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ORIGINAL PAPER

Prospective study of comminuted articular distal radius fractures stabilized by volar plating in the elderly

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Abstract

Purpose The objective was to assess the ability of the volar locking plate to maintain the radiographic parameters over the time in elderly patients with complex intra-articular distal radius fractures.

Methods Prospective cohort of 66 consecutive patients with mean age of 68 (range 60–81) years and AO type C fractures treated with volar locking plate. Radiographic measurements were performed pre and post-operatively at each follow-up. Clinical assessment was made by Patient-Rated Wrist Evaluation scores, Disabilities of the Arm, Shoulder and Hand score, range of motion, and grip strength.

Results The mean post-operative follow-up was 31 (range, 24–47) months. The most difficult parameters to restore intra-operatively were volar tilt and radial height, while radial inclination and ulnar variance were restored in a high rate of patients. There was significant loss of reduction within four post-operative months in volar tilt ($p = 0.001$) and radial height ($p = 0.029$). Mean radiographic parameters had no changes from four months to final evaluation. At final follow-up, 50.1% of the patients had all radiographic parameters restored in comparison with the noninvolved wrist, but 83.3% had all radiographic parameters within a functional range ($p = 0.001$). No significant relationship between radiographic and functional outcomes was found ($p = 0.474$).

Conclusions This study found that volar locking plate fixation for displaced intra-articular distal radius fractures in elderly patients was an effective procedure to obtain success functional outcomes. Although reduction loss in volar tilt and radial height occurred within four first months, volar plate was able to maintain fracture stabilization with radiographic parameters within functional range over the time in most patients of these elderly patients.

Keywords Distal radius fracture · Intra-articular fracture · Elderly · Surgical treatment · Volar locking plate · Radiographic outcome

Introduction

Anatomic reduction with stable fixation is usually the choice treatment for displaced intra-articular fractures. However, treatment of intra-articular fractures of the distal radius in elderly is controversial [1]. Many studies using volar locking plate in distal radius fractures have reported successful outcomes in elderly [2–4] but the correlation between the anatomical and functional outcomes in elderly patients is not clear [5–7]. Compared to younger patients, elderly with distal radius fractures have usually poorer bone quality and higher comminution which may compromise the ability of the internal fixation to stabilize the intra-articular fracture [8]. Newer techniques as volar locking plates have emerged with the goal of providing better fixation compared to standard plates in these more difficult cases [9]. Some authors have also suggested that the ability of the volar locking plate to restore radiographic parameters may be decreased in more complex intra-articular fractures [8].

Thus, the advantages of the volar locking plates to obtain anatomic restoration of the distal radius in intra-articular fractures should be seen particularly in the elderly. However, these potential advantages have not been demonstrated clinically. Few studies have reported data on the loss of reduction over the time in intra-articular fractures treated con internal fixation [10, 11]. Thus, the effectiveness of the volar locking plate to

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maintain over the time the reduction achieved at the time of surgery has not been sufficiently analyzed.

The main objective of this study was to assess the ability of the volar locking plate to stabilize complex intra-articular distal radius fractures in elderly patients by means of the analysis of the evolution over the time of the radiographic outcomes.

Material and methods

This prospective cohort study was approved by the institutional ethics committee and informed consent was required. All patients aged 60 years and over with closed, displaced intra-articular distal radius fractures (AO type C) [12] treated with volar locking plate fixation between 2011 and 2015 were included in study. A minimum post-operative follow-up of two years was also required. Patients in whom bone grafting or bone substitute was used were excluded from the study to eliminate surgical-related bias. The study cohort consisted in 66 patients, 49 females, and 17 males with mean age of 68.1 (range, 60–81) years. Dominant hand was affected in 54 patients (81.8%). Fractures were AO type C1 in 32 patients, C2 in 28, and C3 in 6.

Closed reduction and plaster immobilization was performed for patient comfort until the time of surgery. All surgeries were performed by experienced hand surgeons within five days after injury. All patients were treated with open reduction and internal fixation using a single type of volar locking plate (Acu-Loc, Acumed, Hillsboro, USA) with no other type of additional fixation through a standard Henry approach. A plaster splint was applied for one post-operative week followed by motion exercises under the supervision of a therapist. In addition, active wrist motions were allowed to the patients at their homes but they were advised not to perform efforts. Wrist-loading exercises were allowed when bridging callus was seen on the follow-up radiographs.

Evaluations

The main outcome was radiographic assessment. Anteroposterior and true lateral radiographic views of both wrists were taken pre-operatively, and only of the affected wrist at immediate post-operative, three, four, six, and 12 months, and at the final follow-up were performed. Fractures were classified according to the AO system [12]. Radiographic measurements were performed by two independent observers on digital radiographs with the help of a computer software according to the methods of Medoff [13], and mean values were obtained. Radiographic parameters were volar tilt, radial inclination, radial height, ulnar variance, and articular step-off. These parameters were compared with the unaffected wrist. In addition, thresholds for the reduction to be functionally acceptable were defined according to the literature [6, 8, 14], such as volar tilt of 0 to 15°, radial inclination >= 10°, radial height shortening <7 mm, ulnar variance >= 5 mm, and step-off < 2 mm.

Clinical assessment was made annually with a minimum of two years by the Patient-Rated Wrist Evaluation (PRWE) scores [15] with higher score indicating more disability. Total PRWE score (sum of pain and function scores) of 50 or lower was considered successful functional outcome. Quality of life was also assessed by the Disabilities of the Arm, Shoulder and Hand (DASH) score [16], range of motion with a clinical goniometer, and grip strength with a Jamar dynamometer compared with the noninvolved hand.

Statistical analysis

A posteriori power analysis of the study and effect size was performed in relation to the difference between pre-operative and post-operative measurements of volar tilt, with a standard deviation of 4.0. An effect size of $d = 1.78$ and power of 0.83 for alpha 5% were obtained, which was considered adequate to discriminate differences.

Statistical analyses were conducted with IBM-SPSS 19.0 software. Normal distribution was assessed by the Kolmogorov-Smirnov test. Unpaired Student's t test or non-parametric Mann-Whitney test were used for continuous variables, and the chi-square test or Mantel-Haenszel test for categorical variables. Paired Student's t test or Wilcoxon signed-rank test were used for comparing the outcomes over the time. Inter-observer agreement for radiographic measurements was assessed by kappa coefficient. Statistical significance was set at $p < 0.05$.

Results

The mean post-operative follow-up was 31 (range, 24–47) months. All fractures but one healed within four post-operative months. There were two post-operative complications including one superficial infection and one median neuritis that required removal of the plate after fracture healing.

For radiographic measurements, inter-observer agreement statistical analysis revealed a kappa coefficient of 0.86 ($p = 0.025$). Compared to noninvolved wrist (Table 1), the radiographic parameters at immediate post-operative were significant decrease in volar tilt ($p = 0.036$) and radial height ($p = 0.001$), and without significant differences in radial inclination ($p = 0.116$) and ulnar variance ($p = 0.548$).

There were significant differences from immediate postoperative (IP) to four post-operative months (Table 2) in volar tilt ($p = 0.001$) and radial height ($p = 0.029$), and not significant reduction losses in the remaining radiographic parameters. On x-rays at four months, 8 (12.1%) patients had some reduction loss compared to immediate post-operative. Furthermore, one patient had failure of fixation with secondary fragment displacement at

Table 1 Post-operative radiographic parameters compared to noninvolved wrist

X-ray parameters	Noninvolved wrist	Immediate postoperative	
	Value	Value	*p* value
Volar tilt (°)	13.7 (4.6)	12.1 (4.1)	0.036
Radial inclination (°)	18.6 (4.1)	19.7 (3.9)	0.116
Radial height (mm)	11.8 (2.5)	9.7 (3.4)	0.001
Ulnar variance (mm)	− 0.6 (1.7)	− 0.8 (2.1)	0.548

Values are shown as mean (standard deviation)

three months, and the patient refused revision (Fig. 1). There were no significant differences in any parameter between four and six months and final evaluation (Table 2). Comparing radiographic measurements between IP and final evaluation, there were significant differences in volar tilt ($p = 0.001$) and radial height ($p = 0.037$). There were no significant differences in loss of reduction between C1 and C2/C3 groups (all, $p < 0.05$).

At the final evaluation, 13 (19.6%) patients had more than 3° loss of volar tilt, and 5 (7.5%) patients more than 2° loss of radial height compared to IP. Among these 18 patients, three had initially insufficient initial screw stabilization, 13 had dorsally metaphyseal comminution, and two had dorsal comminution and screw loosening. Articular step-off was visible on x-ray at the final follow-up in seven patients, four of which had 2 mm width. (Fig. 2).

At the final evaluation (Table 3), 35 (50.1%) patients had all radiographic parameters restored in comparison with the noninvolved wrists. However, 55 (83.38%) patients had all radiographic parameters within the functional range ($p = 0.001$). Regarding to functional outcomes (Table 4), all patients but three had a success PRWE (lower than 50) at the final follow-up. No significant relationship between radiographic and functional outcomes was found ($p = 0.474$).

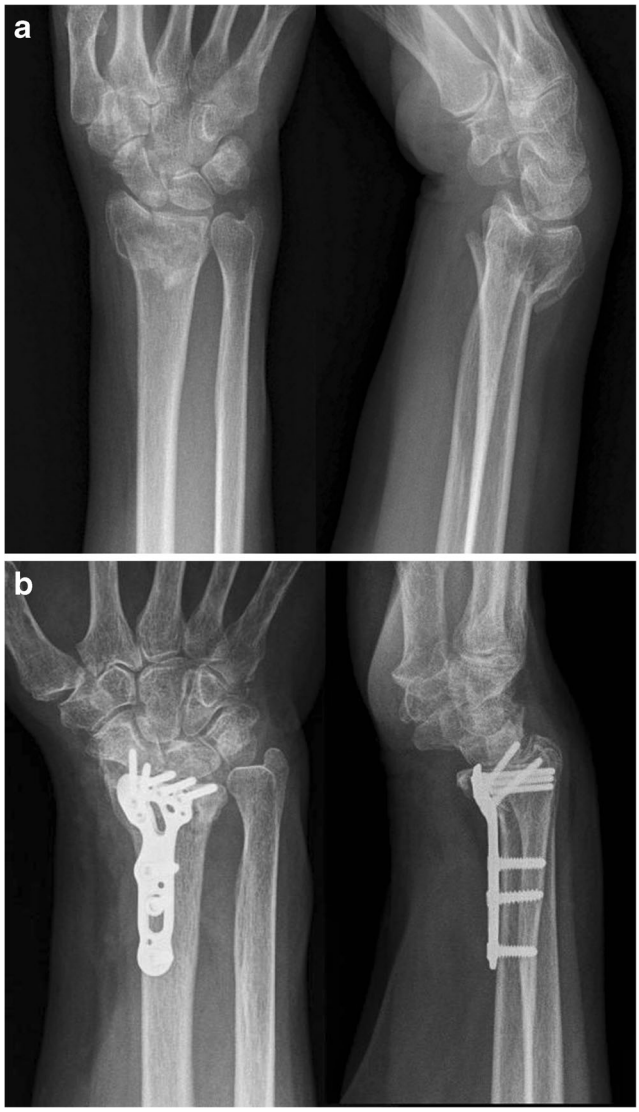

Fig. 1 Female, 68 years old. **a** Fracture AO type C3. **b** After volar plating, failure of fixation with re-displacement at 3 months, and unsuccessful functional outcome

Discussion

The most difficult parameters to restore intra-operatively were volar tilt and radial height. There was significant loss of reduction within four post-operative months in volar tilt ($p = 0.001$) and radial height ($p = 0.029$). Radiographic parameters had no changes from four months to final evaluation. We believe that these early reduction looses could be due to both lack

Table 2 Post-operative radiographic parameters over the time

X-ray parameters	Immediate post-operative	4 post-operative months		6 post-operative months		Final follow-up		
	Value	Value	*p*	Value	*p*	Value	*p*	*p*1
Volar tilt (°)	12.1 (4.1)	9.8 (3.6)	0.001	10.1 (4.0)	0.651	9.9 (3.8)	0.768	0.001
Radial inclination (°)	19.7 (3.9)	19.3 (3.2)	0.520	20.4 (4.5)	0.108	18.9 (5.1)	0.075	0.313
Radial height (mm)	9.7 (3.4)	8.3 (3.9)	0.029	8.2 (4.0)	0.884	8.4 (3.7)	0.766	0.037
Ulnar variance (mm)	−0.8 (2.1)	−0.9 (1.8)	0.769	−0.9 (1.6)	0.991	−0.8 (2.4)	0.778	0.949

Values are shown as mean (standard deviation). *p*, *p* value related to prior immediately evaluation; *p*1, *p* value related to immediate postoperative

Table 3 Number of patients with restoration to normal and functional radiographic parameters at final follow-up

X-ray parameters	Restoring to normal*	Functional range	*p*
Volar tilt (°)	36 (54.5%)	56 (84.8%)	0.001
Radial inclination (°)	49 (74.2%)	59 (89.4%)	0.004
Radial height (mm)	34 (51.5%)	55 (83.3%)	0.001
Ulnar variance (mm)	50 (75.5%)	58 (87.8%)	0.056
Overall	35 (50.1%)	55 (83.3%)	0.001

*Normal x-ray: parameter values compared to noninvolved wrist

of healing in the dorsal comminution and insufficient screw stabilization in poor bone quality in most patients. Although only half of the patients had all radiographic parameters restored in comparison with the noninvolved wrists, most patients in the present study had radiographic parameters within the range considered necessary for an acceptable functional outcome according to the literature [6, 8, 14].

After volar plate fixation, loss of reduction over time had been also reported by other authors. Gruber et al.. [10] reported a small but significant loss of volar tilt and radial inclination upon from immediate post-operative and six post-operative months, but no radiographic changes from that date. Sharma et al.. [11], in the fractures AO type B and C treated with volar locking plate reported that volar tilt and radial height had significant decreases from immediate post-operative to 12 post-operative months.

Perugia et al [5] evaluated 51 patients with articular unstable distal radius fractures treated with volar plate and mean follow-up of 3.4 years. The author reported that normal radial inclination was not restored in 26% of patients, radial height in 34%, volar tilt in 10%, and ulnar variance in 14% at final follow-up. Also, the authors reported that volar tilt and ulnar variance were the most important radiographic parameters to be restored to obtain good functional outcome, and small variations of other radiographic parameters did not affect the outcomes. Earp et al. [17] observed only 10% of loss of reduction in 77 patients with AO C3 fractures treated with volar plate, but the mean follow-up in that study was four months and the mean age was 56 years. In AO C3 fractures, these authors referred that the most common fracture fragment to lose reduction was the lunate fossa and scaphoid fossa. Goldfarb et al [4], in a long-term study of intra-articular fractures treated with open reduction and K-wire fixation, found that radiographic measures could change in the early post-operative years but then remained unchanged until a follow-up of 15 years.

Failure to restore radiographic parameters can have a negative effect on the functional outcome. The main parameters reported have been a volar tilt of less than 5° [20], radial

Table 4 Functional outcomes at final follow-up

Variables	Score
PRWE-total	18.2 (11.2)
Pain	7.8 (5.4)
Function	10.3 (6.3)
DASH	17.1 (11.6)
Motion	
Flexion	53.4 (11.2)
Extension	50.7 (10.4)
Supination	81.7 (9.2)
Pronation	84.5 (10.1)
Grip strength (%)	74.4 (22.7)

Data are shown as mean (standard deviation). Grip strength (% uninvolved hand)

Fig. 2 Female, 63 years old. **a** Fracture AO type C3. **b** Fracture stabilization by volar plate with successful functional outcome

inclination less than 20° [9, 18], radial height loss greater than 6 mm [7, 19], and positive ulnar variance greater than 5 mm [20, 21]. While this can be seen in young patients, the correlation between anatomical reduction and functional outcome in elderly people with displaced unstable distal radius fracture is still a controversial topic [22]. In extra-articular fractures in elderly, other authors [23, 24] have reported differences between patients younger and older than 60 years. Older patients showed no significant relationship between radial length, radial tilt or dorsal tilt, and pain and disability. In intra-articular fractures, success functional outcomes can be obtained in both younger and elderly patients despite a poor radiographic result after volar locking plate [2, 3, 5, 25].

In the present study, success functional outcomes were obtained in most patients even though radiographic parameters were restored to normal values in half of the patients. Other authors [26] suggested that a little wider tolerance than proposed in the literature could be accepted in complex intra-articular fractures of the distal radius. Ruckenstuhl et al. [27], in a long-term follow-up of patients with intra-articular treated with volar plate, reported 90% success outcomes at ten years with no significant differences at two, six and ten years in functional scores or quality of life.

The strengths of this study were its prospective design and availability of contralateral wrist radiographs to assess the normal radiographic parameters in each patient. However, this study also had several limitations. Measurements were made only on radiographic planes, and the measure errors of the used software were 0.5 mm and 2°. Thus, small measure values can have been overestimated. Other measure errors can be due to small changes in the rotation of the radiographs. There were also a relatively short follow-up, but the study was focused on radiographic outcomes.

In conclusion, this study found that volar locking plate fixation for displaced intra-articular distal radius fractures in elderly patients was an effective procedure to obtain success functional outcomes. Although reduction loss in volar tilt and radial height occurred within four first months, volar plate was able to maintain fracture stabilization with radiographic parameters within functional range over the time in most patients of these elderly patients.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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