
M. Kamal

From Kasr Al Ainy Hospital, Cairo, Egypt

Malunion is the most common complication of the distal radius with many modalities of treatment available for such a problem. The use of bone grafting after an osteotomy is still recommended by most authors. We hypothesised that bone grafting is not required; fixing the corrected construct with a volar locked plate helps maintain the alignment, while metaphyseal defect fills by itself. Prospectively, we performed the procedure on 30 malunited dorsally-angulated radii using fixed angle volar locked plates without bone grafting. At the final follow-up, 22 wrists were available. Radiological evidence of union, correction of the deformity, clinical and functional improvement was achieved in all cases. Without the use of bone grafting, corrective open wedge osteotomy fixed by a volar locked plate provides a high rate of union and satisfactory functional outcomes.

Malunion is the most common complication of extra-articular fractures of the distal radius.[1,2] Treatment using a corrective osteotomy was reported by Meyerding and Overton in 1935.[3] This osteotomy has more recently been described using a dorsal plate with strut iliac crest bone grafting.[4-6] The advent of fixed angle volar plates to treat fractures of the distal radius led to combining these with a corrective osteotomy.[7] In 2004, Prommersberger, Moossavi and Lanz[8] described the use of a double trapeziform bicortical iliac crest bone graft and a volar locking plate.[9] Subsequently Malone et al,[10] and Peterson et al[7] described using a non-structural bone graft with a volar fixed angle plate.[10] In 2005 Wieland, Dekkers and Brink[11] reported a series using a dorsal open wedge osteotomy with a dorsal plate without bone graft.

Adopting the same technique as Prommersberger et al,[8] but with an approach through the flexor carpi radialis, we fix the osteotomy with a volar locked plate that avoids the reported problems of dorsal plating.[4,6] We believed that a gap in the metaphysis could heal, provided there was an intact soft-tissue sleeve supported by stable fixation. Therefore, we did not use an additional bone graft.

The aim of this study was to assess the reliability and outcome of this technique of corrective osteotomy using a volar locking plate without bone graft in the management of symptomatic dorsally-malunited extra-articular fractures of the distal radius.

Patients and Methods

This prospective study was performed between 2004 and 2009 on an initial group of 30 wrists in 26 patients. A total of 22 wrists in 19 patients were available at the final follow-up at a mean of 18 months (12 to 25). The missing eight wrists were in seven patients, who were living more than 300 km away from the hospital. Among them three asked to leave the study after they had finished their rehabilitation programme at eight, 10 and 11 months respectively after their operations, two patients went abroad and the final two did not attend their follow-up appointment. While their appointments were being scheduled, all of the seven missing patients reported that they had returned to their previous occupations, but we have no data regarding their final functional assessment.

The study included patients with symptomatic dorsal malunion of an extra-articular fracture of the distal radius, which caused limitation of movement, and impaired their work and daily activities.

We excluded the skeletally immature (two), patients with dorsal scarring (two), advanced radiocarpal (five) and intercarpal degenerative changes, fixed intercarpal malalignment, severe osteoporosis, persistent complex regional pain syndrome (CRPS, two), inability to comply with post-operative therapy, serious medical comorbidities and those with very low physical demands (one). This resulted in a total of 12 wrists in 12 patients (Fig. 1).

The patients were assessed clinically for pain using a visual analogue score (VAS; from 0 to

■ M. Mahmoud, MD, Lecturer of Orthopaedic Surgery Kasr Al Ainy Faculty of Medicine, Cairo University, Al-Manial, 11956, Cairo, Egypt.

■ S. El Shafie, MBBCh, Orthopaedic Surgeon Alhelal Hospital, 34 Ramses Street, Downtown, Cairo, Egypt.

■ M. Kamal, MSc(Orthopaedics), Orthopaedic Surgeon Alhelal Hospital, 34th Ramses Street, Downtown, Cairo, Egypt.

Correspondence should be sent to Dr M. Mahmoud; e-mail: dr.mostmah@gmail.com

©2012 British Editorial Society of Bone and Joint Surgery
doi:10.1302/0301-620X.94B8.28646 $2.00

J Bone Joint Surg Br 2012;94-B:1090–6.
Received 15 December 2011; Accepted after revision 19 April 2012

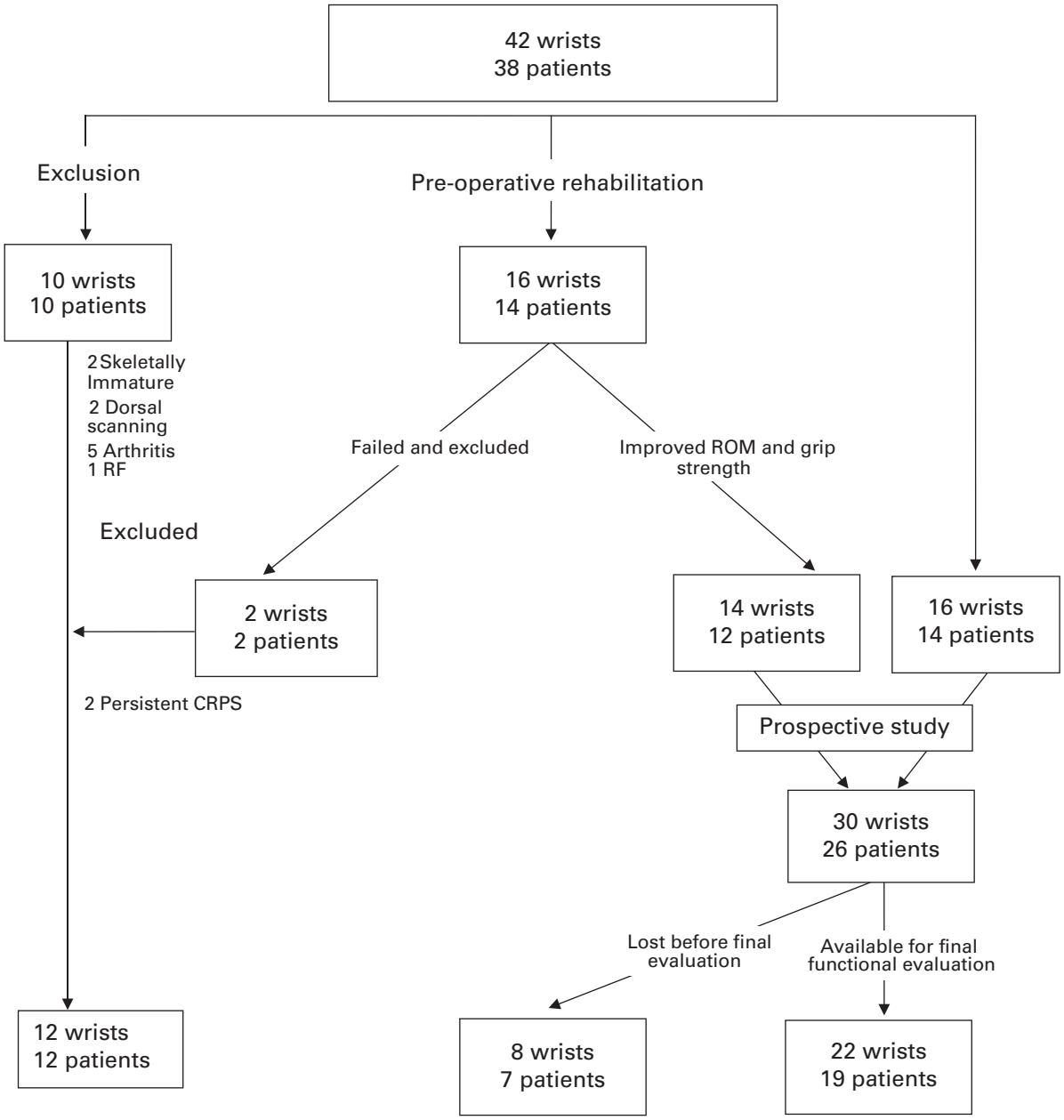

Fig. 1

Flow chart showing the numbers of the wrists and patients involved in the study; either excluded or included without or after rehabilitation.

10, where 0 denotes no pain and 10 agonising pain), grip strength by a dynamometer (Jamar dynamometer; Asimov Engineering Co., Santa Fe Springs, California), associated injuries, general illness (assessed through interview), smoking and nonsteroidal anti-inflammatory drug (NSAID) intake. Function was recorded using the modified Mayo wrist score (MMW)[12] and the Disabilities of the Arm, Shoulder and Hand score (DASH).[13]

The radiological criteria of malunion were those described by Graham[14]; radial inclination of < 7° or > 37°, radial height < 7 mm, ulna plus (positive variance) of ≥ 5 mm, and radial tilt > 15° dorsal or 20° volar. As recommended, we used posteroanterior (PA) radiographs to measure the radial inclination, which is the angle between a line perpendicular to the long axis of the radius and a line reflecting the articular surface of the radius.[14] In addition we measured the radial height, which is the distance between two parallel lines, drawn at the radial styloid and the ulnar pole, perpendicular to their shaft axes. We also measured ulnar variance, which reflects the axial relationship between the ulnar pole and the ulnarmost aspect of the distal radius. A lateral view was taken to measure the radial tilt, which is the angle between the articular surface and a line perpendicular to the radial shaft.[14]

We assumed that the patients' symptoms and disabilities were due to the deformity, and we offered the patients an

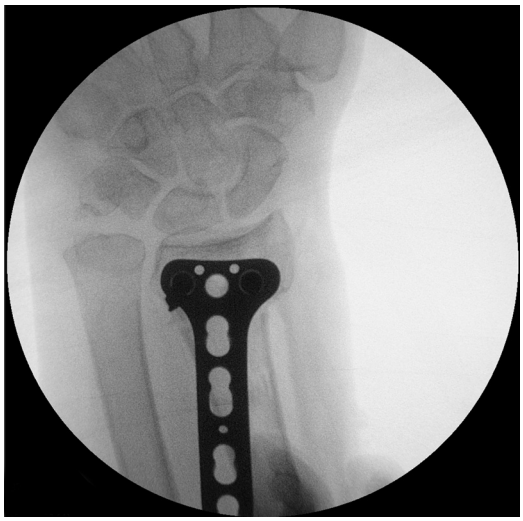

Fig. 2a

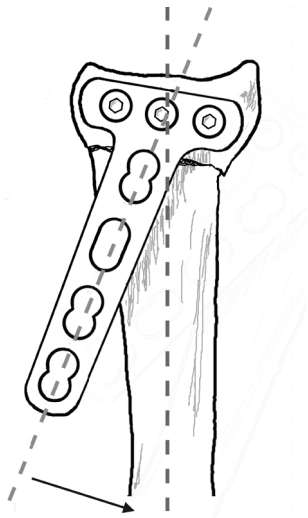

Fig. 2b

Intra-operative radiograph (a) and line drawing (b) showing the desired angle of correction of radial inclination.

osteotomy in the expectation of functional improvement. The timing of the operation was decided according to, range of movement (ROM), grip strength and the local bone quality. Patients with stiffness (13 wrists), weakness of grip (13 wrists) and regional osteopenia diagnosed by fine detail radiography[15] (nine wrists; four due to disuse and five due to CRPS) were referred for pre-operative physiotherapy, which included graduated exercises until satisfactory ROM, strength and radiological bone quality were restored as judged by disappearance of signs of regional osteopenia judged by the senior author (MM). The pre-operative rehabilitation involved 16 wrists in 14 patients and the pain management team simultaneously managed five of these wrists in five patients (Fig. 1). For those patients with regional osteopenia, we prescribed 100 μg/day of Calcitonin, 1000 mg of elemental calcium as calcium carbonate and 400 IU (10 μg) of vitamin D3 supplements for six to 12 weeks (nine patients). Before being considered for operation all patients had to demonstrate a total arc of wrist flexion-extension of 70°, and a grip strength of 15 kg for males and 10 kg for females.

Each operation was performed by the first author (MM) under general or brachial plexus anaesthesia. The arm was exsanguinated and tourniquet applied after a single dose of antibiotic was administered. A 5 cm longitudinal volar incision was made over the flexor carpi radialis tendon proximal to the wrist crease. The sheath was opened, the tendon was retracted radially and sharp dissection was continued carefully through the bed of the flexor carpi radialis to avoid injury to the flexor pollicis longus, which was retracted towards the ulna. Then, the pronator quadratus was released along its radial and distal borders, to expose the malunion of the distal radius.

Guided by an image intensifier, the transverse limb of the plate was fitted to the concavity of the distal radius parallel to the lunate fossa while extending the wrist on a rolled towel, creating an angle between the forearm and the side table equal to that of the dorsal tilt of the malunion. This was to clear the overlap between the proximal row of the carpus and the volar lip of the distal radius, and allow the x-ray beam to be parallel to the joint line.

Three subchondral locking screws were then inserted into the transverse limb of the plate. This created two angles; a sagittal angle between the vertical limb and the radius equivalent to the desired angle of correction of the volar tilt, and a coronal angle between the vertical limb and the radius equivalent to the desired angle of correction of the radial inclination (Figs 2 and 3). An osteotomy was created cutting the volar and dorsal cortices 5 mm to 10 mm proximal and parallel to the subchondral screws, in both the frontal and coronal planes irrespective of the old fracture line. If required, the plate was temporarily removed for clearance of the desired osteotomy site. Using the plate as a joystick, gentle and gradual reduction was performed in order to allow the tissues to stretch, creating an wedge defect open dorsally in the metaphysis (Fig. 4). In two wrists the volar cortex remained intact with minimal loss of the radial inclination or height, in 17 wrists the ulnar part of the volar cortex stayed intact and in three wrists a trapezoidal-shaped defect resulted with a gap in the volar as well as the dorsal cortex after additional distraction.

Intra-operative anteroposterior (a) and lateral (b) radiographs showing a metaphyseal defect.

The plate was then fixed to the shaft of the radius inserting the first non-locking compression screw through the oval (sliding) hole of the plate, to allowing further adjustment of length. After the necessary corrections, the final locking screws were applied. Keeping the transverse limb of the plate fitted within the volar concavity, and keeping the vertical limb of the plate strictly fitted within the anterior

Fig. 3a

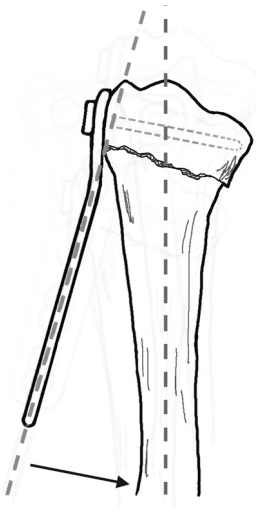

Fig. 3b

Intra-operative radiograph (a) and line drawing (b) showing the desired angle of correction of the volar tilt.

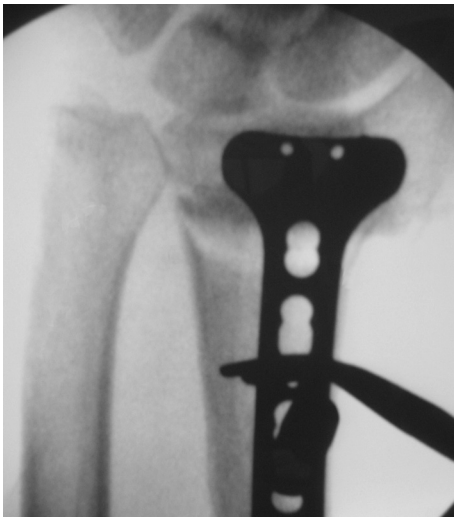

Fig. 4a

Fig. 4b

Intra-operative anteroposterior (a) and lateral (b) radiographs showing a metaphyseal defect.

surface of the radial diaphysis corrected any rotational element of the deformity. No bone graft was used to fill the defect. The pronator quadratus was reattached followed by subcutaneous tissue and skin closure. No drains were used. A post-operative volar splint was applied for ten days and removed at the time of stitch removal. Elevation of the arm was advised for the first 48 hours to avoid post-operative oedema. Soon afterwards, ROM exercises were initiated. Patients were followed up clinically and radiologically every two weeks for the first three months, every month thereafter up to six months, and then every three months for one year and finally at the end of the follow-up.

Statistical analysis. Data were statistically analysed between various variables, using the Pearson moment (p) correlation equation for a linear relation; p values ≤ 0.05 were considered statistically significant. The software used for statistical analysis was SPSS (SPSS Inc., Chicago, Illinois).

Results

There were 22 wrists in 19 patients (17 male and two female) available for final follow-up at a mean of 18 months (12 to 25). Their mean age was 31.8 years (20 to 49), and 12 fractures (55%) were in the dominant hand. The mean time from original fracture to osteotomy was 10.7 months (6 to 18). The mechanism of injury was a fall in 14 fractures and a motor vehicle accident in eight. Nine patients were smokers (defined as > 20 cigarettes a day), five were occasional smokers and five were non-smokers. All the patients

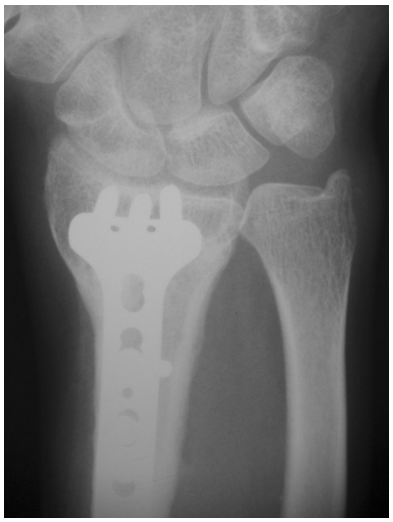

Fig. 5b

Fig. 5b

Anteroposterior (a) and lateral (b) radiographs at 12 months showing union and absence of hardware failure.

Table I. Mean (SD) range of movement of the wrist pre- and post-operatively

Mean (SD) parameter (°)	Pre-operative	Post-operative	Change
Flexion	26.6 (8.5)	71.8 (7.8)	45.2 (10.4)
Extension	77.7 (20.0)	76.4 (9.0)	-1.3 (24.9)
Flexion/extension range	104.1	147.5	43.4 (31.5)
Radial deviation	33.1 (6.6)	16.7 (5.6)	-16.4 (8.2)
Ulnar deviation	5.7 (3.3)	22.9 (6.9)	17.2 (7.2)
Radioulnar range	38.8	39.6	0.8 (11.6)
Supination	23.0 (10.9)	57.9 (13.0)	34.9 (17.7)
Pronation	50.5 (14.8)	70.2 (9.7)	19.7 (16.5)
Supination/pronation range	73.5	128.1	54.6 (25.6)

reported occasional use of NSAIDs for their wrists. They had a mean of 5.3 weeks (4 to 6) of immobilisation from the time of injury, 19 were in a cast, and three in a non-removable splint. In seven patients there were associated injuries, including three fractures of the ulna styloid, one fracture of the shaft of the humerus, one fracture of the surgical neck of the humerus, one fracture of the acetabulum and one fracture of the first lumbar vertebrae.

After operation union was defined radiologically by the presence of bone trabeculae observed crossing the osteotomy site in radiographs. This was achieved in all the patients at a mean of 10.4 weeks (8 to 14) (Fig. 5). In three wrists a CT scan was performed to confirm union; however, it was not used for routine assessment. At the final follow-up, at a mean of 18 months (12 to 25), patients were assessed by the third author (MK) both functionally and by radiologically. He found that there was no loosening or failure of the plate and screws in anteroposterior (AP), and lateral radiographs at a minimum follow-up of 12 months. Clinical, radiological and functional results are illustrated in Tables I, II and III, respectively. We encountered one case of partial loss of the post-operative reduction (10° of radial tilt from -5° to -15°) at the final follow-up; the new position was acceptable so no action was taken. Post-operative DASH scores improved with a shorter time between injury and osteotomy ($p = 0.042$) and the greater the angle of correction of the volar tilt ($p = 0.011$) but this did not reach statistical significance. Higher DASH scores correlated with a greater improvement in grip strength ($p = 0.002$).

Complications occurred in six wrists (27%), an intra-operative longitudinal split occurred in the shaft of the radius in one patient which required an interfragmentary compression screw, and one patient suffered from transient median nerve neuritis in the early post-operative period which resolved within three months. Another patient suffered from CRPS, which was cured by physiotherapy. A prominent screw troubled one patient and was removed after ten months. Residual pain on the ulnar side of the wrist due to ulnar impaction was encountered in two patients, requiring ulnar shortening after 14 and 16 months respectively, both were type I and II according to the method described by Tolat, Stanley and Trail.[16]

Table II. Mean (SD) radiological measurements pre- and post-operatively

Mean (SD) parameter	Pre-operative	Post-operative	Change
Radial tilt (°)	-37.6 (12.7)	4.3 (8.4)	41.9 (15.2)
Radial inclination (°)	10.0 (6.9)	18.9 (4.2)	8.9 (6.2)
Radial height (mm)	-2.6 (5.4)	8.0 (2.6)	10.6 (5.9)
Ulnar variance (°)	4.0 (1.7)	0.0 (0.9)	4.0 (1.9)

Table III. Mean (SD) functional measures pre- and post-operatively

Mean (SD) parameter	Pre-operative	Post-operative	Change
Grip strength (kg)	29.9 (9.0)	47.3 (12.5)	17.4 (9.5)
VAS	4.2 (1.5)	0.8 (1.1)	3.4 (1.5)
DASH score	34.5 (12.8)	12.9 (5.3)	-21.6 (13.5)
MMW score	62.1 (16.7)	84.8 (8.1)	22.7 (20.3)

* VAS, visual analogue scale for pain; DASH, Disabilities of the Arm, Shoulder and Hand; MMW, Mayo Wrist score

Discussion

Malunion of the distal radius can result in biomechanical abnormalities in the radio-ulnar, the radiocarpal and the midcarpal joints.[17-22] For dorsally-angulated fractures, techniques involving a dorsal approach and fixation may improve radiological parameters, as well as pain and function. However, there are well-documented complications as extensor tenosynovitis and tendon ruptures associated with the use of plates in this position, even with the new low profile designs.[4,6,23-27] Applying a plate to the volar surface of the radius potentially has a lower morbidity, but traditionally, this method of volar plating has been used to treat angulation.[8,28,29]

Prommersberger et al[8,9] have published studies using a volar approach to treat 29 malunions of the distal radius. They used a fixed angled device as a joystick after attaching it to the predrilled distal fragment to achieve reduction. Then they used a double trapezoid bicortical iliac crest bone graft to fill the defect. Malone et al[10] described four cases of dorsally-malunited fractures in which they used a volar fixed angle plate. They used an autogenous iliac crest bone graft in two patients, a resected ulnar head in one and an allograft in the last patient.[10] Peterson et al[7] described eight cases of dorsally-malunited fractures with the use of a volar fixed angle plate. They used an autogenous inner table iliac crest bone graft in all cases.[7] In these reports there were few complications.[7,8,10] Although there were reports very early in 1930s concerning corrective osteotomy without a bone graft,[3] there is only one report in the recent literature by Wieland et al[11] in 2005 which emphasised this concept. There were 35 patients with a mean age of 66 years with a deformity and a mean radial tilt of -20°. There was not enough data on the radial height correction; they used a dorsal approach, did not use locking plates to fix the osteotomy, and they reported three cases of tendon rupture due to the dorsal position of the plate.

To our knowledge, this is the first series of patients with symptomatic dorsally-angulated malunion of the distal radius to be treated by corrective osteotomy and a volar locking plate without bone graft. We adopted the approach described by Malone et al[10] as we did not believe that the radial dissection advocated by Prommersberger et al[8] was necessary, but we did use their technique for reduction. After the osteotomy we used the locked plate as a template to produce the required angle for reduction of the deformity as this is easier than pre-operative templating. Using the plate attached to the distal fragment as a joystick could be complicated by cutting through the screws or fracture of the distal fragment, but this can be avoided by excluding local osteoporosis and dorsal scarring in selected cases and using gradual gentle reduction during the procedure. We believe that angle stable fixation plates provide the support needed for union of the metaphyseal defect to occur, without bone grafting.

Limitations of this study were the relatively small number of patients, it did not address how much deformity is acceptable as it was concerned with treatment only of symptomatic patients with malunion and it did not use CT routinely for accurate assessment of the time to union.

In conclusion, corrective osteotomy of extra-articular dorsally-angulated malunited fractures of the distal radius fixed by a volar locked plate without the use of bone graft results in a high rate of union and satisfactory functional outcomes.

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

1. **Slagel BE, Luenam S, Pichora DR.** Management of post-traumatic malunion of fractures of the distal radius. *Orthop Clin North Am* 2007;38:203–216.
2. **Prommersberger KJ, Lanz UB.** Corrective osteotomy of the distal radius through volar approach. *Tech Hand Up Extrem Surg* 2004;8:70–77.
3. **Meyerding HW, Overton LM.** Malunited fracture of the lower end of the radius (Colles' fracture) treated by osteotomy. *Minnesota Medicine* 1935;18:84–89.
4. **Carter PR, Frederick HA, Laseter GF.** Open reduction and internal fixation of unstable distal radius fractures with a low-profile plate: a multicenter study of 73 fractures. *J Hand Surg Am* 1998;23:300–307.
5. **Kambouroglou GK, Axelrod TS.** Complications of the AO/ASIF titanium distal radius plate system (pi plate) in internal fixation of the distal radius: a brief report. *J Hand Surg Am* 1998;23:737–741.
6. **Sanchez T, Jakubietz M, Jakubietz R, et al.** Complications after Pi Plate osteosynthesis. *Plast Reconstr Surg* 2005;116:153–158.
7. **Peterson B, Gajendran V, Szabo RM.** Corrective osteotomy for deformity of the distal radius using a volar locking plate. *Hand* 2008;3:61–68.
8. **Prommersberger KJ, Moossavi S, Lanz U.** Results of corrective osteotomy of malunited extension fractures of the radius at the usual site. *Handchir Mikrochir Plast Chir* 1999;31:234–240 (in German).
9. **Prommersberger KJ, Lanz U.** Biomechanical aspects of malunited distal radius fracture: a literature review. *Handchir Mikrochir Plast Chir* 1999;31:221–226 (in German).
10. **Malone KJ, Magnell TD, Freeman DC, Boyer MI, Placzek JD.** Surgical correction of dorsally angulated distal radius malunions with fixed angle volar plating: a case series. *J Hand Surg Am* 2006;31:366–372.
11. **Wieland AW, Dekkers GH, Brink PR.** Open wedge osteotomy for malunited extraarticular distal radius fractures with plate osteosynthesis without bone grafting. *Eur J Trauma* 2005;31:148–153.
12. **Amadio PC, Berquist TH, Smith DK, et al.** Scaphoid malunion. *J Hand Surg Am* 1989;14:679–687.

13. **Hudak PL, Amadio PC, Bombardier C.** Development of an upper extremity outcome measure: the DASH (Disabilities of the Arm, Shoulder, and Head). *Am J Ind Med* 1996;29:602–608.
14. **Graham TJ.** Surgical correction of malunited fractures of the distal radius. *J Am Acad Orthop Surg* 1997;5:270–281.
15. **Genant HK, Kozin F, Bekerman C, et al.** The reflex sympathetic dystrophy syndrome: a comprehensive analysis using fine-detail radiography, photon absorptiometry, and bone and joint scintigraphy. *Radiology* 1975;117:21–32.
16. **Tolat AR, Stanley JK, Trail IA.** A cadaveric study of the anatomy and stability of the distal radioulnar joint in the coronal and transverse planes. *J Hand Surg Br* 1996;21:587–594.
17. **Miyake T, Hashizume H, Inoue H, Shi Q, Nagayama N.** Malunited colles' fracture: analysis of stress distribution. *J Hand Surg Br* 1994;19:737–742.
18. **Crisco JJ, Moore DC, Marai GE, et al.** Effects of distal radius malunion on distal radioulnar joint mechanics: an in vivo study. *J Orthop Res* 2007;25:547–555.
19. **Park MJ, Cooney WP 3rd, Hahn ME, Looi KP, An KN.** The effects of dorsally angulated distal radius fractures on carpal kinematics. *J Hand Surg Am* 2002;27:223–232.
20. **Pogue DJ, Viegas SF, Patterson RM, et al.** Effects of distal radius fracture malunion on wrist joint mechanics. *J Hand Surg Am* 1990;15:721–727.
21. **Hirahara H, Neale PG, Lin YT, Cooney WP, An KN.** Kinematic and torque-related effects of dorsally angulated distal radius fractures and the distal radial ulnar joint. *J Hand Surg Am* 2003;28:614–621.
22. **Werner FW, Palmer AK, Fortino MD, Short WH.** Force transmission through the distal ulna: effect of ulnar variance, lunate fossa angulation, and radial and palmar tilt of the distal radius. *J Hand Surg Am* 1992;17:423–428.
23. **Schnur DP, Chang B.** Extensor tendon rupture after internal fixation of a distal radius fracture using a dorsally placed AO/ ASIF titanium pi plate: Arbeitsgemeinschaft für Osteosynthesefragen/Association for the Study of Internal Fixation. *Ann Plast Surg* 2000;44:564–566.
24. **Simic PM, Robison J, Gardner MJ, et al.** Treatment of distal radius fractures with a low-profile dorsal plating system: an outcomes assessment. *J Hand Surg Am* 2006;31:382–386.
25. **Suckel A, Spies S, Munst P.** Dorsal (AO/ASIF) pi-Plate osteosynthesis in the treatment of distal intraarticular radius fractures. *J Hand Surg Br* 2006;31:673–679.
26. **Keller M, Steiger R.** Open reduction and internal fixation of distal radius extension fractures in women over 60 years of age with the dorsal radius plate (pi-plate). *Handchir Mikrochir Plast Chir* 2006;38:82–89 (in German).
27. **Kamath AF, Zurakowski D, Day CS.** Low-profile dorsal plating for dorsally angulated distal radius fractures: an outcomes study. *J Hand Surg Am* 2006;31:1061–1067.
28. **Thivaios GC, McKee MD.** Sliding osteotomy for deformity correction following malunion of volarly displaced distal radial fractures. *J Orthop Trauma* 2003;17:326–333.
29. **Koh S, Morris RP, Patterson RM, et al.** Volar fixation for dorsally angulated extra-articular fractures of the distal radius: a biomechanical study. *J Hand Surg Am* 2006;31:771–779.