Fixation Strength in Full and Limited Fixation of Osteoporotic Distal Radius Fractures

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Abstract

Background: The purpose of this investigation is to determine whether osteoporotic intra-articular distal radius fractures surgically treated by filling all 7 distal screws of a volar plate will have a higher load to failure than those treated by filling only 4 distal screws. **Methods:** Ten matched pairs of fresh frozen cadaveric forearms were randomized within each pair to be treated by using either all 7 of the distal holes of a volar plate or only 4 distal screws. The distal radius fixation was performed with unicortical screws going to but not through the dorsal cortex, and the most distal screws were placed within 4 mm of the joint surface. An AO C2 type fracture was then created. All specimens were tested cyclically, with an axial load of 60 N, at 3 Hz for 1000 cycles to simulate early postoperative motion. All specimens were subsequently tested to mechanical failure. **Results:** There were no failures in either group during cyclic testing. There was no difference detected between groups for mean stiffness, yield load, peak load, or load to clinical failure. In both groups, the yield load, peak load, and load to clinical failure were higher than the 60- to 100-N forces encountered during postoperative rehabilitation. **Conclusions:** There was no difference detected between osteoporotic intra-articular distal radius fractures treated by utilizing all 7 of the distal screws of a volar plate compared with those treated with only 4 distal screws.

Keywords: distal radius fracture, osteoporosis, distal radius fracture fixation, volar plate, locking plate

Introduction

Although only 14% of distal radius fractures occur in patients aged 65 years or older, the population of these individuals was 47 695 000 in 2015, and is expected to nearly double by 2060, resulting in a substantial number of these fractures in this age group.^{3,18} In this older age group, distal radius fractures are recognized as fragility fractures occurring in the setting of low bone mineral density.^{9,13} Rozental et al demonstrated that even premenopausal women with normal bone mineral density who sustain a distal radius fracture have deteriorated trabecular architecture when compared with a control group that did not sustain a fracture.¹⁷ Lill et al demonstrated that low bone mineral density is associated with more complex, intra-articular distal radius fractures.⁸

Unlike the management of distal radius fractures in younger patients, the role of operative intervention in patients who are 65 years or older is controversial.^{1,4,11} Arora et al compared nonoperative management with volar locking plate fixation for displaced and unstable distal radius fractures in patients 65 years and older.¹ They found no difference between the groups in range of motion or pain during the 12-month follow-up period. However, the grip

strength was higher in the operative group throughout the entire follow-up period. In contrast, several investigations have demonstrated that excellent outcomes could be achieved with operative fixation of osteoporotic fractures and suggest that operative fixation of these fractures should remain an option for high functioning elderly patients.^{2,6,16,19}

The distal screws in volar plate fixation have been implicated in several complications including ruptured extensor tendons and intra-articular screw migration, particularly in osteoporotic fractures.² Although several investigations have attempted to identify the most ideal distal screw configuration in volar plate fixation of distal radius fractures, no previous investigation has biomechanically tested unicortical

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screw fixation in osteoporotic intra-articular distal radius fractures.^{10,12} The purpose of our study is to determine whether the number of distal locking screws significantly affects construct stability in an osteoporotic intra-articular distal radius fracture treated with a volar plate with locking unicortical distal screws. We hypothesize that osteoporotic intra-articular distal radius fractures treated using all 7 of the distal screws of a volar plate will have a higher load to failure when compared with those treated using only 4 distal screws.

Materials and Methods

Ten matched pairs of fresh frozen cadaveric forearms were included and their bone mineral density measured with quantitative computed tomography (q-CT). All of the included forearms were from female cadavers that were older than 85 years old. They were randomized within each pair to fixation using all 7 of the distal holes (full fixation, group F) of a commercially available volar plate or only 4 holes, 2 in each distal fragment (partial fixation, group P). The soft tissues of the forearm were dissected free, and each radius was instrumented based on the group assignment. Quantitative computed tomography of the specimens yielded a range of bone mineral density between 0.37 and 0.39 g/cm²; the World Health Organization defines osteoporosis in the distal radius as that with a bone mineral density below 0.595 g/cm².^{5,7} The distal radius fixation was performed with unicortical locking screws going to but not through the dorsal cortex, and the most distal screws were placed within 4 mm of the joint surface. An AO C2 type fracture was then simulated by resecting 1 cm of bone at the metadiaphyseal junction and by making an osteotomy between the lunate and the scaphoid fossa (Figure 1).¹²

All specimens were then tested cyclically, with an axial load of 60 N, at 3 Hz for 1000 cycles to simulate early postoperative motion (Figure 2). All specimens were subsequently tested to mechanical failure. Data collected included stiffness, load to yield, peak load, and load at 2-mm displacement, which was defined as a clinical failure.

Statistical analysis was performed utilizing Microsoft Excel (Microsoft Corporation, Redmond, Washington) and StatPlus: LE (AnalystSoft Inc, Walnut, California). A *P* value of <.05 was defined as statistically significant. A paired *t* test was used to compare the mean differences between groups with a cutoff of *P* < .05 for significance. A previous investigation has demonstrated that a 54-N force is transmitted to the distal radius in active flexion and 35 N in active extension.¹⁵ Therefore, we estimated that a 60- to 100-N force is transmitted across the fracture fixation constructs during early postoperative therapy. A 1-sample *t* test was used to compare our results with these values with a cutoff of *P* < .05 set for significance. Post hoc power analysis was performed based on the results of the investigation.

Figure 1. An AO C2 type fracture was simulated by resecting 1 cm of bone at the metadiaphyseal junction and by making an osteotomy between the lunate and the scaphoid fossa.

Figure 2. All specimens were set up as demonstrated in the MTS and were then tested cyclically, with an axial load of 60 N, at 3 Hz for 1000 cycles to simulate early postoperative motion.

Results

Bone mineral density and volumetric bone density were similar in both groups (Table 1). There were no failures in either group during cyclic testing. There was no difference between groups for mean stiffness, yield load, peak load, or load to clinical failure (2-mm displacement) (Table 2).

In group F, yield load was higher than 60 N (*P* = .0002) and 100 N (*P* = .0065); peak load was higher than 60 N (*P* = .0001) and 100 N (*P* = .0001); and load to clinical failure

Table 1. Mean Bone Density of Group F and Group P.

	Group F	Group P	
BMD(g/cm ²) $\pm$ SD	0.37 $\pm$ 0.1	0.39 $\pm$ 0.1	<i>P</i> =0.623
vBMD(mg/cm ³) $\pm$ SD	332.8 $\pm$ 108	350 $\pm$ 136	<i>P</i> =0.702

Note. Group F = full fixation; Group P = partial fixation; BMD = bone mineral density; vBMD = volumetric bone mineral density.

Table 2. Mean Stiffness, Yield Load, Peak Load, or Load to Clinical Failure for Group F and Group P.

	Full (Group F)	Partial (Group P)	
Stiffness (N/m)	245 $\pm$ 116	252 $\pm$ 80	<i>P</i> =0.908
Yield (N)	160 $\pm$ 54	132 $\pm$ 41	<i>P</i> =0.058
Displacement to Yield (mm)	0.83 $\pm$ 0.81	0.54 $\pm$ 0.53	<i>P</i> =0.249
Peak (N)	996 $\pm$ 442	892 $\pm$ 332	<i>P</i> =0.539
Displacement to Peak (mm)	12 $\pm$ 8	7 $\pm$ 3	<i>P</i> =0.517
Load at 2mm Displacement (N)	240 $\pm$ 339	351 $\pm$ 112	<i>P</i> =0.827

Note. Group F = full fixation; Group P = partial fixation.

Table 3. A One Sample T-Test Comparison of Stiffness, Load to Yield, Peak Load, and Load at 2 mm Displacement (i.e. Clinical Failure) to a 60 to 100 N Force (i.e. Estimated Force Transmitted Across Fixation During Postoperative Therapy).

		60 N	100 N
Group F	Yield Load	<i>P</i> =0.0002	<i>P</i> =0.0065
	Peak Load	<i>P</i> =0.001	<i>P</i> =0.0001
	Clinical Failure	<i>P</i> =0.004	<i>P</i> =0.001
Group P	Yield Load	<i>P</i> <0.0001	<i>P</i> =0.0351
	Peak Load	<i>P</i> <0.0001	<i>P</i> <0.0001
	Clinical Failure	<i>P</i> <0.0001	<i>P</i> <0.0001

Note. Group F = full fixation; Group P = partial fixation.

(2-mm displacement) was higher than 60 N (*P* = .0004) and 100 N (*P* = .001). In group P, yield load was higher than 60 N (*P* = .0004) and 100 N (*P* = .0351); peak load was higher than 60 N (*P* < .0001) and 100 N (*P* < .0001); and load to clinical failure (2-mm displacement) was higher than 60 N (*P* < .0001) and 100 N (*P* < .0001) (Table 3).

Discussion

The purpose of our study is to determine whether the number of distal locking screws significantly affects construct stability in an osteoporotic intra-articular distal radius

fracture treated with a volar plate with locking unicortical distal screws. We hypothesize that osteoporotic intra-articular distal radius fractures treated using all 7 of the distal screws of a volar plate will have a higher load to failure when compared with those treated using only 4 distal screws. There was no difference between groups for mean stiffness, yield load, peak load, or load to clinical failure (2-mm displacement). In groups F and P, yield load, peak load, and load to clinical failure were higher than the 60- and 100-N forces we applied to estimate the force is transmitted across the fracture fixation constructs during early postoperative therapy.

There are advantages to using the minimum number of distal screws to achieve adequate stability. Several authors have investigated the consequence of altering distal locking screw configuration and number on construct strength. Complications of volar plating include loss of reduction, intra-articular screw placement, and extensor irritation and rupture.² Once adequate stability is achieved to prevent loss of reduction, each additional screw represents an increased risk of intra-articular placement and extensor irritation, along with overall cost and operative time. However, to our knowledge, no previous investigation has examined the ideal number of distal screws required to fix an intra-articular fracture in osteoporotic bone using unicortical distal locking screws.

A biomechanical comparison of 4 different distal screw configurations used in volar locking plate fixation of an extra-articular cadaveric fracture model demonstrated similar results that we demonstrated with our intra-articular fracture model.¹⁰ In group A, the distal fracture fragment was treated with 4 locking screws in the distal row of the plate. In group B, 4 locking screws were alternately placed in the proximal and distal rows. In group C, 3 locking screws were used in the proximal row of the plate. In group D, all of the distal and proximal holes of the plate were filled with locking screws. Under axial compression, group D had the highest stiffness (429 N/mm) followed by groups B (208 N/mm), A (177 N/mm), and C (83 N/mm). Based on these results, they concluded that 4 screws are likely adequate as long as both distal rows are utilized.

Another biomechanical comparison of 2 different distal screw configurations using a volar locking plate fixation of an intra-articular fracture model that is similar to the model we used also demonstrated that partially filling the holes of the distal part of the volar plate is equivalent to filling all of the holes.¹² In their first group, they filled the distal row with locking screws and left the proximal row of 3 screw holes empty. In the second group, they filled all 7 holes. They found that the initial stiffness of the 7-screw construct was 69 N/m, whereas the stiffness of the 4-screw construct was 48 N/m. The failure load for the 7-screw construct was 139 N/m compared with 108 N/m for the 4-screw construct. Neither of these differences reached statistical significance.

Building upon previous investigations that studied the consequence of altering distal locking screw configuration and number on construct strength, the objective of our study was to biomechanically compare 2 different distal screw configurations using a volar locking plate fixation in the “worst case scenario,” which we represented with an intra-articular fracture pattern in an osteoporotic distal radius.

One of our objectives was to determine whether osteoporotic, intra-articular distal radius fractures fixed with a volar plate could safely undergo a passive range of motion rehabilitation protocol with the goal of preventing wrist stiffness. Investigators have previously used a power grip model to demonstrate the forces that are transmitted through the distal radius with varying degrees of grip force, revealing that 26 N is transmitted through the distal radius with 10 N of grip force.¹⁴ Another study implanted a validated sensor into the wrist of a healthy volunteer and found that 54 N is transmitted to the distal radius in active flexion and 35 N in active extension.¹⁵ These studies are frequently cited in biomechanical studies as estimates of the force transmitted across fracture constructs during early postoperative therapy. Based on these investigations, we estimated that a 60- to 100-N force is transmitted across wrist fracture fixation constructs during early postoperative therapy and compared our data with these values, revealing that in groups F and P, yield load, peak load, and load to clinical failure were higher than the 60 and 100 N forces we applied to estimate the force is transmitted across the fracture fixation constructs during early postoperative therapy.

Our results indicate that there is no difference between the full and partial fixation constructs, which disproves our initial hypothesis that the full fixation construct would have a higher load to failure than the partial fixation construct. We were unable to detect a statistically significant difference in load to failure, clinical failure, or any other tested parameter between the 2 groups. When comparing the results of each individual group with forces considered clinically relevant using a 1-sample *t* test, we found that both groups had clinical failure at forces higher than those encountered in early postoperative range of motion. This suggests that osteoporotic intra-articular distal radius fractures treated with a volar plate and submaximal distal screws are stable enough for early postoperative range of motion.

There are several limitations of our study. First, as a result of the higher than anticipated standard deviations, analysis comparing the partial fixation and full fixation groups is underpowered. Post hoc power analysis revealed that the power was 29%. However, the results of the 1-sample *t* test imply that if an adequately powered study did find a difference between the 2 groups, it would likely be at forces far higher than those deemed clinically relevant. Second, our fracture pattern was created in vitro and so it lacks the

complexity and variability of fractures that occur in vivo. While the metadiaphyseal resection does adequately simulate the lack of axial support that occurs with comminution, the intact dorsal cortex at the level of the screws allowed us to directly measure off the dorsal cortex and maximize the length of our unicortical locking screws. This can be difficult in vivo, where dorsal comminution extends to the articular surface. Third, the method of fixing the plate to the distal radius prior to fracture simulation ensures optimal fit of the plate to the bone, maintenance of anatomical parameters, and reduction of the fragments relative to each other. This is not always possible during surgery, and should be taken into account when interpreting the result of this study.

Authors' Note

Investigation was performed at the Department of Orthopaedic Surgery, Warren Alpert Medical School, Brown University. Instrumentation for this study was provided by Skeletal Dynamics, Inc.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not involve human or animal subjects.

Statement of Informed Consent

This article does not involve human subjects.

Declaration of Conflicting Interests

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