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ORIGINAL STUDY

The threat of longitudinal cracking after distal radius fracture treatment with volar locking plate

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The purpose of this study was to examine the occurrence rate of longitudinal cracks and associated characteristics following volar locking plate fixation of the distal radius. Using case records from Shizuoka Saiseikai General Hospital dated between March 2008 and March 2015, a total of 419 eligible adult patients were identified. Standard anteroposterior postoperative radiographs were evaluated to classify longitudinal crack occurrence. Documented variables were compared between patients with longitudinal cracking and those without. Univariate analyses were conducted among each plate group. There were 38 confirmed cases of cracking (Acu-Loc: n = 25, Acu-Loc 2: n = 11, VA-TCP: n = 2). All cracks healed within 4 to 6 weeks after the operation. Plate type, along with patient age and sex were significantly associated with the occurrence of a longitudinal crack ($p < 0.05$). Although no severe complications related to longitudinal cracking were observed, associated risks for specific patient groups should be considered.

Keywords: Distal radius fracture ; volar locking plate; complication ; longitudinal crack.

INTRODUCTION

Since the introduction of the volar locking plating system for distal radius fractures (DRFs) in 2000 *(16)*, indications for open reduction and internal fixation (ORIF) have expanded *(2,4,10)*. This treatment strategy imparts sufficient, stable fixation to maintain quality anatomic reduction, even for elderly patients *(1,11,17-19)*. Added stability from ORIF can expedite patients' return to normal activities of daily living, especially when compared to the use of other conservative approaches that typically require long periods of immobilization or external hardware.

However, several studies indicate various complications following volar locking plate fixation *(6-8,12,13,23)*. Previous research reports rates of complication ranging from 5.9% to 48% *(5)*. Such complications are predominately hardware-related, and most commonly involve screw penetration

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into the radiocarpal or distal radioulnar joint or tendon complications *(5)*. Fracture collapse and malunion are other frequent pitfalls of volar plate fixation, along with infection and nervous problems (carpal tunnel syndrome, median nerve injury, ulnar nerve injury, etc.). In addition to these major complications, added complications may also arise. Locking screw loosening and breakage of the plate can cause severe consequences and often lead to revision surgery *(3,14,15,20,24)*.

One relatively uncharted risk of volar locking plates is the potential of a longitudinal crack (LC) of the distal radius. Despite the increasing prevalence of LCs in our clinical experience, research on the topic remains sparse. Longitudinal cracking normally begins on the distal part of the diaphysis after ORIF of the wrist using a volar locking plate. One study from Sugun et al. *(22)* describes a significant correlation between cracking and age group, yet further research on different plate types or surgeon factors is lacking.

Using data from patients treated within a seven-year span for distal radius fractures at a local hospital, we investigated the prevalence of LCs after application of a volar locking plate. The purpose of this study was to document the frequency of longitudinal cracking following volar locking plate insertion, specifically though review of all qualifying DRF cases in a single hospital. In addition, we aimed to evaluate associated patient and surgeon characteristics, predicting elderly, female patients to display the highest rates of LCs. We also hypothesized surgeries conducted by less experienced would result in more frequent cracking.

PATIENTS AND METHODS

We performed a retrospective review using all applicable case data from Shizuoka Saiseikai General Hospital collected between March 2008 and March 2015. To be considered for analysis, patients must have been diagnosed with a distal radius fracture, undergone ORIF with the use of a volar locking plate, and have been 18 years or older at the time of surgery. Patients exposed to other methods of treatment (external fixation, K-wire fixation, or conservative non-operative care) were excluded. The following data were recorded: plate type, surgeon experience at the time of surgery, patient age, sex, fracture type, and postoperative complications from a LC. Fractures were classified according to the AO/OTA classification system *(21)*.

IRB approval was obtained to perform this retrospective chart and radiographic review.

Radiographic evaluation was conducted on immediate postoperative standard anteroposterior radiographs by two certified hand surgeons. Follow-up X-rays between four to six weeks after surgery were also examined for each patient. For those classified as positive for LC, preoperative anteroposterior radiographs were evaluated to determine if a longitudinal crack was present before fixation. In cases of disagreement, an experienced hand and trauma surgeon was consulted. Two investigators reviewed medical records and recorded data retrospectively. Both research team members analysed each case independently and then compared results for consistency.

First, we examined the relationship between LC occurrence and specific case characteristics (surgeon experience, patient age/sex, fracture type). To simplify our analysis we modified both surgeon experience and fracture type into bivariate variables. Surgeons were classified as either junior surgeons (less than three years of experience as an orthopaedic surgeon) or senior surgeons (three or more years of experience in orthopaedic surgery). Similarly, fractures were considered either comminuted (AO type A3, C2, C3) or non-comminuted (all other fracture types).

Next, we conducted a univariate analysis to identify unadjusted differences between patients with and without LC. Using chi-square tests for categorical variables and Mann-Whitney's U tests for continuous variables, we determined statistical significance between groups. Then, we performed a second univariate analysis for variables identified as significant in our initial tests. We checked for significance with these variables against plate type, again using chi-squared tests for categorical variables and a Steel-Dwass test for continuous variables. Significance level in these analyses was set at 0.05.

RESULTS

A total of 419 consecutive eligible cases were discovered. LC occurred in 38 cases (Figure 1). Table I describes associated case characteristics stratified by the presence or absence of a LC. Patients who experienced a LC were more likely to be female ($p = 0.009$) and were significantly older than those who did not experience LC ($p < 0.001$). We found no significant differences between surgeon experience levels.

AO fracture types had the following incidences: A2 (n = 148), A3 (n = 78), B1 (n = 5), B2 (n = 15), B3 (n = 16), C1 (n = 86), C2 (n = 40) and C3 (n = 31). Frequencies of each plate type are given in Table II. The Acu-Loc (Acumed, Hillsboro, OR, USA) was the predominant plate chosen by surgeons, followed by VA-TCP (Synthes GmbH, Oberdorf, BL, Switzerland), AcuLoc 2 (Acumed, Hillsboro, OR, USA), Aptus2.5 (Medartis, Basel, BS, Switzerland), DRP (Synthes, Paoli, PA, USA) and others. Plate selection was at the discretion of each surgeon. Table II also provides LC rates for specific plate types. Acu-Loc and Acu-Loc 2 were most common with rates of 13.0% (n = 25) and 27.5% (n = 11), respectively. Neither patient age nor gender was significantly associated with a particular type of plate.

Table I. — Univariate analysis of the characteristics between LC and non-LC groups. Mean age and female rate were significantly higher in LC groups

	LC(+)	LC(-)	P value	test
Case number	38	381		
Female rate (%)	89.5	69.3	.009*	chi-square
Comminution rate(%)	36.8	35.3	.854	chi-square
Junior rate (%)	55.3	50.7	.588	chi-square
Patients' age	77.3	64.6	<.001*	Mann-Whitney's U

LC: longitudinal crack

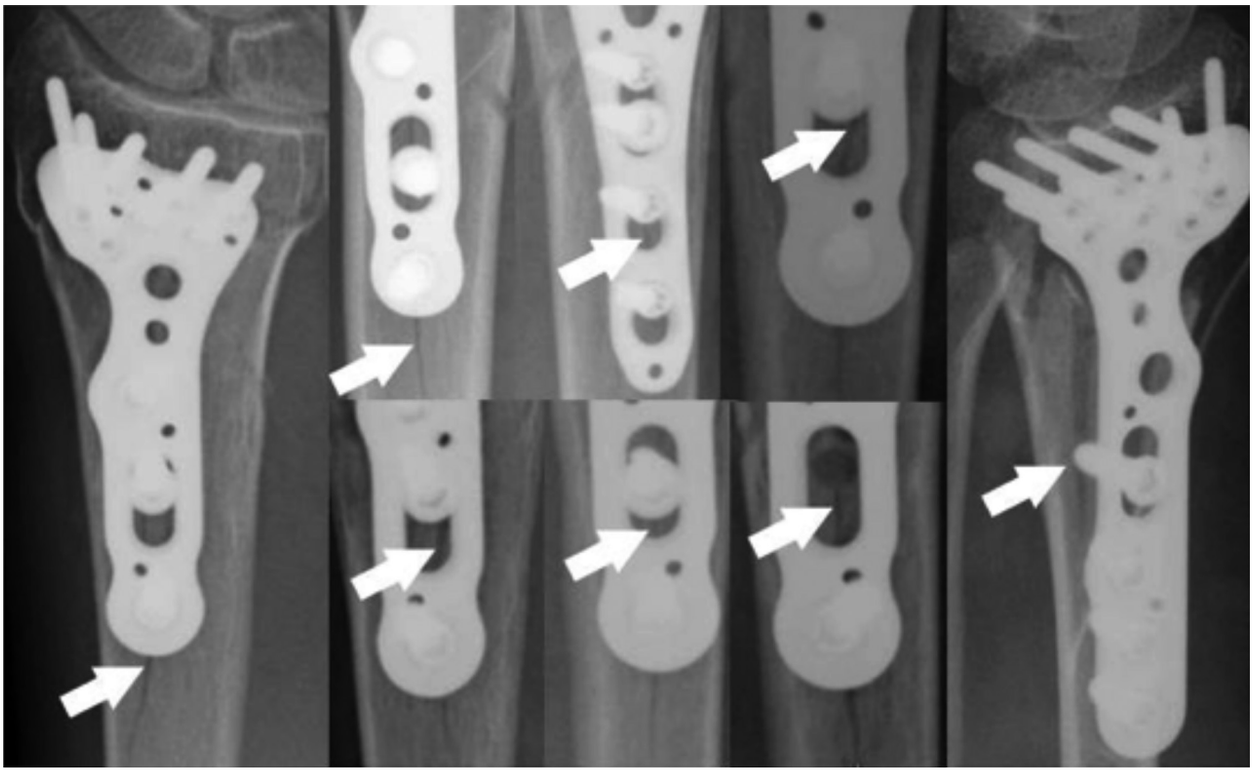

Fig. 1. — LC occurrence after plate fixation LCs sometimes occurred after ORIF of a DRF. The crack was detected mainly through the elliptic slot in the plate

Table II. — Univariate analysis of the LC occurrence rate and characteristics in each plate group
LC occurrence rate was significantly higher in AcuLoc/AcuLoc 2groups.
There were no significant differences for tested patient characteristics between plate groups.

	AcuLoc	AcuLoc 2	Aptus	TCP	DRP	Others	Mean	P value	Test
Case number	192	40	35	125	17	10			
LC case number	25	11	0	2	0	0		<.001*	chi-square
LC rate(%)	13.0	27.5	0.0	1.6	0.0	0.0	9.1		
Female rate(%)	75.5	57.5	65.7	70.4	76.5	60.0	71.1	.237	chi-square
Patients' age	67.0±18.0	57.8±23.1	59.0±19.6	71.8±17.8	67.2±15.1	69.4±18.2	65.7±18.8	P>0.10 for each couples	S-D test

LC: longitudinal crack, S-D: Steel-Dwass

In six out of the 38 LC cases, cracking was present prior to plating (Table III). In all six cases, postoperative radiographs consistently indicated worse fractures after the volar locking plate. The mean follow-up period for patients was 3.1 months (range from 0 to 40 months). Although some patients endured an extended postoperative splinting period, LCs caused no severe complications such as screw loosening or implant dislocation. Secondary postoperative evaluation revealed all cracks healed within four to six weeks after surgery.

Table III. — The rate of preoperative LC occurrence

	AcuLoc	AcuLoc 2	TCP	Total
LC case number	25	11	2	38
Preop LC case number	2	3	1	6
Preop LC rate(%)	8.0	27.3	50.0	15.8

LC: longitudinal crack

Patient is a 71-year-old female who experienced a fall from standing height. She was diagnosed with a left distal radius fracture, classified as AO type C3 (comminuted). Three days after injury, ORIF with external fixation was performed. She had a preoperative LC, which noticeably worsened postoperatively (Figure 2).

DISCUSSION

Volar plating techniques have become progressively more common as a treatment method for DRFs *(2,4,10)*.Increased clinical practise can lead to improved awareness of previously unknown complications. Using data from over 400 patient cases at our hospital, we found LC occurred mainly in patients who received an Acu-Loc or Acu-Loc 2 plate. Previous research from Sugun and colleagues presents similar results. They found patients who developed a LC displayed a higher mean age and were more likely to be female than those who did not. In certain cases, a preoperative LC was identified, and the crack appeared worse after volar plating. These findings provide evidence for an additional risk of volar locking plates and may be used to help uncover the mechanism behind the occurrence of longitudinal cracks.

Several reasons may explain the general knowledge gap on LCs. Because of an immense lack of previous research, surgeons may simply be overlooking longitudinal cracks in their patients. In addition, severe longitudinal cracking typically causes instability of the fixed site. Thus, LCs may be misclassified or overshadowed by other complications such as loss of reduction, plate breakage or screw loosening, which lead to similar consequences *(3,7,14,24)*. Finally, publication bias is

Fig. 2. — Case 1 pre- and postoperative anteroposterior radiographs of distal radius. A LC occurred before ORIF. Screw placement widened and extended the LC

likely present in the literature involving distal radius fracture management, reporting positive outcomes more often than negative *(21)*. Despite these barriers, the dangers of this complication should be considered to provide healthcare providers and patients with the most comprehensive information about all treatment options *(2)*.

The mechanics behind longitudinal cracking remain uncertain. One possibility is that LCs occurs preoperatively and are then widened or extended by the screw during fixation. Only six out of 38 patients (15.8%) with LC evaluated in our study showed indications of cracking preoperatively. This data was obtained through the assessment of plain radiographs. However, other forms of evaluation might have revealed a higher percentage of patients with preoperative cracks that were unnoticeable through x-ray assessment. Yet, this theory does not explain the observed high rate of LC in patients who received an AcuLoc/AcuLoc 2 plate in comparison with other plate types.

Table IV details the specifications of each plate type used. AcuLoc and AcuLoc 2 both incorporate major differences in comparison to other plate

Table IV. — The specifications of implants

Plate	Diameter of the screw	Shape of the locking screw	Locking screw hole angle
Acu-Loc	3.5mm	Tapered	Fixed and tilted
Acu-Loc 2	3.5mm	Tapered	Fixed and tilted
VA-TCP	2.7mm	straight	Fixed and vertical
DRP	2.4mm	straight	Fixed and vertical
APTUS	2.5mm	straight	Variable angle

options. The diaphyseal screw is tapered and has a wider diameter. The screw hole angle is fixed and titled 10 degrees. The tapered shaping may work as a wedge against the volar cortex *(22)*. Additionally, tilted angle screw insertion may generate unintended force toward the volar cortex. Further study is required to adequately detail the mechanism leading to a longitudinal crack. Plate specifics may help explain the increased observation of LCs, and mechanical adjustments may need to be considered.

Although we did not evaluate patient bone density in this study, a relationship might exist between bone density and risk of LC. In general, elderly, female patients exhibit higher rates of fragility. Iki and colleagues report the estimated occurrence rate of osteoporosis (distal radius) among Japanese women is 51.2% in aged 50-79 years *(9)*. Our results indicate a higher probability of being female and an older average age for patients who developed or worsened a pre-existing LC from treatment. Therefore, longitudinal fractures may be a greater risk for patients with weak bone strength, such as the elderly and those suffering from osteoporosis.

Fortunately, no severe complications arose in the LC cases evaluated in our study. In fact, all developed LCs healed within four to six weeks. Although revision is often unnecessary, surgeons and patients should recognize the possibility of cracking when choosing a treatment option. Further research is necessary to determine if screw shape or insertion procedure play a significant role in predicting cracks. Increased LC frequencies from certain plate types should be taken into consideration during implant development to produce the safest, most effective product for patients. Manufacturing developments may improve outcomes not only for treatment of DRFs, but other fracture types as well.

The present study did have a few limitations. We collected data retrospectively and were limited to plain radiographic evaluation. In addition, bone density data was not obtained. Our study included a wide variety of surgeons, which may have led to variations in technique. Yet, this allowed us to analyse surgeon experience as a potential explanatory variable because of this variety. Given the study's retrospective nature, we were not able to control the choice of implant. Rather, implants were chosen solely on surgeon preference and certain types were scarcely used. Possible future research could examine alternate patient, surgeon, and case factors or investigate potential long-term complications after longitudinal cracking.

This study discussed many possible associations of LCs in DRF patients. Not only did we document the LC rate for patients evaluated, but we also considered surgeon experience, fracture type, and certain patient characteristics in our explanation. As a result, we found significant associations between multiple variables and the development of a crack. Although we were not able to evaluate bone density of our patients, we suspect a strong relationship between osteoporosis and increased risk of cracking. Our study provides insight to the meagrely researched dangers of longitudinal cracks resulting from volar plate fixation, and it provides the opportunity for further research to delve deeper not only into more specific patient characteristics, but important surgeon and procedural characteristics as well.

CONCLUSION

LC occurred predominantly in elderly, female patients with an Acu-Loc or Acu-Loc 2 plate. Surgeon experience level did not affect LC rates. Although we observed no severe complications following longitudinal cracks after volar plate fixation, manufactures and healthcare providers should still be cognizant of the potential complication. Intervention may not be necessary, but rare, severe implications may exist. Further study is required to understand the mechanism of cracking and implement appropriate prevention techniques.

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