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ORIGINAL STUDY

Residual wrist pain after volar locking plate fixation of distal radius fractures

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A prospective multicenter clinical study evaluated, using the Hand20 and hand diagram, the disability, incidence, location, and predictive factors of residual wrist pain 18 months after volar locking plate fixation of distal radius fracture in 122 patients. The average Hand20 score and numeric rating scores for pain were 13.1 ± 18.2 and 2.1 ± 2.3, respectively. Fifty-seven patients indicated that they had pain. Among those patients, 25 had ulnar pain and 45 had radial pain. The incidence of radial-sided wrist pain was higher than ulnar-sided wrist pain. Logistic regression analysis showed that female sex and intra-articular fracture significantly correlated with radial-sided wrist pain. Volar locking plate fixation maintained anatomical reduction ; however, a significant number of patients complained of residual wrist pain.

Keywords : distal radius fracture ; volar locking plate ; pain.

INTRODUCTION

Distal radius fracture is a common injury, accounting for one sixth of all fractures treated in the emergency room (*1*). In the past, most distal radius fractures were manually reduced and treated non-operatively with a plaster cast ; however, the results of such non-operative treatment were not always satisfactory, especially when the fractures were unstable and showed cortical comminution (*17,32*). These results encouraged surgeons to use internal or external fixation to maintain reduction after surgery. Among these techniques, volar locking plates have a number of theoretical advantages, including the provision of adequate stability. Recent biomechanical studies have shown that available volar locking plates not only provide significantly higher stiffness but also withstand a significantly higher amount of cyclic loading, which represents normal physiological forces encountered during post-operative rehabilitation (*19*). In fact, recent prospective studies on the use of volar locking plates for distal radius fractures have shown that volar locking plates lead to better radiological (*33*) and clinical outcomes (*9*) early in the post-operative periods compared with other fixation methods. Even in the elderly, who are often frail and have impaired bone quality which can affect fracture stabilization, volar locking plates provide superior stiffness and axial loading strength with improved fixation compared with standard plates (*26*).

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Despite these favourable reports, the use of volar locking plates for this common fracture still remains a matter of controversy and the effect of anatomical restoration on long-term outcome remains uncertain (*10*). Pain largely affects the patient's perspective of outcome. Few studies evaluated pain in detail and validated patient-reported outcome measures have not been used until recently.

Volar locking plates ensure excellent stability of fixation and are able to maintain anatomic reduction after distal radius fractures. We expected a lower risk of residual wrist pain, especially ulnocarpal pain. In this large-scale, prospective, multicenter clinical study, we used a validated questionnaire and a diagram of the upper extremity to clarify the incidence and the location of residual wrist pain. We also investigated predictive factors for residual wrist pain.

MATERIALS AND METHODS

Study Design and Population

In 2006, a prospective cohort study of distal radius fractures was conducted as a part of the study to evaluate outcome associated with the volar locking plate system. Nagoya university hospital and its 13 affiliate hospitals were involved. The study protocol was reviewed and approved by Human Research Committee of Nagoya University. Patients provided informed consent for the use of their results in this study.

Between 2006 and 2007, 241 patients with distal radius fractures that were treated with fixed-angle volar locking plates and screws alone were identified. Inclusion criteria for this study were (1) distal radius fracture, (2) operative treatment using volar locking plate, (3) and age 18 years or older. Exclusion criteria were (1) open fractures, high-energy pilon fractures with significant comminution of the distal radius, (2) confounding factors such as concomitant wrist or upper extremity injuries other than ulna styloid fracture, (3) systemic, multiple organ, or head injuries, and (4) bilateral fractures. A total of 198 patients were included in the study. Two patients were lost to follow-up within 6 months of surgery. One hundred and ninety-six patients underwent wrist radiographs and comprehensive objective functional measurements up to 6 months after surgery. Thereafter, the patients were asked to rate their disability at home at 6-month intervals up to 18 months using Hand20, a validated and self-administered instrument to evaluate disability of the upper extremities (*29*). Intensity of pain was indicated on a 0 to 10-point rating scale. In addition, patients were asked to mark the areas where they feel pain on a diagram of the upper extremity. Those who did not answer at 18 months were excluded from the study, which reduced the number of patients for statistical analysis of disability and pain to 122.

Treatment Methods

All operations were performed under general or axillary block anaesthesia. A standard volar Henry approach to the distal radius was used. If a satisfactory reduction was not achieved through a single approach, an additional dorsal approach was used. The fracture was fixed with one of three systems : the Matrix Smart Lock system (Stryker Osteosynthesis, Freiburg, Germany), Acu-Lock system (Acumed, Hillsboro, OR, USA), or Locking DRP system (Synthes, Paoli, PA, USA). Selection of the plate was based on the surgeon's preference. Because a consensus regarding the need for bone grafts was not reached in a preliminary discussion, bone graft or bone graft substitute was used at the discretion of the surgeon. After surgery, the wrist was immobilized in a volar plaster splint. The total period of wrist splinting was between 1 and 6 weeks, based on the surgeon's preference.

Clinical Examination

At each scheduled follow-up visit, surgeons recorded the presence and absence of postsurgical complications including infection, tendon injury, nerve palsy, and chronic regional pain syndrome. Range of motion was measured by hand therapists. Objective functional outcomes including range of motion were normalized as a percentage of the value for the contralateral wrist.

Radiographic Examination

The fractures were categorized according to the AO classification system (*23*). The degree of fracture displacement was assessed with standard measurements of volar tilt angle, radial inclination angle, ulnar variance, and articular step-off at each patient's visit (*18*).

Statistical Analysis

Data from the 13 institutions were pooled for all analyses. Changes in continuous outcomes between

follow-up investigations were evaluated with use of Friedman test, followed by a series of Wilcoxon tests for discrete variables, and the Cochran Q test and McNemar test for categorical variables.

Univariate analyses to assess predictors of pain were performed to analyze the effects of age, gender, affected hand, duration of cast immobilization, plate selection, implant removal, bone grafting, intra-articular fracture, ulnar fracture, articular step-off (> 1 mm), volar tilt angle, radial inclination angle, and ulnar variance in the final evaluation, surgical approach (additional dorsal approach), plate position, injury compensation status, complications, and surgical experience. Data were compared by chi-square test, Fisher's exact test, Student's t test, or Mann-Whitney U test as appropriate. Age and factors that showed a significant ($p < 0.05$) or a tendency toward association ($p < 0.10$) with radial-sided or ulnar-sided wrist pain in univariate analyses were entered into a multivariate analysis using stepwise logistic regression, with backward elimination (likelihood ratio), to identify factors that were independently associated with pain. We used the Hosmer-Lemeshow test to assess the goodness of fit of the logistic regression models. We calculated odd ratios (OR) and 95% confidence intervals (CI) as measures of risk for significant multivariate predictors of pain at 18 months after surgery. Continuous variables were described using means and standard deviations unless otherwise specified. Two-tailed p values < 0.05 were considered statistically significant.

RESULTS

Of the 198 original patients, 76 did not answer the questionnaires on the third occasion ; thus, a total of 122 patients (61.6%) were included in the final analysis. Among those patients, 91 answered at 6 months and 84 answered at 12 months. Demographic characteristics and injury patterns of the 122 patents are shown in Table I. No significant differences were found in demographic variables between the 122 patients who answered questionnaires at 18 months and the 76 patients who did not.

Clinical Results

The mean flexion-extension and supination-pronation arcs compared with the uninjured side at 6 months were 74.1 ± 16.8% and 90.9 ± 9.8%, respectively. The mean grip strength at 6 months was 75.6 ± 24.3%.

The mean Hand20 score (range : 0-100) at 18 months was 13.1 ± 18.2. Hand20 scores obtained at 12 and 18 months were significantly improved compared with those obtained at 6 months ($p < 0.001$) (Fig. 1A). The mean pain score (range : 1-10) was 2.1 ± 2.3 at 18 months. The numeric pain rating scores at 12 months were significantly improved compared with scores at 6 months ($p < 0.05$). There was no significant difference in pain scores between 12 and 18 months (Fig. 1B).

We used a hand diagram to identify the location of wrist pain. Results showed that 25 of 122 patients (20.5%) complained of ulnar-sided wrist pain and 45 patients (36.9%) had radial-sided wrist pain at 18 months after surgery. Thirteen patients had pain on both the ulnar and the radial side. In terms of pain overall, 65 (53.3%) subjects answered that they had no pain, and 57 subjects (46.7%) answered that they had pain. Statistically significant declines occurred in the reported prevalence of the ulnar-sided wrist pain over the 18-month period (Cochran Q 7.18, df 2, $p < 0.05$), whereas no statistically significant changes were

Table I. — Patient demographics, injury patterns, and type of plate

Age (years)	59 ± 15.9 (range : 19-84)
Sex	Male 33 (27%) ; Female 89 (73%)
Fracture side	Right 55 (45%) ; Left 67 (55%)
Injury compensation	Yes 24 (20%) ; No 95 (78%)
AO classification	Type A 39 (32%) ; Type B 9 (7%) ; Type C 74 (61%)
Ulnar fracture	Yes 72 (59%) ; No 47 (39%)
Type of plate	Acu-Loc 18 ; Matrix 58 ; LCP 46

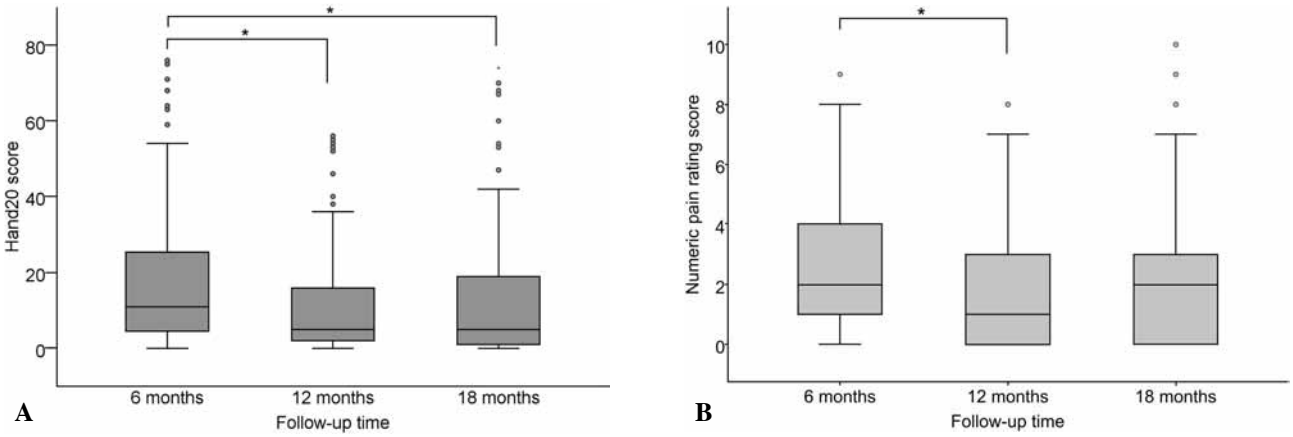

Fig. 1A and 1B. — Box plots represents the Hand20 score (range : 0-100) and numeric pain rating score (range : 0-10) over 18 months. The bottom and top of each rectangle of box plots correspond to the lower and upper quartiles of the data values. The line drawn through the rectangle corresponds to the median value. The whiskers, starting at the ends of the rectangle, indicate minimum and maximum values. An asterisk indicates a significant difference between groups ($p < 0.05$).

detected in the proportion with radial-sided wrist pain over the 18-month period ($p = 0.317$) (Fig. 2).

Radiological results

The average volar tilt, radial inclination, and ulnar variance after surgery were 5.7 ± 6.0°, 21.2 ± 5.1°, and 0.0 ± 1.8 mm, respectively, and correction loss for each variable assessed at 18 months was -0.9 ± 3.4°, 0.1 ± 2.7°, and 0.8 ± 1.5 mm, respectively. Fourteen of 83 intra-articular distal radius fractures had a persistent step-off between fragments of > 1 mm after surgery.

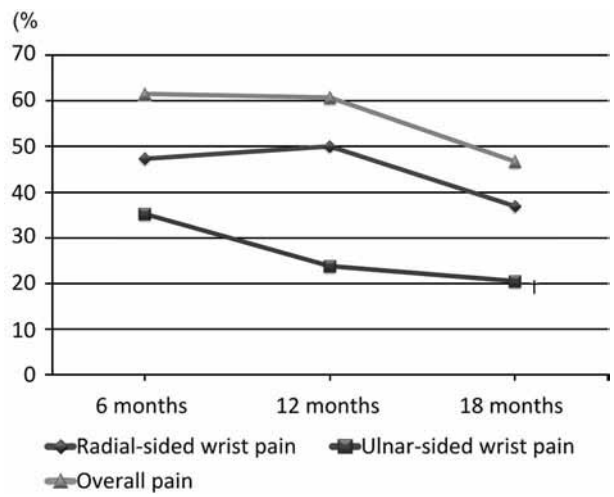

Fig. 2. — Line graph illustrating the rate of radial-sided wrist pain, ulnar-sided wrist pain, and overall pain according to follow-up period. A dagger indicates significant declines occurred in the reported prevalence of the ulnar-sided wrist pain over the 18-month period ($p < 0.05$).

Predictors of Radial-sided Wrist Pain

In univariate analysis, there was a tendency to associate radial-sided wrist pain with female sex, ulnar fracture, intra-articular fracture and additional dorsal approach ($p < 0.10$) (Table II). Multivariate analysis demonstrated that female sex ($p = 0.017$) and intra-articular fracture ($p = 0.036$) (Table III), were the sole variables significantly correlated with radial-sided wrist pain.

Predictors of Ulnar-sided wrist Pain

In univariate analysis, there was a tendency to associate ulnar-sided wrist pain with bone grafting, additional dorsal approach, and affected hand. Female sex and articular step-off were nearly significantly associated (Table II). Multivariate analysis demonstrated that bone grafting was the only factor significantly correlated with ulnar-sided wrist pain ($p = 0.006$) (Table IV). The Hosmer-Lemeshow test did not reject the goodness of fit for any of the models.

Table II. — Univariate analyses of predictors of wrist pain

	n	Radial wrist pain (p value)	Ulnar wrist pain (p value)
Age	122	0.417	0.493
Sex	122	0.078	0.057
Affected hand	122	0.518	0.033
Articular step-off	120	0.337	0.089
Volar tilt (VT)	122	0.817	0.686
Radial inclination (RI)	122	0.511	0.285
Ulnar variance (UV)	121	0.604	0.454
Correction loss of VT	122	0.513	0.237
Correction loss of RI	122	0.611	0.726
Correction loss of UV	121	0.912	0.66
Surgical experience	122	0.983	0.526
Duration of cast immobilization	121	0.574	0.223
Plate position	122	0.471	0.911
Ulnar fracture	119	0.073	0.604
Implant removal	118	0.528	0.904
Injury compensation	119	0.952	0.834
Complications	122	0.717	0.626
Plate selection	122	0.93	0.82
Intraarticular fracture	122	0.078	0.15
Additional dorsal approach	121	0.057	0.033
Bone grafting	121	0.113	0.006

DISCUSSION

The management of distal radius fractures remains a matter of debate. Clinical and biomechanical studies have predicted poor long-term outcome for those treated without restoration of normal anatomy. Therefore, much effort has been made to clarify the association between long-term outcome and the degree of residual deformity. However, the threshold for acceptable mal-union has yet to be defined. Although it has been reported repeatedly that mal-union with radial shortening or persistent irregularity of the articular surface is associated with a poor outcome (*2,4,17,32*), as defined mostly by non-validated outcome measures such as Gartland and Werley (*13*) or Green and O'Brien score (*7,16*), recent studies using validated outcome measures question these conclusions. Barton *et al* studied the effect of radial shortening using the patient rated wrist evaluation (PRWE) score and did not find any correlation between moderate (0-8 mm) shortening and outcome at a mean follow-up of 29 months (*3*). Goldfarb *et al* studied the impact of arthritic changes after severe intra-articular fractures on long-term outcome using two validated outcome measures, the Hand Function Sort and the Musculoskeletal Function Assessment score, and found no correlation between the presence or degree of arthrosis and upper-extremity function at 15 years (*15*). Similarly, Forward *et al* reviewed 106 adults with malunited distal radius fractures who were 40 years or younger at the time of injury (mean, 38 years) : "While there was radiological evidence of post-traumatic osteoarthritis after an intra-articular fracture in 68% of patients (27 of 40), the disabilities of the arm, shoulder and hand (DASH) scores were not different from population norms, and function

Table III. — Risk factors associated with radial-sided wrist pain in multivariate analysis

	Odds ratio	95% confidence interval	p value
Age*	0.98	0.95 to 1.01	0.108
Female sex	3.72	1.26 to 10.96	0.017
Intraarticular fracture	2.65	1.07 to 6.59	0.036

A multivariate logistic regression model, with backward elimination (likelihood ratio), was performed to analyze the multiple effects of the variables of age, sex, intraarticular fractue, ulnar fracture, and surgical approach.

* For each year of age.

Table IV. — Risk factors associated with ulnar-sided pain in multivariate analysis

	Odds ratio	95% confidence interval	p value
Age*	0.97	0.93 to 1.003	0.07
Bone grafting	4.83	1.56 to 14.94	0.006

A multivariate logistic regression model, with backward elimination (likelihood ratio), was performed to analyze the multiple effects of the variables of age, sex, affected hand, bone grafting, articular step-off (> 1 mm), and surgical approach.

* For each year of age.

as assessed by the Patient Evaluation Measure, was impaired by less than 10%" (*12*).

Aanatomical reduction is obviously an important aim of treatment. Volar locking plates, which have a number of theoretical advantages, have been found to provide rigid fixation. Chung *et al* prospectively assessed 87 patients, who underwent open reduction and internal fixation of an inadequately reduced distal radius fracture with use of the volar locking plating system, with the Michigan Hand Outcomes Questionnaire and found that their score approached normal by 6 months (*6*). Based on the existing literature, it is clear that volar locking plates can satisfactorily be used to stabilize both intra- and extra-articular fractures and allow early mobilization. This was further confirmed by the present study, because radiological parameters were fine after surgery regardless of the plate used, type of fracture, and period of immobilisation. Similarly, patients regained satisfactory objective function regardless of any of these factors. However, a significant number of patients complained of residual wrist pain and mild disability even at 18 months after surgery. The discrepancy may be attributed to the use of the Hand20 and the hand diagram to identify the location of wrist pain. The mean of the norms of the Hand20 score is 1.2 ± 3.9 and the norm of the Hand20 is much smaller than that of the DASH (*29*). The small norms may have contributed to detect mild disability.

We expected that anatomical reduction with volar locking plate fixation could prevent ulnar-sided wrist pain. Although our radiological findings, including ulnar variance and its correction loss, were satisfactory, approximately 20% of the patients complained of ulnar-sided wrist pain. Zenke e*t al* found that initial ulnar variance at the time of injury, and not postoperative ulnar variance, affected persistent ulnar-sided pain (*34*). Initial ulnar variance at the time of fracture could be a measure of comminution and also collapse of the radius. A high-energy injury with a large ulnar variance value causing a triangular fibrocartilage complex tear has been reported to be related to a high rate of distal radio-ulnar joint instability (*24*). Persistent ulnar-sided wrist pain might mainly be caused by dysfunction of the triangular fibrocartilage complex and incongruity of the distal radio-ulnar joint (*31*). Our radiological findings were not significantly associated with ulnar-sided wrist pain at the final examination. However, the initial ulnar variance was not assessed in this study due to non-availabi-

lity of data. This might have led our multivariate analysis to conclude that only bone grafting remained a significant factor associated with ulnar-sided wrist pain. In addition, bone grafting was used based on surgeon preference. Technical variance of practicing surgeons might have affected the conclusion, even though surgical experience was entered into a multivariate analysis. Another potential cause of pain around the distal radioulnar joint is surgical intervention near the sigmoid notch of the radius.

We found the incidence of radial-sided wrist pain at final follow-up was much higher than ulnar-sided wrist pain which significantly decreased over time. We hypothesized that radial-sided wrist pain may be related to the plate, taking into consideration the study by Drobetz and Kutscha-Lissberg, which indicated the importance of early plate removal to avoid complications including rupture of the flexor pollicis longus tendon (*8*). Because removal of plate was decided at the surgeon's discretion in this cohort, we compared residual pain between those who had the plate removed (mostly within 6 months after surgery) and those who did not. We did not find any significant differences between the two groups ($p = 0.53$). Our multivariate analysis demonstrated that female sex and intra-articular fracture were significantly associated with radial-sided wrist pain. Our results concur with prior clinical studies reporting pain differences between sexes. Ruau *et al* reported that women suffered pain more often and the most significant differences occurred in patients with disorders of the musculoskeletal systems (*11,27*). In terms of fracture type, a previous study indicated that patients with a complex intra-articular fracture and those with an extra-articular fracture had comparable wrist motion and upper-extremity-specific health status one year after open reduction and volar plate fixation (*28*). Another study of arm-specific disability after volar plate fixation indicated that only age and income were associated with disability one year after fracture (*5*). This study suggests that intra-articular fracture is one of the risk factors for radial-sided wrist pain. Our patients judged their pain and its location by themselves on a diagram of the upper extremity. This localized pain analysis may have led to a different result from previous studies. Intra-articular distal radius fractures were reported to associate with scapholunate ligament injuries (*14,20,25*) and the development of osteoarthrosis (*17,21,22,30*) more frequently than extra-articular fractures. Additional evaluation using arthroscopy might have revealed the association of ligament injuries or chondral defects with radial-sided wrist pain.

One limitation of this study is the approximately 38% patient loss for evaluation with the Hand20 and the diagram at 18 months. However, further analysis demonstrated that no significant difference in demographic variables, grip strength, flexion-extension and supination-pronation arc, and the Hand20 scores at 6 or 12 months was found between the patients who answered at 18 months and those who did not. This provided some assurance that our recruited data did not depend on disabilities. Another shortcoming is that the clinical and radiographic examinations were evaluated by a variety of individuals involved in multicenter clinical trials. Care was taken to evaluate carefully all data points, and those at extreme variance were reassessed.

Although there are various possible causes for pain after distal radius fracture treated with volar locking plates, precise evaluation of pain location reveals different predictor variables for residual wrist pain. This study showed that the incidence of radial-sided wrist pain was higher than ulnar-sided wrist pain, and radial-sided pain was associated with female sex and intra-articular fracture. However, the association of the predictors was weak and these variables would probably predict only a small part of residual pain. Therefore, further study is needed to clarify other factors (eg, psychosocial factors, chondral or ligament injuries) in the future.

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