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A Prospective Observational Assessment of Unicortical Distal Screw Placement During Volar Plate Fixation of Distal Radius Fractures

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Abstract

Purpose—Although volar plating of the distal radius is performed frequently, the necessity of distal bicortical fixation in the metaphyseal and epiphyseal areas of the distal radius has not been proven. This study primarily aimed to quantify the ability of unicortical distal screws to maintain operative reduction of adult distal radius fractures and secondarily to determine if unicortical screw lengths could be predicted based on anatomic measurements.

Methods—This prospective trial enrolled 75 adult patients undergoing volar locking plate fixation of a unilateral distal radius fracture at a tertiary center. Study inclusion required screw fixation in the distal rows of the plate performed with unicortical screw placement. The primary outcome was maintenance of operative reduction, according to pre-defined parameters, quantified by comparing initial operative reduction to final reduction after fracture healing. Repeated measures ANOVA analyzed for systematic change in radiographic parameters between injury, operative, and healed images. Correlation coefficients quantified the relationship of screw lengths with lunate width and other anatomic measurements.

Results—75 patients (mean 54 years±15, 79% female) were enrolled and followed to fracture union. Fracture severity varied and included AO type A (40%), B(12%), and C(48%) fractures. There was no significant change in mean lateral translation, intra-articular gap, intra-articular stepoff, radial inclination or lateral tilt of the radius between the time of fixation and union for the cohort. Two patients lost reduction (increased dorsal tilt 10°, 20° respectively), potentially attributable to provision of unicortical fixation (3%, 95% CI 0-9%). No extensor tenosynovitis or extensor tendon ruptures occurred. Eighty percent of screws were ≤18mm and screw lengths were not correlated with lunate width or any other anatomic measurements.

Conclusions—Unicortical distal fixation during volar locking plate fixation effectively maintains operative reductions of distal radius fractures while potentially minimizing the incidence of extensor tendon ruptures.

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Level of Evidence—IV, Therapeutic

Keywords

volar plate; unicortical; distal radius; fracture; fixation

INTRODUCTION

Volar plating of the distal radius was initially heralded as a solution to the extensor tendon complications associated with dorsal plates. However, hardware related extensor tenosynovitis, extensor pollicis longus rupture, extensor digitorum communis rupture, and second dorsal compartment tenosynovitis remain frequently reported after volar plate fixation.[1-7] The cause of these injuries to the dorsal tendons are likely multifactorial with contribution from injury to the extensor tendons by the initial trauma, drill penetration of the dorsal cortex during fixation, or attrition from dorsally prominent screws.

Although volar plating of the distal radius is performed frequently, the necessity of distal bicortical fixation in the metaphyseal and epiphyseal areas of the distal radius has not been proven. In an effort to prevent extensor tendon complications, some have suggested placing screws in the distal radius that do not penetrate the dorsal cortex. Mechanical testing in an osteoporotic, in-vitro model demonstrated similar construct stability between unicortical screws placed at 75% length to the dorsal cortex and bicortical screws.[8] Provided equivalent construct stability, unicortical fixation may be the superior approach because it may protect against intra-articular hardware and extensor tendon injury.

The primary aim of this study was to quantify the ability of distal unicortical locked-screw fixation to maintain operative reduction of the radius treated with volar plate fixation. Based on *in vitro* data, our working hypothesis was that unicortical locked-screw fixation would maintain operative reductions comparable to historical controls. Our secondary aim was to determine if the length of distal unicortical screws used in practice could be predicted based anatomic measurements as suggested by Ljungquist et al.[9] As lunate depth predicted hypothetical distal radius screw lengths in MRI's of intact wrists, we aimed to determine if screw lengths could be accurately predicted during a pragmatic study of fractured wrists.

METHODS

Participant Selection

This institutional review board-approved, prospective cohort analyzed 75 adult patients with distal radius fractures treated with locked volar plate fixation. All subjects presented to one of 6 fellowship-trained hand orthopedic surgeons at a single tertiary center between January 2014 and February 2016 with a minimum clinical follow-up through the time of complete fracture healing. Inclusion criteria required adult patients, at least 18 years of age, diagnosed with a unilateral distal radius fracture managed with unicortical volar plating fixation. For this observational study, the decision to recommend surgical fixation was determined based on discussion between the surgeon and patient prior to study enrollment and was therefore not based on any standardized study requirements. Patients were excluded if they had

concurrent dorsal or radial plate application, cognitive limitations preventing consent, or lacked English proficiency. Fractures treated operatively at greater than 3 weeks after injury were also excluded because early callus formation increases the complexity of operative reduction and fixation. Study enrollment was completed without restriction according to age, tobacco use, comorbid disease, AO fracture type, or associated ulnar styloid fracture.

Surgical Treatment

Volar locking plates were placed using a standard volar approach, either through, or radial to, the flexor carpi radialis tendon sheath. Unicortical fixation was defined as screw fixation in the distal rows of the plate performed with unicortical drilling to, but not penetrating, the dorsal cortex followed by screw placement at least 2mm short of the dorsal cortex. Frequently, the first distal unicortical screw was nonlocking to ensure the bone and plate were tightly apposed. All other distal unicortical screws were locking. Seventy-three Medartis plates (Basel, Switzerland) and 2 Depuy-Synthes plates (Oberdorf, Switzerland) were applied. Patients were placed in short-arm plaster splints prior to leaving the operating room. Immediate active finger range of motion was always encouraged and initiation of active wrist motion occurred between 1 and 4 weeks depending on surgeon preference and bone quality. Strengthening was delayed for at least 6 weeks until fracture union.

Data Collection

All patients provided written informed consent. Patients were assessed pre-operatively, intraoperatively, and at 2 weeks, 6 weeks, and 12 weeks, postoperatively. At the pre-operative visit, patient demographics, injury mechanism, and fracture classification were recorded. Intraoperatively, the length of each implanted screw was recorded. At each time point, attending surgeons documented complications, fracture union, and ordered orthogonal fluoroscopic or radiographic views (posterior-anterior and lateral) as well as lateral tilt images.[10] Radiographic parameters were quantified by a trained independent researcher.

Outcomes

The primary outcome was maintenance of operative reduction of the radius quantified by comparing initial operative reduction, measured using images taken during the intraoperative or 2-week post-operative visit, to final reduction after fracture healing, measured using radiographs taken during the 6-week post-operative visit or later. Fracture healing was determined by the attending surgeon and was based on a composite assessment of bridging callus, resolution of fracture lines, and clinical examination. Lost reduction was defined *a priori* as a change of ≥10° volar tilt (- change indicating increased dorsal tilting), ≥10° radial inclination, or ≥2mm intra-articular gap and/or step-off. Radial height was not assessed due to redundancy with radial inclination. Secondarily, all postoperative complications were documented.

For our second aim, we compared anatomic indices that were readily measured radiographically or during a standard clinic visit, to screw length to determine whether they could be used as screw length predictors. Anatomic indices studied included sagittal plane lunate width[9], radius diaphyseal width at the oblong hole in the radius plate, patient height, as well as contralateral forearm length and wrist circumference.

Statistical Analysis

Study sample and fracture characteristics were analyzed with univariate descriptive statistics for the frequencies and percentages of categorical variables and the mean and standard deviation for continuous variables.

For our primary aim, repeated measures ANOVA were used to examine for serial change in radiographic parameters between injury, operative, and healed time-points. Significant changes in radiographic parameters on repeated measures ANOVA were further analyzed for pairwise differences using Bonferroni *post-hoc* analysis. The precision of estimates for the incidence of complications were described with 95% confidence intervals.

For our secondary aim, Pearson correlations determined the relationship between screw lengths and each anatomic measurement. Correlation coefficients (r) were interpreted as follows: 0.00-0.29 no correlation, 0.30-0.49 weak correlation, 0.50-0.69 moderate correlation, 0.70-0.89 strong correlation, and 0.90-1.00 very strong correlation.[11] One-way ANOVA testing evaluated screw length according to placement within specific coronal plane radius quartiles. Significant differences between groups were analyzed using Tukey's *post-hoc* analysis. All statistical tests had a threshold of significance set at $p<0.05$.

During study planning, we calculated the sample size necessary to precisely estimate the incidence of lost reduction (95% CI ±3%). Sixty-five patients with complete data were required to satisfy this analysis. We enrolled 75 patients to ensure that we would complete follow up through fracture healing on sufficient patients assuming at least 85% successful study completion.

RESULTS

Aim 1: Clinical Outcomes

Seventy-five patients (mean 54 years ±15) were enrolled. Seventy-nine percent of participants were female. Fracture severity varied and comprised AO type A (40%), B (12%), and C (48%) fractures. Patient demographic data and fracture characteristics are detailed in Table 1. Complete data were collected intraoperatively (64/75, 85%), at 2 weeks (59/75, 79%), 6 weeks (58/75, 77%), and at 12 weeks (54/75, 72%). In total, 66 (88%) of patients completed follow up with at least one office visit after fracture union.

Repeated measures ANOVA testing indicated significant differences between injury, operative, and healed radius lateral translation, intra-articular gap, radial inclination, and volar tilt degree (Table 2). Pair-wise testing demonstrated that lateral translation, intra-articular gap, radius inclination, and volar tilt all significantly improved between injury and operative alignment (all $p<0.05$). No radiographic indices of radius alignment changed significantly from operative to final alignment.

Two patients lost reduction after fixation (2/66, 3%, 95% CI 0-11%). One patient suffered both a recurrence of intra-articular gap (4mm) and change in volar tilt of -10°. The second patient demonstrated a change in volar tilt of -20° between fixation and healing. Neither patient pursued revision surgery so each healed with malunion.

Complications unrelated to the use of unicortical screws occurred in 15 patients (15/66, 23%) (Table 3). No extensor tendon ruptures had occurred by the time of final data analysis at which time enrolled patients were 13-38 months from surgery.

Aim 2: Screw Length

Lunate depth averaged 17mm (±3, range 13-26mm). Among 251 distal screws, 79% were either 14mm(n=41), 16mm(n=91), or 18mm(n=66). Mean lengths of screw varied in absolute length ($p<0.05$) by quartile with a statistically significant difference in screw length choice between the second most ulnar quartile, which received the longest screws (17.3 ±2 mm), and the most radial quartile, which received the shortest screws (15.5±2 mm) ($p<0.05$) (Table 4). There were no relevant correlations between the screw length in each quartile and any anatomic index measured (Table 5). As lunate depth increased, screw lengths measured as a percentage of lunate width decreased, while absolute screw lengths remained stable.

DISCUSSION

Our clinical series demonstrated that unicortical distal screw fixation provides sufficient fixation when performing volar plate fixation of distal radius fractures. This expands upon the data by Wall et al. that unicortical fixation with screws at least 75% length from the volar to the dorsal cortex did not substantially change construct strength in a distal radius fracture sawbones model.[8] Presuming comparable construct stability, unicortical drilling and screw placement may avoid intra-articular hardware and extensor tendon injury.

Although bicortical screws may not have prevented collapse, shorter screws may have contributed to two of our patients losing reduction. Both patients had distal screws within 2 mm of the subchondral bone and screws with >50% length to the dorsal cortex. Both of these patients had over 30 pack-year smoking histories and had fallen from standing. One of these patients required a carpal tunnel release and hardware removal at 3 months after her index surgery which resolved her symptoms. In comparable series, the incidences of lost reduction after fixation are similar, ranging from 1 to 7% (range of 95% CI's 0-17%).[7, 12, 13] Screw lengths were not reported in those prior studies although two of three authors contacted reported either frequent or occasional use of bicortical screws.[7, 12]

The 23% incidence of complications unrelated to unicortical fixation in our study was within the 7-35% range reported in the literature (Table 6). [2, 7, 12-14] A recent systematic review estimated the incidence of complications at 17%, evenly split between minor and major complications, with the most common complications related to nerve and tendon irritation or rupture.[15] We encountered both major and minor complications in our series. Notably, the majority of complications that we encountered were not likely attributable to unicortical screw length.

Extensor pollicis longus ruptures after distal radius fixation are reported with an incidence of 0.3-8.6%.[1-7, 16-19] Undetected prominent hardware is usually attributed to the irregular convex surface of the distal radius and the Lister tubercle prominence.[20, 21] Although multiple specialized static and moving fluoroscopic images have been described to detect prominent screws, none have achieved 100% sensitivity.[22-24] This is one reason behind our

preference, and the recommendation by others, to drill and place unicortical screws.[22] No patient in our series suffered an extensor tendon rupture. However, given the infrequency of extensor tendon rupture, a substantially larger study would be required to demonstrate a statistically significant reduction in tendon ruptures attributable to unicortical screw fixation.[1, 2, 7, 18, 19, 25]

Analyzing the data collected for our second aim, we were unable to determine anatomic parameters that would predict the length of screws needed distally through a volar plate. We considered lunate depth as a marker for screw length to compare screws placed in our series to the study performed by Ljungquist[9] In that study, MRI images of non-fractured wrists determined that lunate depth predicted the maximum theoretical screw lengths for the distal row of a volar plate. Our data confirmed their findings that the longest screws could be placed in the second most ulnar quartile of the radius and that the shortest screws were used in the most radial quartile. In our pragmatic series however, screw lengths failed to correlate well with lunate width. After surgeon debriefing, we attribute this to the tendency for our surgeons to feel comfortable placing screws up to a certain length and not placing longer screws in larger radii. Our data support that concept as 79% of screws were ≤18mm in length and screw length as a percentage of lunate width continued to decrease as absolute lunate width increased.

There are several limitations inherent to our study. We did not use any bicortical screw fixation and therefore relied upon published series as the reference standards. We accepted this compromise since unicortical screw fixation had become the standard in our practice. Second, our series does not include any unicortical fracture fixation for isolated partial articular fractures through the dorsal radius. When assessing lost reduction, we exclusively analyzed radiographic parameters based on the radius and did not consider changes in ulnar variance. In reviewing our cases, ulnar variance was not consistent as it both increased and decreased even after union in several cases suggesting change due to positioning during imaging. In those instances, there were no associated changes in distal screw angles or collapse of the subchondral bone back to screws, which might be indicative of lost reduction. Therefore, ulnar variance was not considered as an independent parameter for malunion. This variability was not appreciated in any radiographic parameters that exclusively measured the radius as opposed to its relationship with the ulna.

As locking technology has improved the rigidity of volar distal radius plate constructs, reliance on the thin and often comminuted dorsal cortex for fixation strength appears less necessary. When treating extra-articular fractures, unicortical drilling and screw placement also offers the potential advantage of avoiding intra-articular penetration or dorsally prominent hardware. We continue to routinely place unicortical distal locking screws when placing volar locking plates on the distal radius.

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Table 1

Patient demographics and injury mechanisms.

Variables	Mean (SD)/N (%)
Age	54 (15)
Sex, Female	59 (79%)
Working, Yes (N=69) *	43 (62%)
Dominant Affected Hand (N=70) *	38 (54%)
Smoker, Yes	6 (8%)
Past Smoker, Yes (N=70) *	13 (19%)
Co-morbidities	
None	31 (41%)
Yes	44 (59%)
Mechanism of Injury	
Fall from standing height	51 (68%)
Fall from height	14 (19%)
Sport	7 (9%)
MVC	3 (4%)

*N listed for any variable when not available from entire cohort.

Table 2

Anatomic parameters for radius alignment at injury, operative fixation, and after healed.

Variables	Injury (SD)	Operative (SD)	Healed (SD)	P-value
Lateral Translation (mm)	1.5 (3.3) *	0.3 (0.7)	0.2 (0.8)	<0.05
Intraarticular Gap (mm)	0.7 (1.9) *	0.0 (0.3)	0.0 (0.0)	<0.05
Intraarticular Stepoff (mm)	0.4 (1.1)	0.1 (0.3)	0.0 (0.1)	0.12
Radial Inclination °	13 (9) *	19 (5)	19 (5)	<0.05
Volar Tilt °	-13 (21) *	1 (7)	1 (8)	<0.05

* Injury measure significantly different than all other times on pairwise post-hoc testing.

Table 3

Complications encountered in this series.

Complications Unrelated to Unicortical Fixation (N=15 patients)		
Description	**N**	**%**
Hardware Removal	8	12%
Limited Extension	1	2%
Infection	1	2%
FPL Rupture	1	2%
Carpal Tunnel Syndrome	4	6%
Volar Barton Displacement	1	2%
Rash	1	2%
Radioscaphoid Arthritis	1	2%
Complications Related to Unicortical Fixation (N=2 patients)		
Description	**N**	**%**
Loss of Reduction in Intraarticular Gap, ≥2mm	1	2%
Loss of Reduction in Tilt Degree, ≥10°	2	3%
Total Patients Affected by Any Complication	15	23%

Table 4

Actual screw length and percent of lunate depth by lunate size category for each quartile of the distal radius

Variable*	**1st Quartile**	**2nd Quartile**	**3rd Quartile**	**4th Quartile**
Expected Mean Screw % of Lunate Depth[1]	*106%*	*116%*	*112%*	*87%*
Mean Screw Length	17mm (2)	17mm (2)	17mm (3)	15mm (2)
Mean Screw % of Lunate Depth (SD)	*99% (18)*	*101% (17)*	*99% (20)*	*90% (17)*
≤16mm Lunate				
Mean Screw Length	17mm (2)	17mm (2)	16mm (3)	15mm (1)
Mean Screw % of Lunate Depth (SD)	*115% (11)*	*116% (12)*	*114% (22)*	*105% (15)*
>16 -20mm Lunate	17mm (3)	18mm (2)	17mm (3)	16mm (2)
Mean Screw % of Lunate Depth (SD)	*95% (15)*	*99% (14)*	*95% (15)*	*91% (12)*
>20-26mm Lunate	15mm (1)	17mm (1)	17mm (2)	14mm (3)
Mean Screw % of Lunate Depth (SD)	*63% (3)*	*78% (8)*	*78% (13)*	*66% (14)*

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* Mean values (Standard Deviations)

Table 5

Correlation of absolute screw length with anatomic measurements.

Variable	Pearson r
Lunate Depth	0.07
Contralateral Wrist Circumference	0.20
Contralateral Ulna Length	0.06
Patient Height	0.16
Ipsilateral Radius Width at Oblong Hole	0.16

Table 6

Incidence of complications reported in representative previous series of distal radius fractures.

Authors (year)	**N**	**Complications N (%)**	**Additional Complications**
Rozental et al (2006)	41	9 (22%)	
Arora et al (2007)	114	31 (27%)	
Soong et al (2011)	594	Early: 24 (4%)	11 Carpal tunnel releases not included in these counts.
	321	Late: 23 (7%)	
Tarallo et al (2013)	303	18 (6%)	4 Carpal tunnel releases not included in these counts.
Esenwein et al (2013)	665	75 (11%)	232 (35%) hardware removals not included in these counts
Current study	66	15 (23%)	