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Research Article

Dorsal Bridge Plates *versus* Volar Locking Plates in an Axially Loaded Cadaver Model for Distal Radius Fractures

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ABSTRACT

Background: Surgical fixation of distal radius fractures with Dorsal Bridge Plating (DBP) has been proposed to allow early weight bearing/mobilization of polytrauma patients. However, there is a lack of biomechanical studies supporting the use of DBP with crutches. We hypothesized that a 3.3 mm DBP is comparable to a Volar Locking Plate (VLP) for distal radius fractures and able to allow for immediate weight bearing.

Methods: VLPs and DBPs were applied to cadaver forearms with a dorsal wedge osteotomy in an axially loaded crutch bearing model. Displacement was measured as specimens were incrementally loaded. Failure was defined as 2 mm of fracture gap displacement. T-tests were used to compare the force at failure for each group and to the target thresholds of 200 N and 400 N. Linear regression analysis was used to determine the association between bone mineral density and load at failure.

Results: VLPs required significantly higher forces to cause 2 mm of osteotomy displacement as compared to DBPs. In this cadaveric study, both plates were stable enough to allow immediate use with a 200 N threshold but only the VLP is stable enough with a 400 N threshold. There was no association between bone mineral density and load at failure.

Conclusion: We found a 3.3 mm DBP to have similar strength to previous reports with thinner plates, but overall had lower load to failure than VLPs. DBPs do not support full crutch-based weight bearing in this cadaver model and caution should be exercised when counseling patients with DBP fixation post-operatively.

Keywords: Dorsal bridge plate; Biomechanical cadaver model; Distal radius fracture

INTRODUCTION

Distal Radius Fractures (DRFs) are the most common upper extremity fracture with over 600,000 cases per year and are estimated to account for 2.5%-16% of all emergency department visits [1,2]. The incidence of these fractures for pediatric, adult, and elderly populations is increasing according to recent reports [1,3]. DRFs represent a significant burden to society due to increasing medical costs, loss of work or school time, and loss of independence [4]. The direct medical socioeconomic impact of DRFs in 2007 was an estimated $170 million [5]. The rate of surgical fixation of DRFs is increasing and options for surgical fixation continue to expand [3-6]. Options for surgical fixation include various modifications of volar or dorsal plates, external fixators, and more recently wrist spanning or Dorsal Bridge Plates (DBPs). DBPs are an attractive fixation option as they allow indirect fracture reduction through ligamentotaxis without the use of an external fixator. They are secured proximally to the radial shaft and into the 2nd or 3rd metacarpal distally. Indications for dorsal bridge plating have expanded and include severe osteoporosis, extensive articular fractures, metaphyseal comminution and radiocarpal instability [7-9]. Potential benefits that have been proposed include limited dissection at the fracture site, avoidance of external fixator pin track complications, and earlier weight bearing [10,11]. Distal radius fractures are common in elderly and polytrauma patients that often require the use of an assistive device for ambulation. Allowing earlier axial weight bearing, with crutches or a walker, through distal radius fracture fixation could potentially improve the mobilization of this patient population. However, many questions on the biomechanical properties of DBPs have yet to

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be answered and only a limited number of studies have evaluated the axial weight bearing properties of DBPs [12-14]. Recently demonstrated that a 2.4 mm bridge plate had earlier failure than volar locking plates in a cadaveric model, and that it was not suitable for early crutch weight bearing. These results contrast previous comparisons of external fixators to DBPs and the proposed benefits of earlier weight bearing with DBPs [12, 13]. The authors of that study suggest a stiffer/thicker construct may be needed [15]. The goal of the present study was to evaluate the stability of a 3.3 mm dorsal bridge plate compared to a volar locking plate in a similar cadaveric axial crutch loading model.

MATERIALS AND METHODS

Methods and study design were adapted from Huang et al. [15]. Imaging was conducted prior to preparation to ensure specimen was free of fracture, deformity, or previous implants. DEXA scans were obtained to determine the bone mineral density of each specimen. Soft tissue was removed from the 6 cm distal to the radial head of the specimens to allow for potting and subsequent testing. Paired forearms were taken from a single cadaver in order to compare two different plates while minimizing confounding factors. One arm from the first pair was randomly selected for the DBP while the other arm received the VLP. The plates were then alternated in subsequent forearms to ensure that there was a random yet equal assignment of left and right forearms. Plates were applied in accordance with the manufacturer's surgical technique guide.

The DBP, produced by Acumed, was applied to the long finger metacarpal, passing beneath the 4th extensor compartment to the radial diaphysis. Manual traction was applied to the index and long fingers of each specimen during plate application as would occur in the operating room. A 2.7 mm non-locking screw was inserted in the most distal screw hole over the long finger metacarpal while a 3.5 mm non-locking screw was inserted in the most proximal screw hole over the radius. Plate and screws were then removed for osteotomy. Skin was dissected dorsally at the distal forearm to allow for a dorsal wedge osteotomy. This was performed with an oscillating saw starting at the base of Lister's tubercle and extending 1 cm proximally with the apex on the volar cortex. Kirchner wires were applied to act as a guide for the saw with their tips intersecting on the volar cortex (Figure 1).

Figure 1: Photograph of k-wires used to guide an oscillating saw for a dorsal wedge osteotomy.

This was confirmed with imaging. The DBP and previously placed screws were reapplied. Two additional locking 2 mm screws were applied distally. Proximally, an additional 3.5 mm nonlocking screw was applied to the most distal proximal screw hole while a 3.5 mm locking screw was applied in the next proximal spot. The slotted screw hole and central screw cluster remained empty. Figure 2 demonstrates radiographs of a specimen with the DBP applied.

Figure 2: Radiograph of specimen with a DBP applied to the long metacarpal.

The VLP was applied using a standard FCR approach. A 3.5 mm cortical screw was placed proximally in the slot in a bi-cortical fashion. Six 2.3 mm locking screws were applied distally in the four most distal holes and the two radial styloid holes. Two 3.5 mm locking screws were then applied in the two remaining proximal screw holes. The plate remained in place as the previously described dorsal wedge osteotomy was again performed on the VLP specimens. Figure 3 demonstrates radiographs of a specimen with the VLP applied.

Figure 3: Radiograph of specimen with a VLP.

The specimens were then potted with the long axis of the radius perpendicular to the potting base. Optical motion tracking sensors were applied to the proximal and distal edges of the dorsal osteotomy site. The Optotrak Certus motion capture system was utilized to track gap displacement at the osteotomy site. The specimen's proximal potted end was mounted to the actuator of an 858 Mini Bionix II materials testing machine while the hand was mounted to a simulated crutch handle fixed rigidly to the testing machine (Figure 4).

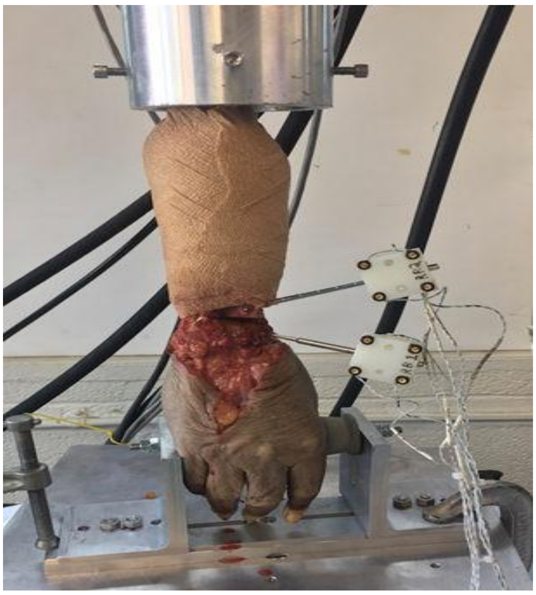

Figure 4: Specimen mounting with optical motion tracking sensors at the osteotomy site.

The hand was positioned to maximize contact with the thenar eminence and first webspace. A preload was applied through the actuator followed by increasing incremental loading until gross failure. Failure was defined as 2 mm of gap displacement at the fracture site. Paired t-tests were utilized to test whether the mean difference between groups was greater than zero. A one-sample t-test was used to compare the mean of each group to the target thresholds of 200 and 400 N, modeling using crutches while lower extremity partial weight bearing and non-weight bearing, respectively. Linear regression analysis was used to test for an association between bone mineral density and the load at 2 mm of displacement.

RESULTS

VLPs required significantly higher forces to cause 2 mm of osteotomy displacement as compared to DBPs (604.8 +/- 129.1 N vs 348.8 +/- 117.6 N, p=0.01) as seen in (Figure 5).

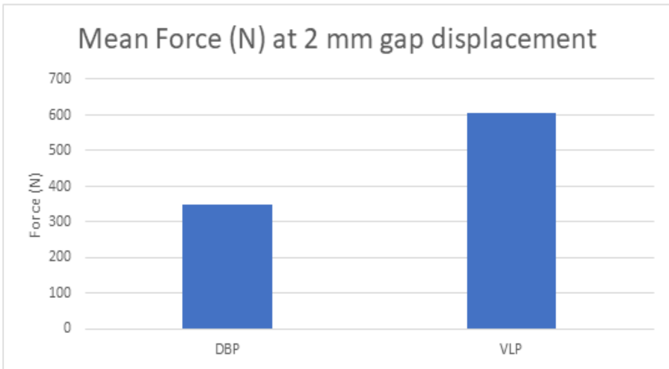

Figure 5: Mean force required to cause 2 mm of gap displacement at osteotomy site.

In this cadaveric study, both plates were stable enough to allow immediate use with assistive devices in patients without lower extremity restrictions with a 200 N threshold (VLP p=0.002, DBP p=0.047).

Only the VLP is stable enough to allow immediate weight bearing with a target threshold of 400 N (p=0.024). There was no statistically significant association between bone mineral density and load at failure on linear regression analysis (VLP R2=0.449, p=0.22; DBP R2=0.453, p=0.21).

There was no significant difference between the bone mineral densities of the matching specimens. Gross failure for the VLP occurred *via* wrist flexion/extension. The mode of failure for the DBP was metacarpal fracture or metacarpal screw cut out.

DISCUSSION

surgeon considers many factors when deciding on the type of fracture fixation. One factor critical for both polytrauma patients and elderly patients is early mobilization. Polytrauma patient's multiple injuries often necessitate assistive devices while elderly patients often depend on these devices for ambulation at baseline. Polytrauma is often the result of high energy accidents such as motor vehicle collisions which can lead to highly comminuted distal radius fractures. Elderly patients most commonly suffer DRFs from low energy trauma such as a fall from standing height, but given the incidence of osteoporosis, can lead to significant comminution and challenging fracture fixation [1,2].

Dorsal bridge plates are often useful when attempting to provide relative stability in highly comminuted or osteoporotic fractures while minimizing loss of independence. These temporary plates make use of ligamentotaxis while avoiding the use of external fixators and the associated complications, though a second surgery is required for removal [16,17]. They allow patients to gain earlier mobility through weight bearing on assistive devices and the use of unrestricted hand movement to facilitate self-care, hopefully decreasing the loss of independence and its associated costs [8, 12, 16]. As such, DBP patients are generally allowed to platform weight-bear within a week of surgery while crutch weight-bearing is allowed at 4-6 weeks [7,8].

Outcomes research has found that DBPs are comparable to other surgical techniques, though a somewhat limited number of studies are currently published [7,9,16,18,19] As As Lauder and Hanel, report, the majority of data on the subject comes from retrospective reviews and only a total of 7 studies encompassing 108 patients report functional range of motion outcomes following DBP, a common concern for many surgeons [16]. Even fewer studies have examined the biomechanical properties of DBPs, especially in relation to axial loading as seen in crutch bearing [12]. Compared a 2.4 mm DBP with a variable number of locking screws to a spanning external fixator as flexion and extension loads were applied through the respective tendons to create bending and found the DBP to be significantly more stable. Similarly, Chhabra et al. [13] found 2 different DBPs to be stiffer than an external fixator in axial loading. Mann et al. [14] investigated whether a 2.4 mm DBP with all cortical screws was stiffer to flexion and extension when placed in physiologic extension of the wrist as compared to neutral and found no difference.

The most applicable study on weight bearing was conducted by [15]. This group compared volar locking plates to a 2.4 mm DBP in axial loading with a novel crutch weight-bearing model. The authors found that the DBP was less stable than VLP to axial loading with the DBP consistently failing in flexion at the radiocarpal joint. The authors concluded DBPs may not offer the advantage of early weight bearing as previously assumed. We used this biomechanical model in our own experiment as it is the first described model to compare wrist spanning versus non-wrist spanning hardware in an axial loading model.

Our study showed that VLP are stronger to axial load than DBP in a cadaver crutch bearing model when using a 2 mm osteotomy displacement threshold, similar to [15]. We selected 200 N and 400 N thresholds as these represent the expected forces with 25% and 50% weight bearing for an 80 kg patient. It has been previously demonstrated that a patient places approximately 50% of their body weight on a crutch when he/she is non-weight bearing on a lower extremity and 25% when using an assistive device and weight bearing on lower extremities [20,21]. Both of these are common situations encountered in patients with distal radius fractures. Polytrauma patients often have concurrent lower extremities fractures while elderly patients may have isolated comminuted distal radius fractures but depend on assistive devices at baseline for ambulation. Both plate constructs were stable at 200 N, however only the VLP was stable at 400 N.

Interestingly, our study found that a 3.3 mm DBP failed at similar forces to thinner plates in a previous study [15]. This is the second study to demonstrate increased failure of DBP as compared to VLP in an axillary loading model, raising the question as to how the forces are transferred with DBPs. We suspect that much of the force with crutch bearing is transmitted through the tenor eminence and thumb metacarpal. In this manner, the distal aspect of the plate is bypassed to some degree and fracture shortening may occur due to laxity in the supporting soft tissues as opposed to plate failure (Figure 6).

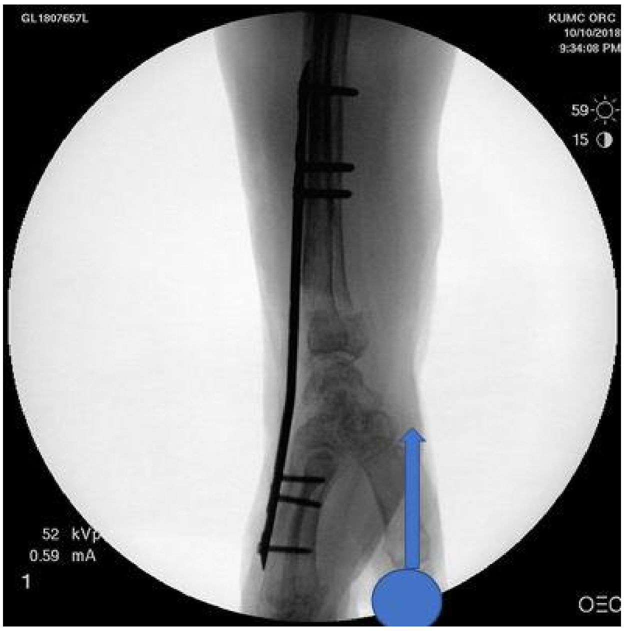

Figure 6: Radiograph of a DBP with a simulated crutch handle and possible force vector which bypasses the distal aspect of the plate.

Offers a radiograph with the possible force vector depicted in order to illustrate this point. Despite the reduced strength to axial loading, DBP still offers an attractive option for distal radius fractures in elderly and polytrauma patients though full weight bearing on assistive devices should be through the forearm based on this model. Importantly, in the clinical experience of the authors, patients with distal radius fractures treated with DBP who have been allowed to bear weight through the forearm have not significant fracture displacement or plate failure.

There are several limitations to our study. First, this was a biomechanical study performed in cadavers with bone that likely differs from live patients. These specimens came from older subjects than the typical patient. Second, we believe this crutch model to the most accurate yet described for the given purposes; however, it fails to account for the ability of patients to balance an axial load through neuromuscular control of their forearms. This likely would lead to a more axial load and less bending at the plates, thus probably increasing the ultimate load to failure. Additionally, soft tissues were stripped from our specimens and origins of the forearm musculature were mostly removed before potting.

CONCLUSION

DBP and VLP offer attractive options for patients. We have shown that both plates are suitable for patients without weight bearing restrictions on a lower extremity that need assistive devices for ambulation. For full weight bearing in patient with lower extremity fractures, VLPs appear suitable for crutch use in carefully selected fracture patterns while DBP patients should bear weight through the forearm or more proximal.

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