Impact of Screw Length on Fixed Proximal Scaphoid Fracture Biomechanics: In Vitro Study with Cyclic Loading and Load to Failure

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Introduction: Internal fixation used as treatment for scaphoid fractures has increased with advances in surgical techniques [1]. Proximal pole scaphoid fractures present a clinical challenge due to their lower success rate when cast immobilization and internal fixation are utilized [2]. Screws maximizing length have been shown to impact wrist motion for fixed scaphoid waist fractures [3]. Additionally, screws with greater diameters and varying geometry have been shown to impact stiffness and ultimate load at the fracture site for fixed scaphoid waist fractures. Currently, the effect of screw length on the structural properties of fixed proximal scaphoid fractures is not well understood even though fixation of proximal scaphoid fractures has a high nonunion rate. Therefore, the objective of this study is to determine the bending stiffness and ultimate load for the loading of fixed proximal scaphoid fractures for screws of various lengths. We hypothesize that longer screws will provide greater biomechanical stability due to there being greater purchase or bone-screw interaction beyond the fracture site.

Methods: Fifteen, fresh frozen cadaveric scaphoids (57.6±10.3 years of age) underwent an oblique osteotomy with a .52mm blade saw to simulate a 7mm proximal oblique fracture with respect to the long axis. Each scaphoid was randomly assigned for fixation to one of 3 possible screw lengths (n=5) of a 2.5mm diameter central threadless screw (Stryker, Kalamazoo, MI, USA): 10mm, 18mm, and 24mm length. The distal pole of the scaphoids was potted in epoxy putty (Bondo, St. Paul, MN, USA) with the scaphoid long axis perpendicular to the horizontal plane. The scaphoid was then oriented at 45° to simulate clinical dorsal to volar bending load (Figure 1). Each specimen was cyclically loaded for 1000 cycles with an 800Nmm bending moment, where the applied load (40.0N-66.7N) depended on the moment arm between the potting and a plunger driven by a materials testing machine (Instron, Eden Prairie, MN). Stiffness was calculated at the 1000th cycle and cyclic failure was defined as either plunger extension greater than 2.5mm or a proximal pole crack in the construct [4]. Each specimen was loaded to failure after cyclic loading. Failure was indicated by loss of fracture reduction or a proximal crack in the construct as a result of loading (Figure 2); this was defined by as a distinct decrease in the load-displacement curve. One-way analysis of variance (ANOVA) tests were performed to evaluate differences in stiffness and load to failure. Significance was set at p<0.05.

Results: No significant difference in long axis lengths between the randomized groups of scaphoids was found. Additionally, no significant difference in stiffness at the 1000th cycle between different screw lengths was found (Figure 3). All specimens with 18mm and 24mm screw fixations were able to withstand cyclic loading, however 1 specimen fixed with a 10mm screw failed during cyclic loading. As a result, a proximal fracture fixed with a 10mm screw was able to withstand 845 ± 346 cycles. Load to failure was significantly (p<.05) impacted by screw length utilized for fixation. A significant difference (p<.05) in load to failure between a 10mm screw and 24mm screw was found, however no significant difference (p=.606) occurred in load to failure between an 18mm and 24mm screw (Figure 3).

Discussion: This study examined the effect of screw length on bending stiffness during cyclic loading and load to failure. The results of this study show that a screw that maximizes the length (24mm) within a specimen withstands significantly greater load to failure than a screw that is centered
(10mm) with respect to the fracture site. The 10mm screw gains less purchase in the bone on either side of the fracture compared to the 24mm screw. However, there is no statistically significant difference in load to failure between an 18mm screw, that does not maximize its length within the specimen, and a 24mm screw; this could be occurring because the 18mm screw is more centered with respect to the screw compared to the 24mm screw. We disproved our hypothesis to a certain degree; longer screw lengths do length greater stability, however, there is no statistically significant difference between 18mm and 24mm screws. Our data contradicts a previous study that contends that maximizing the screw length significantly optimizes wrist biomechanics and fracture healing [3].

**Significance:** The results of this study will provide surgeons with useful information that will help them in determining an optimal screw length for the fixation of proximal scaphoid fractures using central threadless screws. Fixation utilizing an 18mm screw compared to a 24mm screw minimizes the risk for injury to the distal radius articulation during surgery.

**Acknowledgements:** Summer support from the Swanson School of Engineering is gratefully acknowledged.

**References:**
[3] Dodds SD et al J Hand Surg Am. 2006; 405-413

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**Figure 1:** Experimental setup with the distal scaphoid potted in the epoxy putty. Bending load was applied with a plunger attached to a materials testing machine. The scaphoid was oriented at a 45° angle.

**Figure 2A:** Displays failure by proximal crack.

**Figure 2B:** Displays failure by loss of fracture reduction.

**Figure 3:** Stiffness at the 1000th cycle during cyclic loading of an 800 Nmm bending moment and load to failure withstood based on screw length utilized for fixation. (mean ± SD, *p<.05)