

Volar plating of distal radius fractures does not restore the anatomy

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SUMMARY

INTRODUCTION: The objective of this study was to evaluate whether volar locking plating can restore the anatomical volar tilt of 12° and the anatomical length of the radius relative to the ulna. We retrospectively reviewed the radiographic outcome of distal radius fractures treated with two different first-generation locking plate systems; VariAx (Stryker) and Acu-Loc (Acumed).

METHODS: Three independent observers evaluated radial volar tilt and ulnar variance (> 2 mm) on radiographs taken preoperatively, immediately after the operation and five weeks later. In addition, the radial inclination, distal radioulnar joint incongruity and articular step-off were assessed in order to describe the personality of the fracture.

RESULTS: A total of 576 fracture cases were included in the study. Preoperatively, the mean volar tilt was 18 ± 6° and -15 ± 11° for volarly and dorsally displaced fractures, respectively. After operation, the mean volar tilt was 4.5 ± 6° without any significant changes after five weeks, $p = 0.79$ and no significant differences with respect to fracture type or type of plate. Thus, the anatomical angulation of 12° was not achieved at any point in time after surgery ($p < 0.001$). Shortening of the radius (> 2 mm ulnar variance) was still seen in 9% of the cases immediately after surgery and in 22% after five weeks.

CONCLUSIONS: Volar locking plating did not restore the anatomy after distal radius fractures. The clinical implication of these findings is unclear because the functional outcome of the patients was not available. Level of evidence: level IV.

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Distal radius fractures constitute approximately one third of all fractures in the elderly and has an incidence of 190/100,000 person-years [1, 2]. The lifetime risk of acquiring a distal radius fracture is 15% for women and 2% for men [3, 4].

In order to help the surgeon to decide on optimal treatment, it is commonly accepted to use four to five different measurements on radiographs to investigate how severe the fracture appears. Those typically used are volar/dorsal tilt, radial inclination, ulnar variance and intraarticular step-off [5]. Currently, a common treatment option for unstable distal radius fracture is

open reduction and internal fixation with a volar locking plate [6, 7]. Some authors have argued that volar plates are better than other methods at restoring and maintaining the anatomy of the distal radius [8].

A good functional outcome after volar plating combined with early mobilisation has been reported in short-term studies. However, in other studies, there was no clinically relevant difference in functional outcome after one year when compared with other methods of fixation [7, 9-11]. Besides the potential clinical advantage, other studies also question the cost-effectiveness of volar locking plating [4, 12].

The purpose of our study was to investigate to what degree volar plating of distal radius fractures is able to restore the anatomy of the wrist.

METHODS

Included in the present study were all radiographs of patients who sustained a distal radius fracture that was operatively treated with a volar locking plate at a single level I academic trauma centre between February 2009 and June 2013. Patients were identified based on the international Classification of Diseases, tenth version (ICD-10) codes DS525 in conjunction with KNCJ65. The exclusion criteria were open fractures, miscoding and additional fracture fixation methods. The complication rate and further details of the retrospective cohort have been published previously [13].

The volar locking plates used in the present study were first-generation VariAx (Stryker, Kalamazoo, MI, USA) and first-generation Acu-Loc (Acumed, Hillsboro, OR, USA). They were inserted through a modified Henry approach, and fixation was performed according to the manufacturers' instructions. All procedures were performed under fluoroscopic assistance. At the end of the procedure, the distal radioulnar joint (DRUJ) stability and scapholunate ligament were tested using fluoroscopy. Post-operative immobilisation consisted of a short dorsal plaster cast, which after two weeks was changed to a removable prefabricated orthosis for an additional three weeks. After two weeks, an occupational therapist instructed patients in unloaded range of motion exercises of the radiocarpal joint and oedema-prophylactic exercises [13].

Based on the initial displacement of the fracture,

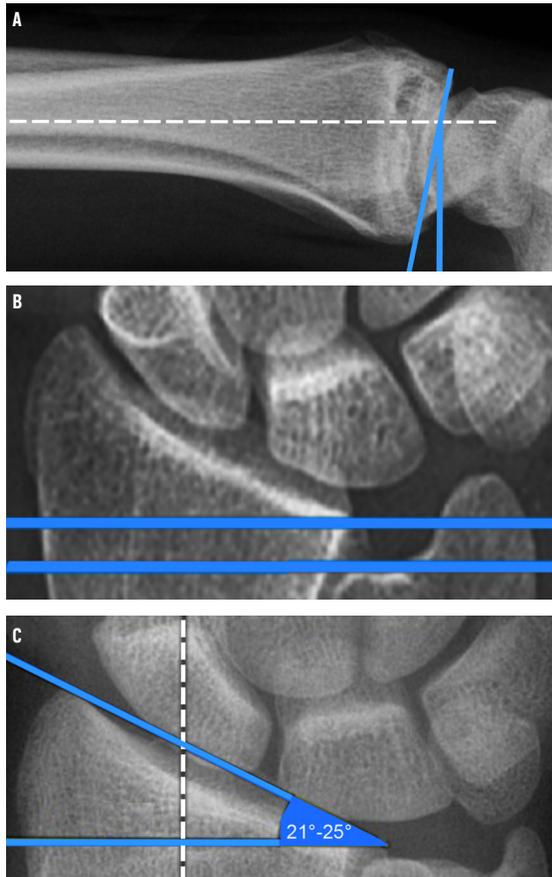
ORIGINAL ARTICLE

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 **FIGURE 1**

How to measure volar tilt (A), the angle formed between a line connecting the distal edges of the volar and dorsal rim of the radius and a second line perpendicular to the long axis of the radius; ulnar variance (B), the distance between two perpendicular lines to the long axis of the radius that intersects the ulnar corner of the radius and the distal articular surface of the ulna; and radial inclination (C), the angle between a perpendicular line to the long axis of the radius, which intersects the distal ulnar corner of the radius and the line that connects the distal tip of the radial styloid and the ulnar corner of the radius.



patients were divided into two groups of volarly displaced fractures ($> 10^\circ$ volar tilt) and dorsally displaced fractures ($< 10^\circ$ volar tilt).

Evaluations

A consultant of radiology, an orthopaedic consultant and an orthopaedic intern evaluated dorsal or volar tilt, ulnar variance (> 2 mm), radial inclination ($< 21^\circ$ or $> 25^\circ$), radiocarpal joint step-off (> 2 mm) and distal radioulnar joint incongruity on standard anteroposterior and lateral projections of the injured distal forearm obtained preoperatively and five weeks post-operatively. Furthermore, perioperative fluoroscopic imaging of anteroposterior lateral projections was assessed. The continuous variable (volar tilt) was based on the average of measurements performed by the three independent observers. In cases of disagreement on dichotomous variables (yes/no), the majority of the three observers was defined as the truth. No consensus meeting was held throughout the study. However, before the study was commenced, all observers were given guideline illustrations of how to evaluate the variables according to **Figure 1**. Neither written nor illustrated in-

formation on how to evaluate distal radioulnar joint congruity was provided.

Statistical methods

Data were analysed with repeated measurement ANOVA with two repeated factors (observers and time points) with Tukey's multiple comparison test utilising GraphPad Prism 6 and STATA.

Trial registration: not relevant.

RESULTS

Radiographs of 576 patients were evaluated in the study (**Table 1**). In total, 344 patients were operated by consultants, 191 patients by 2-5-year residents and 41 patients by one-year residents. The gender-specific age distribution is presented in **Figure 2**.

There was no statistically significant difference in age or gender, nor in any other outcome measure at any given point of time between patients treated with VariAx or Acu-Loc (**Table 2**). Before surgery, the mean tilt was $18 \pm 6^\circ$ and $-15 \pm 11^\circ$ for volarly and dorsally displaced fractures, respectively.

After surgery, there was no statistically significant difference between the volarly and dorsally displaced fractures. The mean volar tilt was $4.5 \pm 6^\circ$. The mean difference in volar tilt when measured on the post-operative radiographs and compared with the mean volar tilt five weeks post-operatively was 0.06° .

Consequently, the mean volar tilt of $4 \pm 7^\circ$ after five weeks did not differ statistically significantly from the post-operative tilt, $p = 0.79$.

The mean differences between the measurements of the three observers ranged 0.3 - 1.8° at the different time points, which was statistically significant ($p < 0.05$); however, of limited practical importance.

An ulnar variance of more than 2 mm was noted on one or more radiographs in 9% of all cases immediately after operation and in 22% after five weeks ($p < 0.05$). For data regarding radial inclination and DRUJ congruity, please see **Table 2**.

DISCUSSION

In this large-scale setting with volar locking plating of distal radius fractures, we found a mean volar tilt of $4.5 \pm 6^\circ$ after surgery, independently of whether the fracture had been displaced volarly or dorsally, which is not a restoration of the normal anatomy. Furthermore, a trend towards a persisting shortening of the radius in relation to the ulna was still seen.

Evans et al [14] reported the anatomical volar cortical angle of the distal radius to be mean 32.9° based on an evaluation of the CT of 100 patients, 31° at the radial side and 34.1° at the ulnar side depending on the patient's gender. However, both plates used in their study

had an angle at the flat radial side of 28° and at the flat ulnar side of 32°, and therefore they suggested to prebend the plate before osteosynthesis to obtain the anatomical volar cortical angle [14]. The fact that there is a difference between the angle of the plates and the anatomical angle may partially explain the results obtained in our study where we observed an almost neutral position of the distal radius after operation.

A potential weakness of our study is that the prefracture anatomy of the distal radius of our patients remains unknown. In a prospective setting, this could be clarified by determination of the anatomy of the patients' non-fractured wrist in order to obtain a more precise understanding [15].

Perugia et al [16] suggested that the two most important parameters to evaluate and restore are the volar tilt and ulnar variance to obtain a good functional outcome. Therefore, it would be interesting to design a study focusing on the restoration of the volar tilt and the ulnar variance and its correlation with the functional outcome.

When comparing the findings of Orbay et al [8], who studied 23 patients older than 75 years and found an average volar tilt of 5° (range: 0-14°), to our findings, the results were comparable both post-operatively and at the five-week follow-up. They suggested that treatment with a volar locking plate is a successful technique that gives acceptable results in the elderly population based on early mobilisation. However, Plant et al [17] compared volar locking plating with percutaneous pinning in 50 patients and found a poor correlation between radiological outcome measurements and functional outcome. They suggested that for the patient it might not be necessary to restore normal anatomy to get a satisfactory long-term functional outcome. It would be interesting to investigate the relationship between radiological outcome and functional outcome in future research.

We report a high rate of DRUJ incongruity prior to surgery, which was significantly reduced after operation and throughout follow-up with conservative management. The varying results of DRUJ congruity may partly be attributed to the lack of written or illustrative information on how to assess this outcome. The longitudinal evaluations of DRUJ congruity, articular step-off and inclination were inconsistent in the present study. The inconsistency of the results may partially be explained by the fact that the immediate post-operative radiographs were obtained and saved in the picture archiving and communication system by the operating surgeon in the operating room and hence were not completely standardised. This might constitute a limitation for the interpretation of the longitudinal data of the present study. When planning prospective studies on distal radius fractures, one should consider to evalu-

TABLE 1

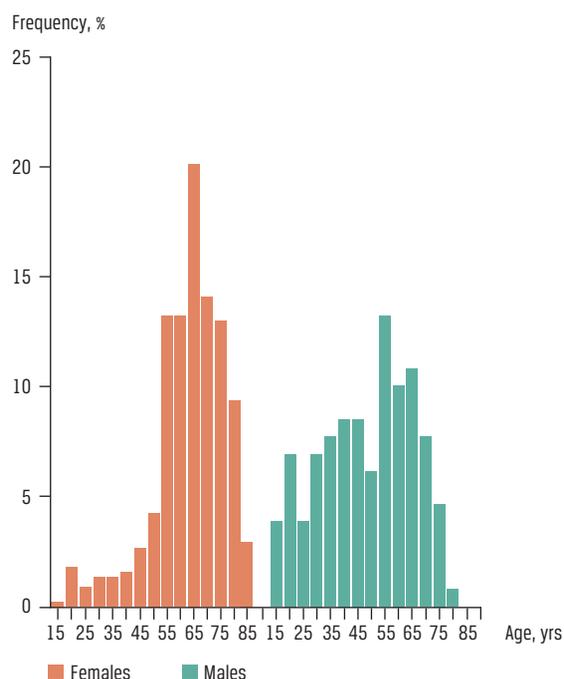
	n (%)
<i>Gender</i>	
Female	447 (78)
Male	129 (22)
<i>Type of plate</i>	
VariAx	451 (78)
Acu-Loc	125 (22)
<i>AO/OTA fracture type</i>	
A	374 (65)
B	35 (6)
C	167 (29)

Demographic information.

AO = Arbeitsgemeinschaft für Osteosynthesefragen; OTA = Orthopaedic Trauma Association.

ate all radiographic outcomes based on radiographs taken under standardised conditions rather than using intraoperative images. This is especially important when evaluating the ulnar variance. As the radius rotates around the ulna from full supination to full pronation, the ulna also migrates distally and the ulnar variance increases [18-20]. In the operating room, the majority of radiographs are likely to be taken in full supination during/after volar plating, whereas the five-week post-operative radiographs are taken under protocolled, standardised conditions like sitting posteroanterior radiographs with the forearm in pronation. This change in forearm position is likely to be

FIGURE 2



Age distribution.

TABLE 2

Radiologic outcome after primary reposition, immediately post-operatively and after five weeks.

	Preoperatively			Post-operatively			5-week follow-up		
	total	VariAx	Acu-Loc	total	VariAx	Acu-Loc	total	VariAx	Acu-Loc
Volar tilt, mean \pm standard deviation, °									
Total	-10 \pm 15	-	-	4 \pm 6*	-	-	3 \pm 7	-	-
Primary dorsally displaced	-15 \pm 11	-16 \pm 11	-13 \pm 10	3 \pm 6*	4 \pm 6	2 \pm 5	2 \pm 7	3 \pm 7	2 \pm 5
Primary volarly displaced	18 \pm 6	17 \pm 6	19 \pm 5	6 \pm 5*	7 \pm 5	5 \pm 5	8 \pm 6	8 \pm 5	7 \pm 7
Ulnar variance > 2 mm, %	40	40	38	9	9	7	22*	23	21
Articular step-off > 2 mm, %	5	5	5	2	2	3	6	5	6
Inclination (< 21° or > 25°, %)	68	67	70	49	53	32	34	35	31
Distal radioulnar joint incongruity, %	23	23	25	2	2	2	8	7	9

*) p < 0.05.

the main determining factor for the measured post-operative increase from 9% to 22% with an ulnar variance of more than + 2 mm. Another theoretical explanation for the increase in ulnar variance could be a true loss of radial bone length due to insufficient stabilisation. However, we did not observe screws migrating distally or proximally within the bone.

Regarding articular step-off measurements, another explanation for the diverging results is the lack of radiographic calibration, which could result in an inaccuracy in the evaluation of the presence of a > 2 mm articular step-off. Based on the inconsistency of our results regarding DRUJ congruity, articular-step-off and inclination, we recommend caution when using these factors for clinical decision making.

Combining the results of the present study with the data of our previously published complication rate of 14.6% (95% confidence interval: 11.8-17.7%) in the same cohort [13], we noted that three out of 14 patients (21%) with a persisting dorsal tilt over 10° five weeks post-operatively suffered a complication (one extensor tendon rupture and two carpal tunnel syndromes) that required reoperation.

CONCLUSIONS

Volar plating of distal radius fractures did not restore the anatomy. After operation, the mean volar tilt was $4.5 \pm 6^\circ$ without any significant changes after five weeks, $p = 0.79$ and no significant differences with respect to fracture type or type of plate.

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