Radiographic analysis in reduction loss after distal radius fracture fixation with variable angle volar locking plate

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Research article

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Abstract

Background Reduction loss is commonly seen even in the newly designed locking plate fixation for distal radius fractures. Our study purpose is to investigate the efficacy of the variable angle volar locking plate (VAVLP) in maintenance of fracture fixation.

Methods A total of 37 patients of unilateral distal radius fractures receiving VAVLP fixation were included. Forearm radiographs immediately after surgery and those at 3 months were retrospectively reviewed for analysis of radiographic parameters including radial height (RH), ulnar variance (UV), radial inclination (RI), volar tilt (VT), tear drop angle (TDA), distal dorsal cortical distance (DDD) and Soong classification (SC).

Results By comparing the 3-month measurement and normal data, the difference of RH/UV/TDA was significant (p-value < 0.001) while the difference of RI/VT was insignificant. However, there was no significant difference regarding those five parameters between postoperative and 3-month measurement. Linear regression on DDD exhibited positive dependence with p-value of 0.002 between postoperative and 3-month changes. Postoperative SC was grade 0 in 13 patients, grade 1 in 21, and grade 2 in 3. There were 7 of Gr 0 and 2 of Gr 1 making one grade up.

Conclusion VAVLP fixation in distal radius fracture can maintain radiographic alignment without significant reduction loss for at least 3 months. Realignment within normal range was in RI and VT, but not in RH/UV/TDA.

Background

Distal radial fracture is a very common injury, which has shown a bimodal distribution of age-specific incidence with an increasing prevalence in adults and aging people [1]. There had been multiple treatment modalities for displaced distal radius fractures; however, no single one would be effective for all types of fractures [2]. With recent evolution in fixation implants and technical refinement, volar locking plate (VLP) has been increasingly adopted for realignment and fixation in distal radius fractures [3]. Being different from the conventional screw-plate fixation, locking plate and screw works as a fixed construct to provide superior biological and mechanical advantages and facilitate fracture realignment and healing [4].

VLP can be divided into two types, one is of locking screws and pegs in fixed angles; the other is of variable angle locking design. While a fixed-angle VLP fixation can improve the stability by providing a rigid construct with screws inserted and locked in a predetermined direction [5, 6], the variable-angle volar locking plate (VAVLP) allows a greater adaptability for screw angle insertion to support the dorsal subchondral bone for weak and comminuted fractures [7]. However, significantly decreased ultimate failure moment noted at 15°-inclined screw insertion indicated potential reduction loss and recommend titanium VAVLP be used with precaution [8]. Given that reduction loss remains a critical issue after treatment of distal radius fractures [9] even when using newly designed locking plates [10], radiographic parameters anecdotally used in fracture evaluation and functional correlation [11, 12] have been currently

adapted for assessment of secondary collapse after fracture fixation [13]. This study aims to evaluate the efficacy of VAVLP fixation in the maintenance of realignment through a retrospective review and comparison of postoperative radiographs in distal radius fractures.

Methods

To evaluate the stability of VAVLP fixation of radial fractures, posteroanterior (PA) and lateral views of forearm x-ray immediately and 3 months after operation were evaluated [14, 15]. The inclusion criteria were: (1) extra-articular or partial articular fracture of distal radius, (2) fractures receiving VAVLP (Synthes, 2.4 mm Variable Angle LCP) fixation. Totally, the medical records of 43 patients with 43 fractures which underwent surgical management for distal radial fractures between October 2011 and October 2019 in our hospital were being reviewed. There were 5 Smith’s type fractures (AO types A2.3), 18 Colles’ type fractures (AO type A2.2), and 19 volar Barton’s type fractures (AO type B3). The exclusion criteria were: (1) patient with incomplete medical records and follow-up (5 patients), and poor quality of radiographs (1 patient). Finally, 37 patients with a mean age of 54 years (range 18 to 90) were included in this study. All patients underwent VAVLP fixation for unilateral distal radius fracture; postoperative protection with short-arm splint was applied for six weeks. Postoperative x-ray images were taken at a mean of 1 day after operation; radiographs of 3 months following the operation were taken at a mean of 84 days after operation. All and the diagnostic imaging studies were reviewed by a radiologist and an orthopedist, and consensus on the assessment was reached.

Radiographic parameters and analysis

To standardize our measurement, radiological parameters were measured on standard x-rays of the wrist according to the methods introduced by Kreder et al [16]. For both PA view and lateral view, the center of radius was measured at 3 and 5 cm below the mid-region of the proximal lunate articular surface in order to form the central axis of the radius. Radial height (RH), ulnar variance (UV) and radial inclination (RI) were measured on PA view taken with both shoulder abduction and elbow flexion in 90°, forearm pronation and supination in 0° [17]. Volar tilt (VT), tear drop angle (TDA) [18], distal dorsal cortical distance (DDD) [19] and Soong classification (SC) [20] were measured on lateral view x-rays taken with shoulder abduction, elbow flexion and forearm supination, all in 90°. RH represents the distance between the two parallel lines perpendicular to the long axis of the radius where one line passing through the distal articular surface and the other one intersects the distal articular surface of the ulnar head. UV refers to the distance between the levels of radial and ulnar articular surfaces, one line passing through the distal ulnar articular surface parallel to the other one passing through the medial radial articular surface perpendicular to the central axis of the radius. RI on AP projection represents the angle between a line connecting the radial styloid tip and ulnar aspect of the distal radial articular surface and a line perpendicular to the central axis of the radius. VT refers to the angle between a line perpendicular to the central axis of the radius and a line along the distal radial articular surface at the joint margin. TDA is the angle between a line passing through the central axis of the tear drop and a line perpendicular to the central axis. DDD refers to the distance between the tip of the most distal screw and the dorsal rim of

distal radius. SC represents a tangential line drawn to the volar rim, which is parallel to the diaphyseal bone of the radial shaft in order to determine the plate prominence. Plates that do not extend the line were graded as Grade 0; Plates that extend volar to the line but remain proximal to the rim were graded as Grade 1; Plates that are distal or directly on the volar rim were graded as Grade 2. The above parameters were measured on the digital images with accuracies up to 0.01 mm and 0.1° (Fig. 1).

According to the central limit theorem, when the sample number is greater than 30 (N = 37), it tends to be normal distribution. Thus, a 2-sample paired T-test was used for comparing the postoperative radiographs with those of 3 months following operation. A 1-sample T-test was used for comparing the parameters of radiographs of 3 months following operation with the normal values quoted in past studies [11, 21], in order to determine if the normal anatomy was restored. Level of significance was set at less than 0.05. Linear regression was applied for comparing the DDD immediately after operation with the change in value of 3 months following operations. Fisher's exact test was used for comparing SC immediately after operation with those of 3 months following operation. With reference to different literatures, the average value of parameters was as follows: RH 11.6 mm; UV 1.5 mm (negative ulnar variance), RI 22.5°; VT 11.2; TDA 68°; value of DDD immediately after the operation is in correlation with the variance of DDD over the 3 months after surgery [19]. All statistical analyses were performed with SPSS v21 (IBM Corporation, Armonk, NY).

Results

Comparison with normal values

The result of comparison between radiographic parameters of 3 months following the operation with normal values [11, 21], revealed significant differences in RH, UV, TDA when compared to their own normal values, with $p < 0.001$, $p < 0.001$ and $p < 0.001$ respectively. However, there is no significant difference for RI and VT compared to the normal values, with $p = 0.184$ and $p = 0.127$ respectively (Table 1).

Table 1
Comparison of 3 months following operative radiographic parameters with normal values

		Normal values	Mean	SD	Range	*p-value*
Radial height	**(mm)**	11.6	9.57	3.19	3.16 to 15.8	0.000
Ulnar variance	**(mm)**	1.50	1.67	2.21	-3.90 to 6.06	0.000
Radial inclination	**(degree)**	22.5	21.35	5.17	7.10 to 33.40	0.184
Volar tilt	**(degree)**	11.2	12.93	12.93	-4.90 to 24.20	0.127
Tear drop angle	**(degree)**	25.4	54.79	9.14	35.00 to 69.30	0.000

Abbreviation: SD, standard deviation.

Comparison with values immediately after operation

The result of comparison between radiographic parameters immediately after operation with 3 months following the operation, showed no statistical difference was noted when comparing the above values to the values of 3 months following the surgery, with p = 0.207, p = 0.267, p = 0.049, p = 0.368 and p = 0.276 respectively (Table 2).

Table 2
Comparison of 3 months following operative radiographic parameters with radiographic parameters immediately after the operation

		A mean	B mean	SD	Range	*p-value*
Radial height	**(mm)**	9.57	9.33	3.17	3.26 to 16.58	0.207
Ulnar variance	**(mm)**	1.67	1.41	2.05	-4.05 to 5.10	0.267
Radial inclination	**(degree)**	21.35	20.37	4.92	6.00 to 31.40	0.049
Volar tilt	**(degree)**	12.93	13.69	5.53	0.80 to 22.70	0.368
Tear drop angle	**(degree)**	54.79	56.46	8.76	25.20 to 70.20	0.276
A = Radiographic parameters at 3-month follow-up						
B = Radiographic parameters immediately after the operation						
Abbreviation: SD, standard deviation						

Comparing the DDD immediately after operation with the change in value of 3 months following operations

DDD right after surgery and at 3 months averaged 5.24 ± 1.70 mm (range, 1.99 to 8.66) and 4.64 ± 1.46 mm (range, 1.83 to 8.82) respectively; there was significant difference (p = 0.005). Based on linear regression analysis, significantly positive dependence with p value of 0.002 was found between postoperative DDD and 3-month DDD; regression equation was Y= -0.4 + 0.26X (Y = DDD change in 3 months, X = DDD right after operation)(Fig. 2).

Comparing the grading of SC immediately after the operation with SC of 3 months following the operation

Regarding SC, 13 cases were graded as Grade 0 after operation; 6 cases remained as Grade 0 (6/13) and the other 7 cases (7/13) were progressed to Grade 1 in radiographs of 3-month postoperatively. Twenty one cases were graded as Grade 1 after operation; 19 (19/21) of them remained as Grade 1, and the other 2 (2/21) cases were progressed to Grade 2 in radiographs of 3 months following the operation. Three

cases were recorded as Grade 2 after operation, and all 3 cases remained as Grade 2 (3/3) in radiographs of 3 months following the operation.

To compare the grading of SC immediately after operation and 3 months following operation, Fisher's exact test was used and revealed significant dependence with $p < 0.001$ (Table 3).

Table 3
Comparing the grading of SC immediately after the operation with SC of 3 months following the operation by Fisher's exact test

		SC of 3 months following operation				
		Grade 0	**Grade 1**	**Grade 2**	**Total**	**p-value**
	Grade 0	7	6	0	13	
SC immediately after operation	**Grade 1**	0	19	2	21	< 0.001
	Grade 2	0	0	3	3	
Total		7	28	5	37	
Abbreviation: SC, Soong classification						

Discussion

This study revealed that when using VAVLP for fixation in distal radius fractures, RH, UV, TDA could not be restored to its normal values, while RI and VT were successfully restored to their normal values. The above results were noted in cases using fixed angle VLP as well [14, 15]. The potential causes behind might be due to the heterogeneity in individuals, fracture patterns and the length of treatment [22]. Another study by Pienaar et al in 2013 also stated that no matter which kind of reduction and fixation was used, TDA cannot be restored to its normal value [21].

By comparing the values of parameters immediately after operation with those of 3 months following operation, results showed that RH, UV, RI, VT, TDA were able to sustain at least a 3-month period in radioulnar variance. Optimization of screw/plate position by measuring DDD was first proposed in 2016 and recommended a limitation of 6 mm in maximum during surgery to avoid subsequent displacement [19]. It was even more critically concerned for elderly patients with osteoporotic bone according to another publication analyzing both intra-articular and extra-articular fractures in 2018 [23]. In our cases, both average postoperative DDD and 3-month DDD fit the criteria of 6 mm; no significant difference was found and indicated optimized screw position and maintenance of realignment with VAVLP fixation. Positive dependence of postoperative DDD on the 3-month DDD may suggest proper screw fixation to minimize DDD during operation is crucial for firm fixation in treatment of distal radius fractures. Design

of variable-angled locking holes in VAVLP allows screw insertion in greater adaptability to reach subchondral bone and minimize DDD for providing superior maintenance of fracture reduction.

The SC was originally proposed to evaluate volar locking implant prominence and risks in flexion tendon rupture. A recent clinical report analyzed 400 cases receiving two different kinds of locking plates and stated that the group using variable angle LCP had a greater SC grading [24]. In analyzing the 37 patients of our study, we found there is a trend that patients with postoperative SC grade 1 and 2 show less subsequent displacement than those with grade 0; the difference is statistically significant ($p < 0.001$).

There are several limitations in our study. This is a radiographic analysis based on retrospective case review without control group. The sample size is small with heterogeneity in fracture pattern. Preoperative radiographs were not included; only radiographs immediately and 3 months after surgery were evaluated. In addition, no clinical correlation is documented.

Conclusions

VAVLP can maintain radiographic realignment up to 3 months after surgery. No significant reduction loss is found. Radiographic parameters are restored to normal range in RI and VT, but not in RH/UV/TDA. Variable- angled locking holes provide greater adaptability to minimize DDD facilitating maintenance of fracture fixation.

List Of Abbreviations

VAVLP variable angle volar locking plate

RH radial height

UV ulnar variance

RI radial inclination

VT volar tilt

TDA tear drop angle

DDD distal dorsal cortical distance

SC Soong classification

VLP volar locking plate

PA posteroanterior

Declarations

Ethics Approval: Institutional review board approval (IRB no. 202000939B0) was obtained to perform a review of patient records and radiographs.

Consent for publication: Not Applicable.

Availability of supporting data: The datasets generated during the current study are available from the corresponding author on reasonable request.

Competing interests: 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. The authors report no competing interests.

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Figures

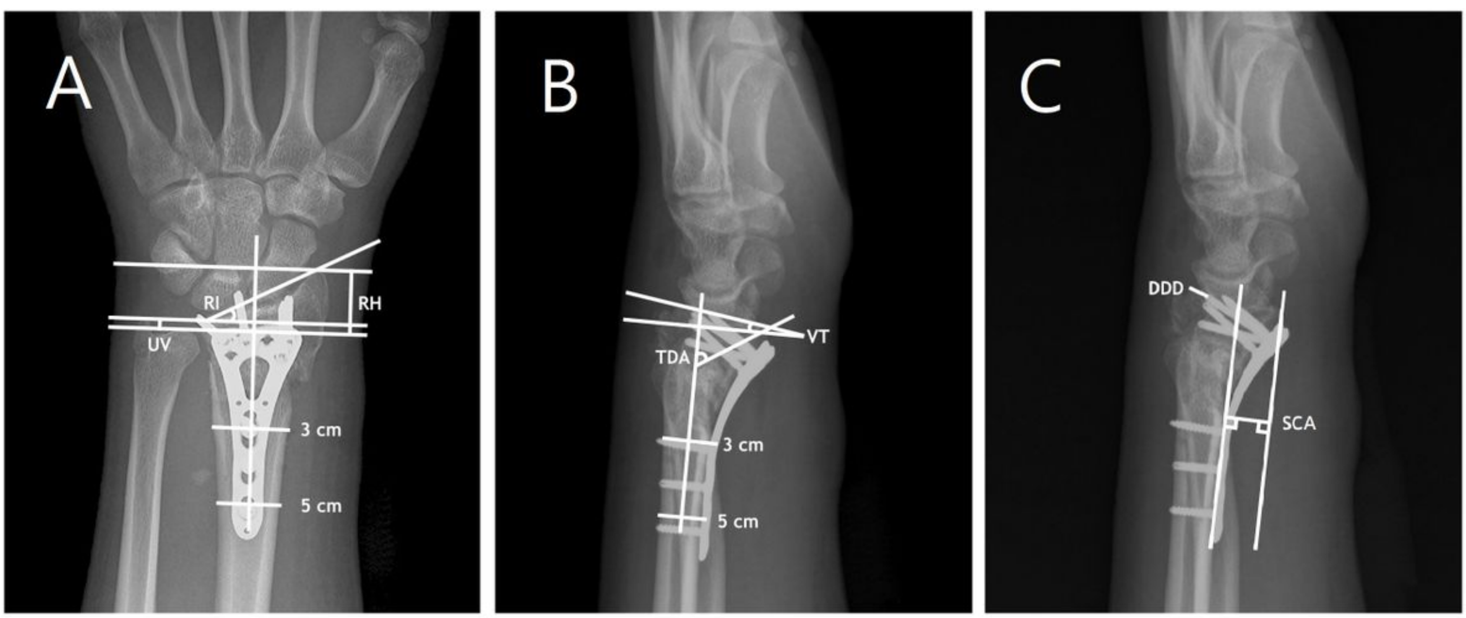

Figure 1

Radiographic parameters and analysis. Radiographs of posteroanterior (A) and lateral view (B and C) at 3 months following operation of distal radius fracture with variable-angle volar locking plate RH= Radial

height, UV= Ulnar variance, RI= Radial inclination, VT= Volar tilt, TDA= Tear drop angle, DDD= Distal dorsal cortical distance, SCA= Soong classification auxiliary-line

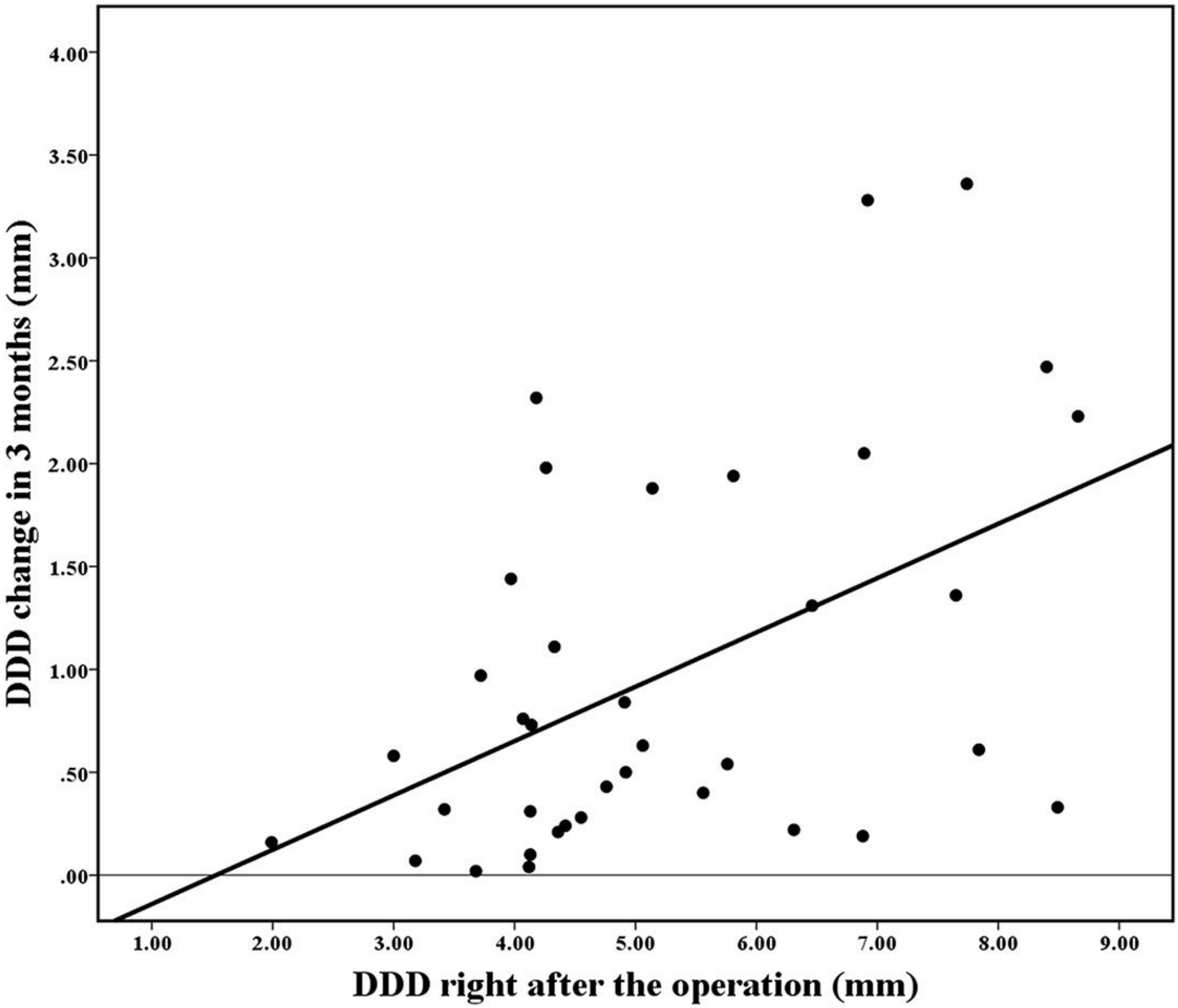

Figure 2

Linear regression demonstration of DDD DDD= distal dorsal cortical distance