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Original article

Distal locking screw length for volar locking plate fixation of distal radius fractures: Postoperative stability of full-length unicortical versus shorter screws

Longueur des vis de verrouillage distal lors de l'ostéosynthèse par plaque verrouillée palmaire d'une fracture de l'extrémité distale du radius : stabilité postopératoire de vis unicorticales longues vs. vis courtes

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ABSTRACT

We compared post-operative distal radius fracture (DRF) displacement after volar locking plate fixation using full-length unicortical and shorter-length distal locking screws. In this non-inferiority, retrospective cohort study, DRFs treated with volar locking plate fixation were evaluated on X-rays. In the full-length group, volar locking plate fixation was performed with full-length unicortical distal locking screws. In the shorter-length group, the distal locking screws were planned pre-operatively to be approximately 75% of the distal radius depth based on the lunate depth, and the same depth was drilled. Three radiographic parameters – ulnar variance, volar tilt, and radial inclination – were measured intra-operatively and at the final follow-up. The displacements were compared between the two groups. Each group contained 34 fractures. The mean ulnar variance between the two periods increased 1.1 mm in the full-length group and 1.3 mm in the shorter group (mean difference, 0.2 mm; 90% confidence interval, −0.3 to 0.6). The shorter group was not significantly inferior to the full-length one. Volar tilt increased 0.6° in the full-length group and −0.1° in the shorter group, while the radial inclination increased 0.1° in the full-length group and 0.2° in the shorter one. The differences in the increases were not significant. The post-operative DRF stability of 75%-length distal locking screws was not inferior to that of full-length unicortical screws. To prevent extensor pollicis longus tendon rupture, shorter distal locking screws and the same drilling depth may be preferable for volar locking plate fixation.
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Mots clés :
Plaque d'ostéosynthèse
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RÉSUMÉ

Nous avons comparé le déplacement post-opératoire de fractures de l'extrémité distale du radius (EDR) après ostéosynthèse par plaque palmaire utilisant des vis verrouillées distales unicorticales longues à des vis plus courtes. Dans cette étude rétrospective de cohorte portant sur l'absence d'infériorité, les fractures de l'EDR traitées par plaque verrouillée ont été évaluées sur des radiographies. Dans le groupe des vis longues, l'ostéosynthèse par plaque verrouillée palmaire était réalisée avec des vis verrouillées distales unicorticales longues. Dans le groupe des vis courtes, la longueur des vis de verrouillage distal était calculée avant l'intervention et représentait approximativement 75 % de l'épaisseur de l'EDR, sur la base de l'épaisseur sagittale du lunatum, après un forage de même longueur. Trois paramètres radiographiques, la variance ulnaire, la bascule palmaire et la bascule radiale, étaient mesurés en cours

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d'intervention et au dernier recul. Les déplacements ont été comparés entre les deux groupes. Chaque groupe regroupait 34 fractures. L'augmentation moyenne de la variance ulnaire entre les deux périodes était de 1,1 mm dans le groupe des vis longues et de 1,3 mm dans le groupe des vis courtes (différence moyenne, 0,2 mm; intervalle de confiance de 90 %, −0,3 à 0,6). Le groupe des vis courtes n'était pas significativement moins bon que celui des vis longues. La bascule palmaire augmentait de 0,6° dans le groupe des vis longues et de 0,1° dans le groupe des vis courtes, alors que l'angle radial augmentait de 0,1° dans le groupe des vis longues et de 0,2° dans le groupe des vis courtes. Les différences concernant ces augmentations n'étaient pas significatives.

La stabilité post-opératoire des fractures de l'EDR n'est pas inférieure quand on utilise des vis dont la longueur est de 75 % de la valeur maximale par rapport à des vis unicorticales de longueur maximale. Pour éviter des ruptures du tendon de l'extensor pollicis longus, des vis de verrouillage distal plus courtes et un forage de même longueur peuvent représenter un compromis favorable lors de l'ostéosynthèse par plaque verrouillée palmaire.

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1. Introduction

Volar locking plates have become a popular treatment for distal radius fractures (DRF). Many authors report that volar locking plates can maintain adequate fracture stability [1,2].

However, post-operative extensor pollicis longus tendon rupture has been reported after volar locking plate fixation for DRF [3–5]. Previous articles indicated that either over-drilling or a protruding screw tip through the dorsal cortex of the distal radius caused extensor pollicis longus tendon rupture [3,6–8].

The purpose of this study was to compare post-operative fracture displacement between full-length unicortical and shorter-length distal locking screws placed in volar locking plate for DRFs. As the primary outcome, the potential increase in ulnar variance was compared between the two groups. A previous biomechanical study showed that 75%-length unicortical distal locking screw fixation was mechanically similar to bi-cortical fixation [9]. Our hypothesis was that shorter-length distal locking screws are not clinically inferior to full-length unicortical screws with regard to post-operative fracture stability.

2. Materials and methods

2.1. Study design

The study was a single center, non-inferiority, retrospective cohort study. Ethics approval was obtained from our institutional research ethics committee. Patients who had undergone volar plate fixation for either intra- and extra-articular DRF were included in this study. The patients were operated on and followed at the regional referral hospital in Nagano Prefecture in Japan between April 2014 and January 2017. Since a 2015 article reported that distal radius depth could be calculated from lunate depth [10], patients were treated with shorter-length screws instead of full-length screws. Therefore, early cases were assigned in the full-length group while later cases were in the shorter-length group.

2.2. Study population

Inclusion criteria for this study were:

- DRF (AO type A and C) treated with a volar locking plate;
- adult patients (18 years old or older);
- minimum follow-up period of six months.

Exclusion criteria were:

- open fracture;
- buttress plating for Smith's or Barton's fracture;
- dorsal plating or other fixation;
- concomitant distal ulnar fracture, except for the ulnar styloid.

All surgeries were performed or supervised by one of two orthopedic specialists with more than 15 years' experience, although six residents performed these procedures. Most (60 of 68 surgeries, 88%) were handled by one of the two specialists.

2.3. Plan for surgery

2.3.1. Full-length group

Screw and peg lengths were not calculated pre-operatively but measured with a depth gage during surgery. Surgeons drilled while avoiding penetrating the dorsal cortex of the distal radius and measured them with a depth gage. However, since the dorsal cortex was often comminuted, no feeling of cortex penetration was perceived by the surgeon during drilling. In this situation, the tip of the depth gage was placed on the dorsal cortex line visible with fluoroscopy, and then the screw length was selected as being 2 mm shorter than the depth gage measurement.

2.3.2. Shorter-length group

Pre-operatively, the lunate depth was measured on a lateral X-ray of the injured or contralateral wrist (Fig. 1a), and the depth of each of the four evenly divided quarters of the distal radius was calculated [10]. Then, the length of the four distal locking screws or pegs in the first distal row was set at approximately 75% of the distal radius depth, based on a previous biomechanical study [9]. The percentage of the first distal row from the lunate depth is shown in Fig. 1b. For example, the full length of the most ulnar line of the distal radius was calculated as 106% of the lunate depth [10]. Then, 75%-length of the distal radius was calculated as 79% (= 106% × 75%) of the lunate depth. Because the prior study did not describe the second distal row as proximal to the first (= most) distal row, we applied the length of the first distal row to the second distal row. For example, 65% screw length of the lunate depth was used in the radial side of the second row whereas 79% screw length of the lunate depth was in the ulnar side of the second row.

2.3.3. Plate selection

The locking plate products were independently selected by the surgeons, and two different products were used. Twenty-one plates with distal screws and 13 plates with distal pegs were used in the full-length group while two plates with screws and 32 plates with pegs were used in the shorter group. Twenty-three plate products with distal screws were the ADAPTIVE Distal Radius Plate 2.5 (Medartis, Basel, Switzerland), and the 45 with distal pegs were the 2.4 mm Variable Angle LCP Two-Column Volar Distal Radius

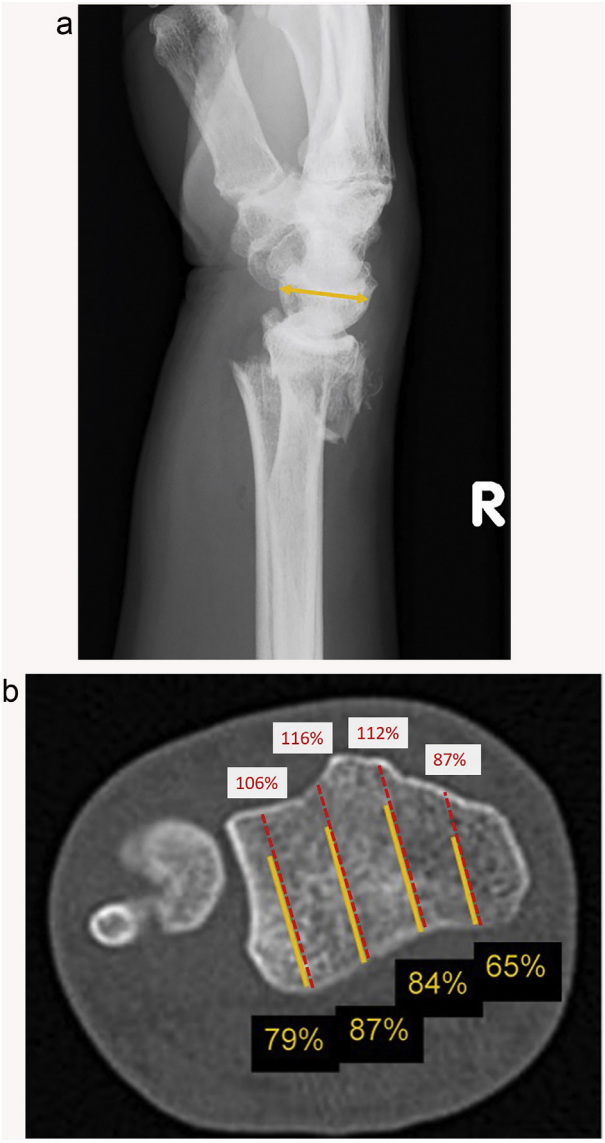

Fig. 1. The lunate depth on a lateral X-ray view (A). Percentages of the full distal radial depth (red dotted line) reported by Ljungquist et al., and percentages of the 75% distal radial depth (yellow solid line), compared with the lunate depth (B).

Plate (Synthes, West Chester, PA, USA). In all plates, four screws or pegs were inserted in the first distal row and two screws or pegs were inserted in the second distal row. Surgeons also must be aware that "screw length" in many products includes the screw "head" length, approximately 2 mm.

2.4. Surgical treatment

Through a transflexor carpi radialis approach, the pronator quadratus muscle was released from the radial side of the radius and elevated subperiosteally from the radius. The exposed fracture site was reduced and fixed temporarily with a K-wire. After the volar locking plate was positioned at the center of the radius, immediately proximal to the watershed line under fluoroscopy, four distal locking screws or pegs were inserted in the first distal row of the plate. Then, three cortical screws were added to the proximal plate holes. Finally, two locking screws or pegs were inserted into the second distal row of the plate (Fig. 2). After the pronator quadratus muscle was repaired, the skin was closed.

2.5. Post-operative protocol

On the next day, active range of motion exercises were started using the same rehabilitation protocol in both groups without any immobilization, based on a recent prospective randomized study describing the benefits of early active wrist exercises [11]. Weight-bearing was limited in both groups until callus formation appeared on X-rays. Skin sutures were removed after ten days.

2.6. Radiographic assessment

Post-operative radiographs were examined every month until six months after the surgery, with at least two wrist views, including posteroanterior and lateral X-rays in neutral forearm rotation and 90 degrees elbow flexion. Three radiographic parameters of the wrist – the ulnar variance, volar tilt, and radial inclination – were evaluated intra-operatively and at the final follow-up (mean 10.6, range 6.0 to 22.8 months after surgery), using our hospital's picture archiving and communications system (EV Insite version 3.4; PSP corporation). It was reported that measurements of the ulnar variance and palmar tilt had good intra- and inter-observer consistency, although that of the radial inclination showed fair agreement [12]. Therefore, in our study, the radiographic measurement was performed by an independent rater with 15 years' experience as an orthopedic surgeon, who was not involved in treating the patients or aware of the study design. He measured the three parameters in the two different periods and calculated the changes in the parameters between the intra-operative stage and the final follow-up.

2.7. Outcomes

2.7.1. Primary outcome

The potential increase in ulnar variance between the two periods was calculated in each group because an increase means radial shortening, which is caused by post-operative fracture displacement. Then, the difference in the ulnar variance increase was analyzed by a non-inferiority trial between the groups.

2.7.2. Secondary outcomes

The increases in the volar tilt and radial inclination between the two periods were assessed in each group, and the differences in the increase were compared between the two groups.

2.8. Sample size

Clinically tolerated radius shortening (= ulnar variance increase) is 2 mm in DRF [13]. In our previous studies, the post-operative ulnar variance increased by an average of 1.0 mm. Therefore, the non-inferiority margin was calculated as a 1.0 mm difference (= 2.0–1.0) between the two procedures. Sample size calculation required 34 patients for each group to reach 80% power, with a 0.05 one-tail alpha error [14].

2.9. Statistical analysis

The demographic characteristics of the patients were analyzed using Student's *t*-test for continuous variables and the Chi^2 test for categorical data. For the primary outcome, a two-sided 90% confidence interval (CI) for the difference in the ulnar variance increase was calculated to test for non-inferiority because the one-sided alpha error was set at 0.05. When the maximal difference of the 90% CI was less than 1.0 mm, non-inferiority was established. For secondary outcomes, including the increase in volar tilt and radial inclination, superiority trials were conducted using the *t*-

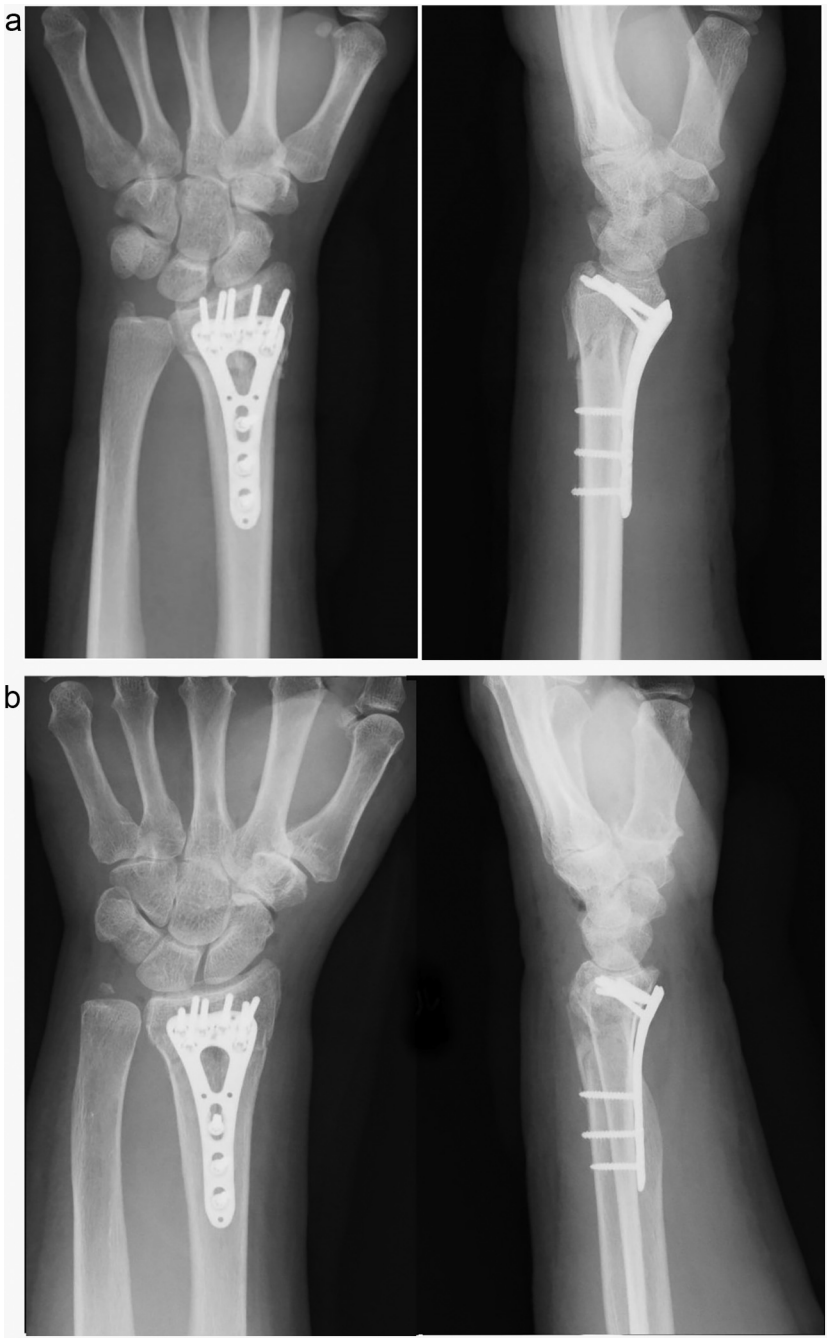

Fig. 2. Post-operative X-rays. Full-length unicortical distal locking screws for volar locking plate fixation (full-length group) (A). Shorter-length screws (shorter group) (B).

test. A *P*-value of less than 0.05 was considered a statistically significant difference.

3. Results

Seventy-eight fractures (40 full-length unicortical and 38 shorter ones) in 76 patients fulfilled the inclusion criteria. Of these 78 fractures, ten were followed for less than six months post-operatively or had bilateral fractures, thus were excluded. Finally, 68 fractures (34 in each group) were assessed. The baseline characteristics of the two groups are shown in Table 1. There were no significant differences between the groups regarding fracture type (AO classification), age and sex.

Table 1
Baseline characteristics of the patients included in this study.

	Full-length (n = 34)	Shorter (n = 34)	*P*-value
Mean age, (SD)	65.3 (15)	65.2 (11)	0.74
Female, n (%)	30 (88)	28 (82)	0.73
AO classification, n (%)			0.62
Type A	15 (44)	12 (35)	
Type C	19 (56)	22 (65)	
Injured wrist, n (%)			0.20
Right	9 (27)	15 (44)	
Left	25 (73)	19 (56)	
Mean days since injury (SD)	2.4 (3.3)	3.2 (3.0)	0.32
Mean follow-up in months (SD)	11.7 (5.4)	9.5 (3.1)	0.11

P-value by *t*-test for continuous variables and Chi^2 test for categorical data.

Table 2
Intra-operative (Intraop) and post-operative (Postop) radiographic parameters in both groups.

	Full-length (n = 34)			Shorter-length (n = 34)			Mean difference in the increase between groups (90% CI)	P-value
	Intraop period	Final postop period	Increase between periods	Intraop period	Final postop period	Increase between periods		
Mean ulnar variance, mm (SD)	−2.1 (2.3)	−1.1 (2.3)	1.1 (1.1)	−1.5 (1.7)	−0.2 (1.9)	1.3 (1.1)	0.2 (−0.3 to 0.6[a])	0.51
Mean volar tilt, ° (SD)	7.2 (8.0)	7.8 (8.4)	0.6 (2.0)	9.3 (3.7)	9.1 (4.0)	−0.1 (1.7)	−0.8 (−1.5 to 0.0)	0.10
Mean radial inclination, ° (SD)	19.6 (3.7)	19.7 (4.0)	0.1 (1.7)	21.2 (3.1)	21.4 (3.5)	0.2 (1.4)	0.1 (−0.5 to 0.7)	0.82

[a] Maximum difference of 90% CI < 1.0. Non-inferiority was established.

3.1. Primary outcome (ulnar variance increase)

The mean increase in ulnar variance was 1.1 mm in the full-length group and 1.3 mm in the shorter group. The mean difference between each group was −0.3 to 0.6 mm of the 90% CI (Table 2). Since the upper boundary of the two-sided 90% CI was below the predefined non-inferiority margin, the shorter-length group was not inferior to the full-length group.

3.2. Secondary outcomes (volar tilt and radial inclination increase)

Volar tilt increased 0.6° in the full-length group and −0.1° in the shorter group (P = 0.10). The increase in radial inclination was 0.1° in the full-length group and 0.2° in the shorter group (P = 0.82) (Table 2). These increases in both parameters were not significantly different between the two groups.

3.3. Complications

Three fractures in the full-length group had a subsequent post-operative extensor pollicis longus tendon rupture while none in the shorter group had tendon rupture. One of the three was performed by an orthopedic specialist while the remaining two were performed by a resident under supervision. The post-operative CT scans showed that one case had a peg (not screw) tip protrusion into the third compartment penetrating the dorsal cortex, another had over-drilling through the dorsal cortex without screw tip protrusion, and the other had neither screw tip protrusion nor over-drilling. Since post-operative CT in the second case showed a hole in the dorsal cortex under the third compartment, the cause of the tendon rupture was considered as over-drilling. The last case had dorsal cortex comminution; therefore, the comminution may imply the possibility of over-drilling into the extensor tendon because the surgeon could not feel the dorsal cortex during drilling. One of the three patients underwent a tendon transfer whereas the remaining two refused reoperation.

4. Discussion

The post-operative fracture stability of shorter distal locking screws was not inferior to that of full-length unicortical screws, which was consistent with our hypothesis. The previous biomechanical study showed that 75%-length unicortical distal locking fixation was mechanically similar to bi-cortical fixation in terms of axial compression, dorsal bending, and volar bending [9]. The current clinical study showed there was no difference in the post-operative displacement between full-length unicortical and 75%-length distal locking screws of the volar locking plate for DRF. This study provides clinical confirmation of the prior biomechanical findings.

In order to prevent distal screw protrusion of the dorsal cortex, specific intra-operative radiographic views have been suggested [15–18]; however, over-drilling into the dorsal cortex can also cause extensor pollicis longus tendon rupture [3]. In the current study, the full-length group had three tendon ruptures while the shorter group had none. Hence, our technique suggests that both drilling and screw length should be 75% of the distal radius depth, calculated pre-operatively based on the lunate depth.

To calculate the distal screw length pre-operatively, we used the lunate depth on a lateral X-ray view. Although a recent article reported there was no relevant correlation between distal screw length and lunate depth after volar locking screw fixation, it also raised the possibility that surgeons did not place longer screws in larger radii [19]. Another article reported the ratio between the lunate depth and each distal radius depth to prevent extensor tendon rupture after volar locking plate for DRFs [10]. We modified the ratio to percentages between the lunate depth and 75% of the distal radius depth (Fig. 1). Surgeons can select the length of the distal drilling and locking screw pre-operatively. This saves time during surgery because surgeons do not need to measure the depth after drilling.

There are several limitations to our study. This was a retrospective study, thus confounding variables were not investigated. The full-length group was constituted earlier while the shorter group was later, and the baseline characteristics of the two groups were not significantly different (Table 1). Therefore, we believe there was little need to adjust for confounding factors. Moreover, the surgeons' skill levels were also not the same, although most cases (88%) were handled by one specialist. In addition, the plate product was independently selected by the surgeons. This also contributed to different distal locking hardware selection, whether screws or pegs. However, a previous clinical study showed no difference in post-operative fracture stability between volar locking screws or pegs in DRFs [20]. Finally, the screw length was limited to increments of 2 mm; hence, surgeons could not select precisely 75%-length screws. However, the current study had a sufficient sample size to establish non-inferiority and it is the first clinical study to provide evidence that shorter distal locking screws are stable post-operatively. These findings are relevant to most volar locking plates for DRF because this study included both extra- and intra-articular fractures, despite the restricted generalizability related to it being a single center study. Further studies are necessary to analyze AO type A and C fractures separately because our sample size was insufficient to conduct a subgroup analysis.

5. Conclusion

Our study showed that the post-operative fracture stability of shorter distal locking screws was not inferior to that of full-length unicortical screws for volar locking plate fixation. Therefore, to prevent extensor pollicis longus tendon rupture, shorter (approximately 75% of the distal radius depth) screws and the same depth drilling may be preferable for volar locking plate fixation.

Disclosure of interest

The authors declare that they have no competing interest.

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