Carpal Translocation Following Dorsal Bridge Plate Fixation of Distal Radius Fractures: A Cadaveric Study

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Distal radius fractures are one of the most common injuries of the upper extremity with a 17% increase in incidence over the past 40 years.1–3 The goal in surgical fixation of distal radius fractures is to restore and maintain anatomic reduction to optimize hand and wrist function.4 Over the past decade, volar plate fixation has become an increasingly popular approach in the management of distal radius fractures requiring surgical management.5–9 However, this

Abstract

Background Dorsal bridge plate fixation is an effective technique for stabilization of highly comminuted, complex distal radius fractures. However, it is unknown whether fixation to the second or third metacarpal is optimal. Given dorsal bridge plating spans the radiocarpal joint, it is unclear if the dorsal spanning plate affects carpal position. This study investigates differences in carpal translocation resulting from bridge plate distal fixation to either the second or third metacarpal.

Methods Ten paired cadaveric upper extremities without evidence of gross deformity or prior surgery distal to the elbow were evaluated with three-view wrist fluoroscopic images for baseline radiographic measurements. An unstable distal radius fracture model was created via a volar approach using a 1-cm osteotomy. Following fracture creation, a dorsal bridge plate was applied with random to the second metacarpal on one limb, and the third metacarpal on the contralateral limb. Laterality for distal fixation was chosen randomly. Fluoroscopic images were repeated and radial inclination, radial height, radiocarpal angle, volar tilt, ulnar variance, radiolunate angle, radioscaphoid angle, radial rotation index, and carpal translocation were measured.

Results Radial inclination, radial height, radiocarpal angle, volar tilt, ulnar variance, radiolunate angle, and radioscaphoid angle were not statistically different before and after fixation, or when comparing the second or third metacarpal fixation. Additionally, there was no difference in Taleisnik’s ulnar translocation index, Chamay’s ulnar translation index, or McMurtry’s carpal translation index based on which metacarpal was used for distal fixation.

Conclusions Dorsal bridge plate fixation of distal radius fractures restores preoperative physiologic measures of the radius, ulna, and carpus. Carpal translocation was similar when comparing distal fixation to the second or third metacarpal in distal radius fractures stabilized with a bridge plate.

Level of Evidence This is a Level V, therapeutic study.

Keywords► distal radius fracture
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fixation method proves challenging in the setting of fracture patterns involving significant comminution, a large zone of injury, fracture dislocations, and osteopenic bone.10

One alternative to volar plating is external fixation of the distal radius. This technique relies on ligamentotaxis to aid in fracture reduction and avoids incisions from the zone of injury. However, external fixation has limited ability to prevent dorsal collapse or maintain palmar tilt in unstable distal radius fractures.11 In addition, this construct is often troubling to the patient and associated with an array of complications including pin tract infection, complex regional pain syndrome, hand and wrist stiffness, and nerve injury.11–17

To address these shortcomings, Burke and Singer developed a novel fixation method using internal radiocarpal distraction via spanning plate fixation.10 Similar to an external fixator, this technique relies on ligamentotaxis for indirect reduction of the fracture. In addition, it provides a dorsal buttress to prevent dorsal tilt and subsidence. Biomechanical studies comparing the 2.4-mm radiocarpal spanning plate and external fixation have shown greater stability in both flexion and extension with the spanning plate.11 This technique was initially described for comminuted and displaced fractures. Subsequent studies have expanded the indications to include distal radius fractures with metaphyseal and diaphyseal comminution, patients with multiple extremity involvement, and elderly osteoporotic patients with extensive comminution.13,14

Two techniques for internal distraction plating of distal radius fractures have been described using distal fixation to either the second or third metacarpal. Multiple cadaveric studies have been described the anatomic implications of plating to the second versus third metacarpal. Lewis et al demonstrated a higher rate of tendon entrapment with fixation to the third metacarpal and thus advocate for formal exposure of the extensor tendons over the zone of injury when plating to the third metacarpal.9 Dahl et al also demonstrated increased tendon–plate contact when plating to the third metacarpal in cadaveric models.18 However, Dahl et al also demonstrate increased contact between the superficial radial nerve and plate when plating the second metacarpal.18

Controversy remains over the ideal distal fixation for the bridge plate. There are anatomic risks for fixation to both the second and third metacarpal. In addition, concerns have arisen that carpal translocation may occur in the process of immobilizing the wrist with a dorsal bridge plate, which could in turn hinder functional recovery.4 The purpose of this study is to evaluate carpal alignment following dorsal bridge plating of distal radius fractures. We hypothesized that there is no difference in carpal alignment with distal fixation to the second or third metacarpal and that both fixation methods provide adequate radiocarpal alignment.

**Methods**

Ten fresh cadaveric specimens of unknown age and gender were examined for signs of prior injury to the hand, wrist, forearm, or elbow. None of the specimens included for analysis had signs of trauma distal to the elbow. To control for anatomic variations between the specimens, each cadaver was used as its own internal control, with one limb undergoing distal fixation to the second metacarpal, and the contralateral limb with distal fixation to the third metacarpal. Distal fixation of the second or third metacarpal was assigned randomly to either the right or left hand of each cadaver, which resulted in a total of 20 specimens. Each specimen was used only once for this study.

Prior to dissection, an initial posterior–anterior (PA) and lateral wrist radiograph was obtained using fluoroscopy. Next, an unstable distal radius fracture model was created through a standard volar Henry approach. An osteotome and oscillating saw were used to create a 1-cm defect at 1 cm proximal to the watershed line of the distal radius (Fig. 1A). The wrist was then manipulated to 90° of hyperextension to simulate soft tissue disruption. Repeat PA and lateral radiographs were then obtained.

Three investigators (AA, JI, HL) performed distraction plating to the second or third metacarpal, using each cadaver as a matched control, as described by Lewis et al.9 A 2.4-mm distal radius bridge plate (DePuy-Synthes, West Chester, PA) was superimposed along the dorsal hand and forearm and incisions were marked in line with the screw holes proximally along the radial diaphysis and distally overlying the second or third metacarpal. A 3-cm dorsal incision was made over the second or third metacarpal diaphysis and a second 4-cm incision was made along the diaphysis of the radius. Care was taken to sharply incise through skin and subcutaneous tissue followed by blunt dissect to bone at each location. The plate was inserted distal to proximal, sliding underneath the extensor retinaculum. Plate fixation was then achieved with three 2.4-mm nonlocking cortical screws distally into the appropriate metacarpal and three 2.4-mm nonlocking cortical screws proximally into the radial diaphysis (Fig. 2).

Repeat PA and lateral radiographs of the wrist were then obtained after placement of the dorsal bridge plate. Radiographic measurements obtained included radial inclination, radial height, volar tilt, ulnar variance, radiocarpal angle, scapholunate angle, Taleisnik ulnar translocation index,19,20 McMurtry carpal translation index,21 and Chamay ulnar translation index.22,23

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Fig. 1 (A) Distal radius fracture model. (B) 2.4-mm distal radius bridge plate (DePuy-Synthes, West Chester, PA).
Statistics
A power analysis for two sample means (SAS System 9.4; SAS Institute Inc., Cary, NC) was performed for 80% power with 95% confidence, eight specimens were required for each group; 10 specimens were used. By using each cadaver to test both metacarpals, the specimens served as their own internal controls and resulted in analysis of 20 specimens. Student’s t-test was used to compare continuous variables ($p = 0.05$).

Results
Ten fresh cadavers with paired wrists were used to create the fracture model as previously described. Demographic data were not collected, and cadavers were free of gross deformity or evidence of prior trauma. All cadavers (20 wrists) were included in data analysis. Laterality and metacarpal fixation were evenly distributed.

Radiographic measurements of radial inclination, radial height, volar tilt, ulnar variance, radiocarpal angle, and scapholunate angle were found to be consistent across all 10 cadavers ($\text{Table 1}$). There were no statistically significant differences between the second metacarpal cohort and third metacarpal cohort prior to fixation. An analysis of radiographic measurements after dorsal bridge plate fixation revealed no statistically significant difference when compared with baseline measurements for the respective metacarpal. Additionally, this held true when comparing baseline measurements for all 20 specimens to those after fixation. A comparison of measurements between the second and third metacarpal cohorts following fixation also revealed no statistically significant differences.

Taleisnik Ulnar Translocation Index
Baseline and postfixation measurements for the second and third metacarpal groups were all found to have a positive type-1 ulnar translocation (radioscaphoid distance of $> 2$ mm). However, there was no statistically significant difference when comparing postfixation translocation values to their internal control for each respective metacarpal or when comparing postfixation translocation values of the second metacarpal group to the third metacarpal group. No groups in the study had type-2 ulnar translocation (radiolunate overlap $< 50\%$). Additionally, there were no statistically significant differences found when intergroup comparisons were performed ($\text{Table 2a}$).

McMurtry Carpal Translation Index
Ulnar translation did not occur based on the McMurtry index in the baseline and postfixation groups. Each group was within the normal index value (0.3 $\pm$ 0.03). Additionally, there were no statistically significant differences found when intergroup comparisons were performed ($\text{Table 2b}$).

Chamay Ulnar Translation Index
Ulnar translation did not occur based on the Chamay index in the baseline and postfixation groups. Each group was within normal.
the normal index value (0.28 ± 0.03). Additionally, there were no statistically significant differences found when intergroup comparisons were performed (► Table 2c).

Discussion

Distal radius fracture treatment has evolved over the past decade. The goal of treatment remains restoration of anatomic alignment to allow for optimized hand and wrist function. Volar plate fixation has become an increasingly popular approach for the treatment of these fractures; however, it has limited utility in the setting of significant comminution, a large zone of injury, fracture dislocations, and osteopenic bone. In these instances, approaches that rely on ligamentotaxis, namely external fixation and dorsal internal distraction plating can provide stable fixation. Both external fixation and bridge plating distract the radiocarpal joint, allowing for ligamentotaxis to reduce and maintain fracture alignment as well as allowing the articular surface to heal without collapse. However, due to the high complication rate (52–63%) and loss of reduction associated with distal radius fractures treated with external fixation, many surgeons have favored the use of dorsal internal distraction plating. Investigation of soft tissue complications associated with differential metacarpal plating has demonstrated potential tendon and nerve entrapment. However, there remains a paucity of data on carpal alignment after internal distraction bridge plating. Reporting on the clinical importance of carpal instability following dorsally displaced distal radius fractures, Stoffelen et al performed a prospective study of 272 patients.
with various types of wrist instability. Clinical function at 1 year was significantly worse in patients with only dissociative dorsal intercalated segment instability (DISI) and ulnar translocation patterns of instability. The average age of patient’s with carpal instability was 55.2 years compared with 48.5 years in the normal group. This study sought to determine if there was a difference in carpal alignment depending on the distal fixation of bridge plating, second or third metacarpal. Radiographic parameters including radial inclination, radial height, volar tilt, ulnar variance, radiocarpal angle, and scapholunate angle were similar between groups. Additionally, ulnar translocation was measured by three different means: Taleisnik ulnar translocation index, McMurtrey carpal translation index, and Chamay ulnar translation index. Distal fixation to both the second and third metacarpal yields acceptable carpal alignment compared with preoperative values without significant difference between groups.

Although our findings reveal that the dorsal bridge plate fixation to the second or third metacarpal results in maintenance of normal carpal alignment, several publications have revealed soft tissue complications associated with each type of fixation. Hanel et al reported a major complication rate of 9%, primarily involving tendon injury. Ruch et al reported on 22 patients who underwent dorsal bridge plating with fixation to the third metacarpal, with 3 patients exhibiting middle finger extensor lag of 10 degrees at final follow-up. In a series of 62 consecutive patients with distal radius fractures treated by dorsal bridge plating with distal fixation to the second metacarpal, Hanel et al reported the complications of extensor carpi radialis longus (ECRL) rupture with hardware failure in a single patient. Richard et al retrospectively reviewed 33 patients with comminuted distal radius fractures treated by distraction plating. In 21 patients, fixation was to the third metacarpal, and fixation was to the second metacarpal in 12 patients. Ten patients developed digital stiffness, one patient required tenosynovectomy of index finger extensor tendon adhesions. Superficial radial neuritis and chronic regional pain syndrome were each reported in one patient. In an anatomical study by Lewis et al, plating to third metacarpal using a two-incision technique resulted in the entrapment of extensor tendons in all specimens; however, plating to the second metacarpal did not entrap tendons.

There are several limitations to this study. The fracture model was performed using fresh cadavers; however, surgically created fractures do not reproduce the fracture morphology or soft tissue injury that occurs in the general trauma population. Additionally, as a cadaveric study, final carpal alignment measures after healing of the fracture and soft tissues remain unknown.

Based on the findings of this study, we can conclude that the plate fixation to the second or third metacarpal maintains carpal alignment. Further studies performed in a prospective fashion are needed to elucidate the effects of dorsal bridge plating on carpal alignment in more complex perilunate fractures patterns and dislocations.

Conflict of Interest
None declared.

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