



## ORIGINAL PAPERS

# Open reduction and internal fixation of unstable dorsally displaced distal radius fractures using a fixed-angle volar plate with locking screws

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### KEYWORDS

Distal radius fractures;  
Internal fixation;  
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Fixed-angle plates

### Abstract

**Purpose:** To assess the medium-term results of (DVR) fixed-angle anatomic plates in the treatment of unstable distal radius fractures.

**Materials and methods:** Retrospective study of 93 dorsally displaced unstable distal radius fractures, treated by means of open reduction with a volar approach and DVT plate fixation. Mean age was 46 years and mean follow-up was 13 months. A clinical-functional evaluation was carried out for all patients by measuring range of movement, degree of pain, surgical outcomes (using the Gartland-Werley and Green-O'Brien scales) and degree of disability as reflected by the DASH scale. Radiographs were used to assess volar and radial inclination angles as well as radial height, articular step-offs and radiocarpal arthritis. The last X-ray follow-up value obtained was used to carry out a statistical comparison with immediate pre- and post-operative radiographs.

**Results:** All our fractures but one healed in a mean 8.2-week period. The radiological parameters studied showed that the mean correction achieved was within normal values and now significant variations occurred at the end of follow-up ( $p \leq 0.05$ ). Some degree articular step-off persisted in 12 fractures. 73,33% of patients were pain free. The score of excellent and good results were higher than 80% according to the scales used, and the disability index was low (18.32) according to the DASH score.

**Conclusions:** The use of fixed-angle volar plates with locking screws in a safe and efficient treatment for dorsally displaced unstable distal radius fractures. We think these constitute an excellent alternative for the treatment of this kind of injury.

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**PALABRAS CLAVE**

Fracturas del radio distal;  
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Fijación volar;  
Placas de ángulo fijo

## Reducción abierta y fijación interna de fracturas inestables del radio distal desplazadas dorsalmente: resultados al emplear placa volar de ángulo fijo con tornillos bloqueados

**Resumen**

**Objetivo:** Evaluar a medio plazo los resultados de la placa anatómica de ángulo fijo (DVR [*distal volar radius*]) en el tratamiento de las fracturas inestables del radio distal.

**Material y método:** Estudio retrospectivo de 93 fracturas inestables, distales, del radio y con desplazamiento dorsal, tratadas mediante reducción abierta por vía volar y osteosíntesis con placa DVR. La edad media fue de 46 años y el seguimiento medio de 13 meses. A todos los pacientes se les realizó evaluación clinicofuncional mediante medición de los rangos articulares, valoración del dolor, medición de los resultados con escalas Gartland-Werley y Green-O'Brien, y del grado de discapacidad a través del DASH (*Disabilities of the Arm, Shoulder and Hand*). Se realizó evaluación radiográfica de los ángulos de inclinación volar y radial, altura radial, escalones articulares, y artrosis radiocarpiana y se tomó el último control radiológico obtenido para la comparación estadística con las radiografías preoperatorias y postoperatorias inmediatas.

**Resultados:** Todas estas fracturas, excepto una, consolidaron en un tiempo medio de 8,2 semanas. En los parámetros radiológicos estudiados se obtuvo corrección media dentro de los valores normales y no hubo variación estadísticamente significativa al final del seguimiento ( $p \leq 0,05$ ). En 12 fracturas quedó algún grado de escalón articular. El 73,33% de los pacientes estaba libre de dolor. Las tasas tuvieron de excelentes a buenos resultados: superiores al 80% según las escalas aplicadas y un bajo índice de discapacidad (18,32) según el DASH.

**Conclusiones:** El empleo de placas volares de ángulo fijo con tornillos bloqueados es un tratamiento seguro y eficaz para fracturas distales del radio, inestables y con desplazamiento dorsal. Los autores de este artículo creen que es una excelente alternativa en el tratamiento de este tipo de lesiones.

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**Introduction**

Different methods have traditionally been employed for the treatment of displaced distal radius fractures<sup>1</sup> that range from cast immobilization to external and internal rigid fixation. The goal of treatment is achieve anatomic fracture healing, promote early restoration of joint motion and prevent complications. Many unstable dorsally displaced fractures of the distal radius have traditionally required stabilization with dorsal plates to obtain rigid fixation and allow early joint motion<sup>2-4</sup>. However, this treatment method is fraught with disadvantages, including potential difficulties in reducing comminuted intra-articular fractures<sup>5-7</sup>, increases in the volar tilt angle following fixation<sup>7,8</sup> and high rates of irritation and soft tissue disruption in the periprosthetic area<sup>9-11</sup>. Other treatment options include external fixation and the percutaneous use of Kirschner wires, the former leading to significant stiffness<sup>12-14</sup> and the latter resulting in unsatisfactory outcomes, both functionally and radiographically<sup>15-17</sup>.

Knowledge of new concepts of surgical anatomy, fracture stabilization biomechanics and open reduction techniques, together with the development of fixed-angle plates with screws locked into the plates, have facilitated and generalized use of stabilization through a volar approach for dorsally displaced distal radius fractures<sup>18-21</sup>. Orbay et al

were the first to apply this type of treatment. In the multiple papers they have published<sup>18,22-25</sup> they provide us with a good understanding of the most appropriate surgical approaches for these fractures (a standard approach or an extended volar approach). They also dwell on their preferred technique for reducing intraarticular and dorsal fragments, which has afforded them a high success rate with fixed-angle implants and screws locked to these implants (DVR [*distal volar radius*] [Hand Innovations, LLC, Miami, FL]). Other authors<sup>21,26,27</sup> show comparable results using implants with similar biomechanic principles. Among them, Musgrave et al who used 2.4 mm plates (LCP Distal Radius Plates, Synthes Ltd, Paoli, PA), Drobetz & Kutscha-Lissberg, who used the Mathys plate (Synthes, Switzerland) and Osada et al, who used the DRV plate (Mizuho Ikaogogy Co, Ltd., Tokyo, Japan).

The purpose of the present study is to carry out a medium-term review of a series of unstable distal radius fractures operated in our hospital following the currently favored approach, i.e. open reduction through a volar approach and stabilization with a DVR-anatomic plate (DePuy Orthopaedics, Inc., Leeds, England). The hypothesis of the authors of the present study is that fixation of these fractures by means of a volar approach with this type of implant provides enough stability to promote healing of dorsally displaced extraarticular and intraarticular distal radius fractures

without the need of additional grafting, making early mobilization and rehabilitation possible without losing the reduction achieved initially.

## Materials and Methods

This study contains a retrospective review of a total of 90 patients (93 fractures) operated with open reduction and DVR-anatomic plate fixation in our hospital between October 2006 to July 2008. The patients presented with dorsally displaced distal radius fractures that either were unstable or showed unsatisfactory radiographic reduction at previous attempts at orthopedic treatment by means of closed reduction and cast immobilization. Of the 90 patients in the study, 52 were male and 38 female. Forty-eight of them presented with left wrist fractures; in 39 the fracture was in the right wrist and in 3 cases the fracture was bilateral. This gave us a total of 93 fractures. Mean patient age was 46 years (range: 18-73 years). Of these, 35.5% was under age 40; 53.3% was between 40 and 65, and the remaining 11.2% was over 65. Mean postoperative follow-up was 13 months (range: 6-24 months). Mechanism of injury was a fortuitous fall in 64 patients, a vehicle accident in 14, a sports accident in 6, pedestrian knock over in 4 and a fall from a height over 3 m in 2 patients. Fractures were classified according to the AO (Arbeitsgemeinschaft für Osteosynthesefragen) system<sup>28</sup> on the basis of preoperative standard anteroposterior and lateral radiographs: 27 were extraarticular (AO type A), 5 were partially intraarticular (AO type B) and 61 were completely intraarticular (AO type C) (table 1). In 6 of the patients the injury was a grade I open fracture according to the classification by Gustilo<sup>29</sup>. In

26 patients there were concomitant injuries of the ipsilateral upper limb, which comprised 18 ulnar styloid fractures, 4 distal ulnar metaphyseal fractures, 2 supacapital humeral fractures, a supracondylar humeral fracture and a radial head fracture. In addition, 6 patients presented with lower limb fractures associated to high-energy multiple trauma sustained at a vehicle accident.

Mean time from injury to surgery was 9 days (range: 2 to 23 days). Regional anesthesia with axillary block of the brachial plexus was used in 56 patients and general anesthesia in 34. All the procedures were carried out with limb ischemia induced by a pneumatic cuff prior to gravity assisted venous drainage and compression with an elastic bandage. Mean OR time was 65 min (range: 50-92 min). All the procedures were done under fluoroscopic guidance. The surgical technique comprised a standard longitudinal volar approach with a skin incision of 8-10 cm over the flexor carpi radialis (FCR), with a zigzag incision at the flexor crease of the wrist. The sheath was exposed and then opened and retracted toward the ulnar side of the FCR. The floor of the FCR tendon sheath was opened distally until the level of the scaphoid tuberosity in order to gain access to the deeper layers. The plane between the flexor pollicis longus and the radial septum was dissected, exposing and dissecting Parona's space and the pronator quadratus. An L-shaped incision was made into this muscle, which was subsequently detached from its radial insertion with a periosteal elevator. This maneuver made it possible to access the anterior aspect of the radius. A distal release of the radial septum was performed in all intraarticular fractures, opening the first extensor compartment and carrying out a Z tenotomy of the brachioradialis tendon, which allowed a more effective treatment and a reduction of the bone fragments. In cases of gross dorsal comminution or difficult fragment reduction, the proximal radial fragment was pronated away from the fracture plane (extended approach to the FCR) with the help of a pair of bone forceps, which allows excellent access to the dorsal cortex, and the use of an intrafocal reduction technique. Once a satisfactory provisional reduction of the fracture has been achieved, a (DVR-anatomic) fixed-angle plate was placed on the anterior aspect of the radius; the so-called *watershed line* was taken as the distal border and the final reduction was checked fluoroscopically with the assistance of the angulation provided by the plate. The distal fragments were provisionally fixed with Kirschner wires. Subsequently, definitive fixation was obtained by means of the fixed-angle guides built into the plate to facilitate screw insertion; smooth locked pegs were placed in the distal-most row of the implant and partially or completely threaded screws in the proximal-most row. In 3 cases, it was necessary to leave one or 2 Kirschner wires for definitive fixation of the radial styloid fragment.

In none of the cases was a bone graft needed for fixing the fracture. At wound closure, the brachioradialis tendon was reattached and the pronator quadratus sutured in all patients. A Redon Slicon drain left in place and the skin was sutured with non-resorbable monofilament. A forearm splint was used in 22 patients until wound healing; the remaining 68 patients only required a bandage in the immediate post-op period, which allowed them to initiate early joint motion

**Table 1** Fracture type according to the classification of the Association for the Study of Osteosynthesis

Fracture type (AO classification)	Number of fractures
A1	0
A2.2	6
A3.2	13
A3.3	8
B1.2	1
B2.2	4
C1.1	4
C1.2	6
C1.3	2
C2.1	8
C2.2	12
C3.1	20
C3.2	8
C3.3	1
Total	93

AO: Association for the Study of Osteosynthesis.

as tolerated. Mean length of postsurgical stay was 2 days, although patients presenting with associated injuries had longer stays; an immediate post-op x-ray was performed for all patients.

Patients were called for their first follow-up visit 2 weeks after surgery. It was then that the skin suture was removed (as well as the plaster cast in the patients that had been immobilized) and the patients were set to the Rehabilitation Unit of the hospital to start a physical therapy program for the operated wrist. Patients were subsequently followed-up at 3, 6 and 12 months. A clinico-functional evaluation of the patient was carried out by measuring the wrist joint range of motion with a goniometer; results were assessed using the Gartland-Werley functional scale<sup>30</sup> and the Green-O'Brien<sup>31</sup> functional scale as modified by Cooney et al<sup>32</sup>. Residual pain was also measured and classified into mild (only present at the extremes of active motion), moderate (present during strenuous manual activity or when some physical or psychological dysfunction was present) and severe (present during basic activities of daily living or at rest). The degree of disability was measured through the Spanish version<sup>33</sup> of the DASH (*Disabilities of the Arm, Shoulder, and Hand*) questionnaire. Standard anteroposterior and lateral radiographs were taken at all follow-up appointments to assess the degree of healing achieved and to measure volar tilt, radial tilt, radial height, joint step-

offs and to determine the degree of radiocarpal arthritis present on the Knirk-Jupiter scale<sup>34</sup>. In this series, the last x-ray follow-up views were compared with the patients' preoperative and immediate postoperative radiographs. All complications and the treatment used to address them were introduced in the patients' clinical records.

A paired Student's "t" test with two-tailed distribution was used to carry out a comparative statistical analysis of x-ray parameters (Microsoft Excel software [Microsoft Corp, ES]). The degree of statistical significance used was  $p \leq 0.05$ .

## Results

All but one of the 93 fractures treated healed over a mean period of 8.2 weeks (range: 7.1-14.3). There was one outlier: a 26-year-old male patient who had presented with an open grade I extraarticular fracture, aggravated by a superficial wound infection during the immediate post-op period and which at 6 months from surgery presented with hardware fatigue (plate breakage) and radiographic nonunion (fig. 1A and B). A new osteosynthesis was carried out with a longer DVR plate plus autologous iliac crest graft, which resulted in a satisfactory outcome 3 months from the second procedure.

table 2. All of the studied parameters showed that the mean degree of correction achieved in the immediate post-op period fell within the normal range, without any statistically significant change in these values at the end of follow-up ( $p \leq 0.05$ ). Complete congruence with an articular step-off smaller than 1 mm was achieved in 54 of the 66 fractures with joint involvement. As regards the remaining 12, in 8 there persisted an articular step-off between 1 and 2 mm and in the other 4 the step-off was larger than 2 mm. At the end of follow-up, 8 of the patients experienced grade I osteoarthritic changes, according to the radiographic criteria of Knirk & Jupiter<sup>34</sup>. The 8 patients had presented with AO C3.2 type fractures, and all of them showed articular step-offs larger than 1 mm on their postoperative x-rays.

As far as the clinico-functional assessment is concerned, we observed that at the end of follow-up 66 (73.33%) of these patients were pain-free, 12 (13.33%) presented with mild pain, 8 (8.88%) presented with moderate pain and 4 (4.44%) presented with severe pain. Of these 90 patients, 78 (86.66%) were able to go back to their everyday occupational or domestic activities. The following values for wrist joint range of motion were achieved: 58° extension (range: 34°-70°), 56° flexion (range: 38°-78°), 26° ulnar deviation (range: 16°-30°), 16° radial deviation (range: 10°-20°), 78° pronation (range: 58°-88°) and 76° supination



**Figure 1** Anteroposterior and lateral radiographs of the 26-year-old male patient who had sustained an open grade I extraarticular fracture, aggravated by a superficial surgical wound infection (A) in the (B) immediately postoperative period which, 6 months following surgery, presented with hardware fatigue (plate breakage) with lack of healing.

**Table 2** Radiographic parameters

	Volar tilt ( $\pi$ )	Ulnar tilt ( $\pi$ )	Radial height (mm)
Pre-op	-20 (-4 to -38)	16 (0-27)	4 (-9-7)
Immediate post-op	4 (9 to -2)	22 (14-30)	10 (5-13)
End of follow-up	3 (8 to -2)	20 (16-30)	9 (5-12)



(range: 60°-88°). According to the Gartland-Werley scale<sup>30</sup> there was 66.6% (62) excellent results, in 20.8% (19) good results, 8.4% (8) de fair results and 4.2% (4) poor results. Results were quite similar on the modified Green-O'Brien scale<sup>31,32</sup>, with 87.09% (81) excellent and good results and 12.9% (12) fair and poor results. Upper extremity disability, as measured by the Spanish version of the DASH questionnaire<sup>33</sup> on the basis of the patients' function and symptoms, reached a score of 18.32 (range: 0-48) out of a maximum 100 points (higher scores indicating greater disability than lower scores).

A total of 11 complications were recorded during follow-up: 5 superficial infections, one deep infection, 2 cases of complex regional painful syndrome, 2 cases of paresthesia in the area of the median nerve, one pseudoarthrosis with breakage of the fixation plate (fig. 1A and B). Except for this case, no patient required a reoperation for hardware removal.

### Discussion

The use of volar plates for unstable dorsally displaced radial fractures have multiple advantages over the use of dorsal plates<sup>18,19,35</sup>. The approach, the reduction and the final stabilization of the fracture are easier and safer than with dorsal techniques<sup>22</sup>. In addition, blood supply to the metaphyseal fragments is preserved and no injuries are caused to the extensor tendons<sup>25</sup>. Additionally, the introduction of fixed-angle plates with screws locked to the plate provides greater stability to these fixation systems<sup>36-38</sup>. In the present study we have used DVR-anatomic plates with highly satisfactory clinical and radiographic results in the treatment of these fractures, as is demonstrated by the fact that nearly all of these patients achieved solid fracture healing in about 2 months without requiring grafting or bone growth stimulation factors (not even in elderly patients). The excellent level of correction obtained (table 2) over the initial post-op period persisted throughout the follow-up period. Only in patients with intraarticular AO C3.2 type fractures was surgical correction less than wholly anatomic since these patients still had some degree of postoperative articular step-off; it was also these patients who experienced type I osteoarthritic changes (Knirk and Jupiter scale<sup>34</sup>) during follow-up. As a result of the technique used and the excellent stability afforded by this osteosynthesis system, these patients were able to start an early mobilization and rehabilitation program that allowed most of them to achieve excellent degrees of joint motion. At the same time, the amount of good and excellent results was higher than 80% according to the Gartland-Werley scale and the modified Green-O'Brien scale, with a low disability index (18.32) according to the DASH questionnaire; which meant that all these patients either were pain-free or had mild pain and could go back to their former occupational or domestic activities.

These results were compared with those of other studies published<sup>18,19,21,27,35,39,40</sup>, which contained series of unstable dorsally displaced distal radius fractures and which treated them with volar plates with or without locking screws (table 3). Constantine et al<sup>19</sup> used a volar plate ( $\pi$ -plate [Synthes,

**Table 3** Comparison of the results published in the literature

	No. of fractures	AO C2 or C3 (%)	Mean age	Fixation system	Graft use	Post-op immobilization	Mean follow-up (months)	Gartland & Werley scale (excellent and good results) (%)	Modified Green & O'Brien scale (excellent and good results) (%)	Mean DASH	Complications (%)
Orbay, 2000	31	32	54	DVR plate	3 cases	4 weeks	12	100	—	—	3
Kamano et al, 2002	33	60	54	Asymmetrical plate	Yes	1 weeks	14	96	—	—	0
Constantine et al, 2002	20	—	41	D.R.P	5 cases	—	12	80	75	—	15
Drobetz & Kutsch-Lissberg, 2003	50	36	62	Mathys	—	2-4 weeks	26	92	68	—	30
Wright et al, 2005	21	90	50	SCS V	Yes	No	17	—	—	16.0	14
Chung et al, 2006	87	24	49	DVR plate	—	No	—	—	—	—	9
Osada et al, 2008	49	86	60	DRV plate	No	No	12	100	98	6.1	2
This study	93	53	46	DVR plate	No	AO type C3	13	87.4	87.09	18.3	11.8

AO: Association for the Study of Osteosynthesis; DASH: Disabilities of the Arm, Shoulder and Hand; DPP: distal radius plate; DVR: distal volar radius; SCS V: subchondral support / volar plate.

Paoli, PAJ) in 20 fractures with 12 months' follow-up. Eighty percent of these dorsally displaced fractures were intra-articular, and this same percentage of patients initiated early preoperative joint motion. The authors reported a mean range of flexion-extension of 123°, a mean range of pronosupination of 156°, without any significant loss of reduction, and a low incidence of complications. Orbay<sup>18</sup>, who employed the DVR plate, conducted a prospective study of 29 patients with 31 unstable dorsally displaced distal radius fractures and a mean follow-up of 13 months. With a mean final range of flexion-extension of 112° and mean pronosupination of 158°, he obtained 100% of excellent or good results. Only 2 patients lost part of the radial length obtained in the immediate post-op period. The only complication in the series was a case of dorsal tendinous irritation caused by a screw of incorrect length. Drobetz and Kutscha-Lissberg<sup>27</sup> reviewed 50 dorsally displaced distal radius fractures (two-thirds of these fractures were intra-articular), with 26 months' follow-up, treated with a fixed-angle volar plate (Mathys Plate, Synthes, Solothurn, Switzerland). Loss of initial reduction achieved occurred in 21 patients and implant failure in 2 cases. Final range of motion was not reported. They had 12 complications, 6 of which were tears of the flexor pollicis longus attributable to the design of the plate. Chung et al<sup>40</sup> treated 87 distal radius fractures with a DVR plate and their patients were able to start mobilizing the operated wrist at the first week post-op, without any apparent losses of the initial reduction achieved. Similarly, Osada et al<sup>21</sup> in a series of 49 patients with this type of fracture, used the DRV Locking Plate (Mizuho Ikkogyo Co, Ltd, Tokyo, Japan) and, without recourse to splinting in the first few weeks post-op, observed that, physiologically, wrist joint motion during everyday activities transmitted an axial load of 100 N through the joint, while the load rose to 250 N on active finger flexion<sup>21,36,38</sup>. This seems to confirm that an antebrachio palmar splint does not neutralize the axial load generated by finger movements in the operated wrist. In view of these results, the authors do not recommend routine use of the splint, except in patients where there is doubt as to the stability afforded by the fixation system used.

This study has its limitations, since it is no more than a retrospective review merely intended to present a series of clinical cases, without a control group that can be used as a standard of comparison. In spite of this, on the basis of the satisfactory clinico-radiographic results obtained in the present series and those published in the International medical literature, the authors conclude that the use of fixed-angle volar plates with locking screws without recourse to bone grafting, in conjunction with a early postoperative rehabilitation program, is a safe and efficient treatment for unstable dorsally displaced distal radius fractures. Moreover, they believe that this kind of plate should be considered the gold standard for treatment of these kinds of injuries.

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