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Comparison of crossed screw versus plate fixation for radial neck fractures

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ABSTRACT

Background: Fixation of radial neck fractures can be achieved with a plate and screw construct or, in absence of comminution, with two obliquely-oriented screws. This study investigated the mechanical properties, specifically the stiffness and load to failure, of these two fixation strategies in a cadaver model.
Methods: Ten matched-pair radii were removed from fresh cadaver arms. A transverse osteotomy was created at the neck of each radius. Right-sided radii were fixed with two oblique headless compression screws; left-sided radii were fixed with a radial neck plate. The distal aspect of each radius was potted in urethane casting resin. The radial head was loaded in shear in 4 different planes (medial to lateral, lateral to medial, posterior to anterior, and anterior to posterior) using an Instron machine. Stiffness and load to failure were recorded.
Findings: The stiffness of both constructs was similar in all planes except for loading from medial to lateral where the screw construct was 1.8 times stiffer. Average ultimate failure occurred at 229 N for the screws and 206 N for the plate. Failure strength was not statistically different. However, mode of failure differed for both fixation constructs, the plate failed in bending while the screws failed by pullout and fracture.
Interpretation: The two strategies provide similar strength and stiffness for the fixation of transverse, non-comminuted radial neck fractures. While plate and screw constructs are more appropriate for axially unstable or comminuted fractures, two oblique screws might be preferred for simple transverse neck fractures since this strategy requires less exposure and the implant is buried.
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1. Introduction

Displaced radial head and neck fractures frequently require open reduction with internal fixation to restore alignment and stability. Options for internal fixation include plates, screws, and k-wires in various configurations. If there is displacement or instability between the head and shaft segments, fixation across the neck is recommended (Duckworth et al., 2013). The results of plate fixation are generally favorable though implant related complications have been reported (Geel et al., 1990; Ikeda et al., 2003; King et al., 1991). Soft tissue release around the radial neck, required to secure the plate, has raised concern for heterotopic ossification, tethering scar, and devascularization of the radial head (Neumann et al., 2011). Hardware prominence and soft tissue adhesions, resulting in limited forearm rotation, loss of fixation, and painful crepitus are associated with plate fixation, and are frequent reasons for revision surgery. Countersunk crossing lag screws and headless compression screws have also been used successfully to fix radial head and neck fractures (Ruchelsman et al., 2013). Compared to plate fixation, this strategy allows for a potentially less invasive surgical approach and less prominent implants.

Studies in the literature evaluating biomechanical characteristics of various radial head implants are limited (Burkhart et al., 2007; Capo et al., 2008; Giffin et al., 2004; Patterson et al., 2001). This study differs from others currently available in the literature due to its load to failure testing with shear force, as well as its focus on radial neck fractures without fracture gap. The goal of this study was to determine the biomechanical properties, specifically the stiffness and load to failure of a radial head locking plate versus crossing headless compression screw fixation for fixation of radial neck fractures. The null hypothesis is that crossed screw fixation is biomechanically equivalent to locking plates for a radial neck fracture without a gap in a cadaveric study.

2. Methods

Ten fresh cadaveric forearm specimens were used. The study was designed to have 5 matched pairs. They were from 2 male and 3 female donors with average and standard deviation age of 70 (15) and with

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T-score of −2.12 (0.86). Prior to dissection, the bone density of each specimen was measured. Physical examination, and fluoroscopy evaluation were performed to identify any previous injury. The radii were stripped of soft tissues and cut at the mid-shaft, leaving an approximately 10 cm long proximal segment. A transverse osteotomy was made at the head–neck junction using a micro sagittal saw, simulating a longitudinally-stable radial neck fracture. The osteotomy was then fixed with either a locking radial head plate and screws (Medartis, Basel, Switzerland), or with two 2.2 mm bicortical oblique cannulated headless compression screws (Medartis, Basel, Switzerland) placed approximately 45° apart as described by Smith et al. (2007). The plate was applied to match the radius anatomy and secure the osteotomy without a gap. Our plating construct involved 8 screws, all of which were bicortical: four nonlocked screws to reduce the plate to bone, and four locked screws to create a fixed angle construct for maximum strength. The headless compression screws were countersunk just below the articular cartilage surface, so they came to rest just flush with the cortical rim. The length and trajectory of the screws were selected to ensure bicortical penetration distal to the PRUJ, but with screw tips not more than 1–2 mm proud to avoid ulnar impingement. One fellowship-trained upper extremity surgeon performed the fixation on all ten specimens to minimize the variability of fixation parameters, e.g., the torque used to tighten the screws. The fixations were evaluated by taking x-ray images. Representative fixed radii with the two methods are shown in Fig. 1.

The transversely-cut end of the radial shaft was then potted using a urethane casting resin (R1 Fast Cast, #891, Goldenwest Mfg, CA) in aluminum rectangular cups. The length of proximal radius exposed, outside of the potting material, was one quarter of the radius length.

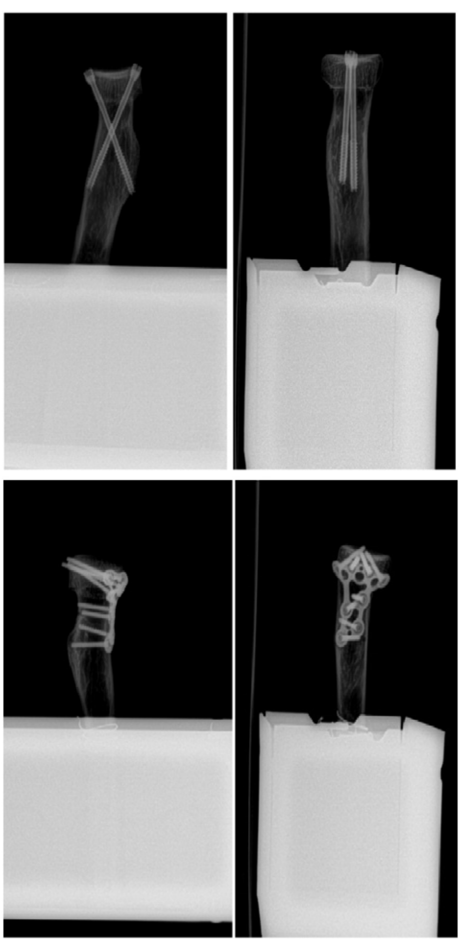

Fig. 1. Representative x-ray images of fixation and potting of radial neck fracture specimens with screws (top row) or plate (bottom row).

The exposed length was 57.65 (5.32) mm and the diameter of the radial head was 20.90 (2.43) mm. Fig. 1 displays representative potted specimens. The cup was clamped rigidly to the bed of an Instron machine (Instron, MA, model 8874, 10 kN maximum load) with the radial head positioned horizontally under the machine actuator. A 5-mm-thick metal plate with rounded edge, attached to the actuator, was utilized to create downward-directed shear force on the radial head at 5 mm distance from the osteotomy line. The rate of displacement was 2 mm/min, similar to Giffin et al. (2004). Fig. 2 demonstrates the testing setup with the actuator loading the radial head.

Two loading conditions were applied to each specimen. First, to evaluate specimen stiffness, four non-destructive loading cycles with 1 mm amplitude were applied in each of 4 orientations: posterior to anterior (PA), anterior to posterior (AP), lateral to medial (LM), and medial to lateral (ML). The radial tuberosity was considered the medial aspect of the radius. Next, a load to failure in the PA orientation was applied with the same rate to evaluate the failure strength and mechanism. The PA direction was chosen so the failure properties could be compared with other studies (Giffin et al., 2004). The failure point was selected at maximum force after which the load-displacement curve slope reduced significantly. The corresponding displacement was designated as the failure displacement.

To account for the variability in specimens' lengths and diameters, stiffness (k), failure load (L_f), and failure displacement (d_f) values were normalized based on the specimen dimensions to obtain the corresponding structural effective modulus (E), failure stress (σ_f), and failure strain (ε_f) values. A cantilever beam model was utilized and the measured values of the radial head radius (R), moment of Inertia ($I = 0.25\pi R^4$), and exposed length (L) for each specimen were used. The modulus was calculated as $E = kL^3/3I$. The failure stress and failure strain were calculated at a 5 mm distance from the contact point, at the osteotomy site, from $\sigma_f = 5L_fR/I$ and $\varepsilon_f = 15d_fR/L^3$ respectively.

The stiffness was determined from the slope of the regression line fitted to the loading segment of the cyclic load displacement curves. The values calculated for the modulus in PA, AP, LM, and ML directions for the two fixation methods were compared using two-factor analysis

Fig. 2. Experimental setup for loading of radial head fixed with screws or plate in shear to failure in the PA direction.

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