SCIENTIFIC ARTICLE

Biomechanical Comparison of 2 Methods of Intramedullary K-Wire Fixation of Transverse Metacarpal Shaft Fractures

Stephen V. Hiatt, MD,* Mark T. Begonia, PhD,† Ganesh Thiagarajan, PhD,† Richard L. Hutchison, MD‡

Purpose To determine the relative importance of intramedullary wire (IMW) diameter and IMW number in conferring stability to a metacarpal fracture fixation construct. Our research hypothesis was that the stiffness of IMW fixation for metacarpal shaft fractures using a single 1.6-mm-diameter (0.062-in) wire would be greater than three 0.8-mm-diameter (0.031-in) wires.

Methods Our study compared the biomechanical stiffness between one 1.6-mm K-wire and three 0.8-mm K-wires in a composite, fourth-generation, biomechanical metacarpal construct under cantilever testing to treat transverse metacarpal shaft fractures. Six composite bone-wire constructs were tested in each group using constant-rate, nondestructive testing. Stiffness (load/displacement) was measured for each construct.

Results All constructs demonstrated a linear load-displacement relationship. Wires were all tested in their elastic zone. The mean stiffness of the 1-wire construct was 3.20 N/mm and the mean stiffness of the 3-wire construct was 0.76 N/mm. These differences were statistically significant with a large effect size.

Conclusions The stiffness of IMW fixation for metacarpal shaft fractures using a single 1.6-mm-diameter wire was significantly greater than using three 0.8-mm-diameter wires.

Clinical relevance When IMW fixation is clinically indicated for the treatment of metacarpal fractures, the increased stiffness of a single large-diameter construct provides more stability in the plane of finger flexion-extension. *(J Hand Surg Am. 2015;40(8):1586−1590. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Metacarpal, fracture, intramedullary wires, K-wires, internal fixation.

When operative stabilization of metacarpal fractures is indicated, there are several common operative techniques, each with its relative merits.[1−3] No single operative method has been shown to be superior in clinical studies.[2,4−6]

*From the Departments of *Orthopaedic Surgery and †Civil and Mechanical Engineering, University of Missouri—Kansas City; and the ‡Section of Hand Surgery, Division of Orthopaedic Surgery, Children's Mercy Hospitals and Clinics, Kansas City, MO.*

Received for publication January 28, 2015; accepted in revised form March 30, 2015.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

Corresponding author: Richard L. Hutchison, MD, Section of Hand Surgery, Division of Orthopaedic Surgery, Children's Mercy Hospitals and Clinics, 2401 Gillham Road, Kansas City, MO 64108; e-mail: rlhutchison@cmh.edu.

0363-5023/15/4008-0009$36.00/0
http://dx.doi.org/10.1016/j.jhsa.2015.03.035

The intramedullary wire (IMW) technique is useful for metacarpal neck and shaft fractures. Modifications in the technique include changing the number of intramedullary wires, the diameter of the wires, or the insertion method. Clinical results have been reported using K-wires or custom rods as single wires or in groups of 2 to 5 wires. Wire diameter varies from 0.8 mm (0.035 in) to 2.0 mm (0.078 in). The most common clinically studied configurations use multiple small-diameter wires or a single large wire.[4,7−18]

Few biomechanical studies have compared IMW and other methods of fixation; to our knowledge, only 2 studies have compared different sizes and numbers of intramedullary wires.[19,20] Clinical studies have compared IMW with percutaneous pinning.[15,21]

The purpose of this biomechanical study was to determine the relative importance of IMW diameter and IMW number in conferring stability to a metacarpal fracture fixation construct. Our research hypothesis was that stiffness using a single 1.6-mm-diameter wire would be greater than three 0.8-mm-diameter wires.

MATERIALS AND METHODS

We tested our hypothesis with 70-mm-long composite, fourth-generation, third-metacarpal, biomechanical polyurethane bones using a transverse metacarpal shaft fracture model (Sawbones, Pacific Research Laboratories, Vashon Island, WA). We simulated the transverse fracture with a band saw using a 1-mm blade at the midshaft of the metacarpal, 35 mm from each end, maintaining a 3-mm bone bridge on the volar aspect of the metacarpal. We used the temporary bone bridge to prevent shear displacement and translation during initial load application. The bones were randomly placed into 1 of 2 groups, each consisting of 6 metacarpals. The single IMW construct consisted of a single 1.6-mm (0.062-in) K-wire, and the multiple IMW construct consisted of three 0.8-mm (0.031-in) K-wires (Synthes, West Chester, PA). We placed all wires antegrade through the entire length of the medullary canal of the composite bones with the distal aspect of the wire at the level of but not penetrating the distal cortex. The wires were not bent before testing. A custom jig 13 mm in diameter provided proximal fixation. The cantilever jig was 3 mm wide and fixed 25 mm from the most proximal aspect of the construct, as seen in Figure 1. We performed testing with a Bose ElectroForce 3220 with a 225-N loading cell (Bose Corp, Eden Prairie, MN). The force was applied 5 mm from the distal aspect of each bone at a rate of 0.2 mm/s until the displacement limit was reached. All metacarpals sustained disruption of the volar bridge during the initial construct loading before evaluation. During the testing phase, all samples displaced at least 9 mm. All samples in the 1-wire construct received at least 20 N of force (fracture site moment, 60 N-cm) and the 3-wire constructs received at least 5 N (fracture site moment, 15 N-cm). We measured the stiffness (load/displacement) for each construct. The K-wires did not experience complete failure before reaching the displacement limits of the testing machine. Failure was defined as a sharp change in the load-displacement curve.

A 2-tailed P value of less than .05 was considered significant. We used an independent-sample t test. A priori power analysis showed that a sample size of 6 in each group would provide greater than 80% power to detect a 25% difference in mean stiffness.

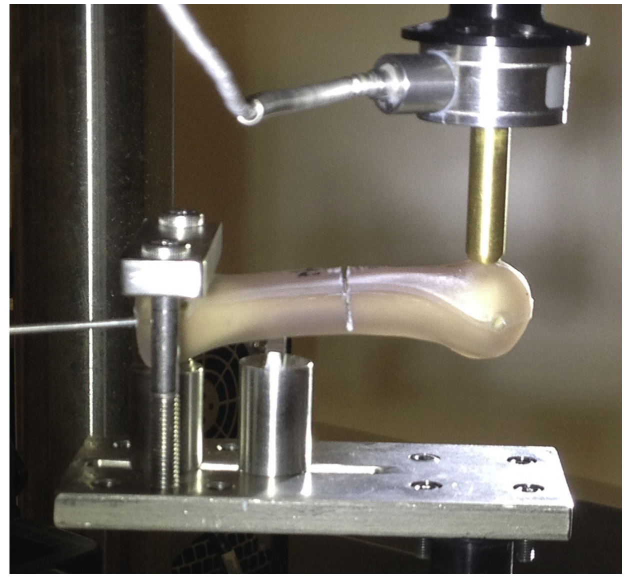

FIGURE 1: Cantilever jig setup.

RESULTS

All constructs demonstrated a linear load-displacement relationship. The wires were all tested in their elastic zone. The 1-wire construct demonstrated a higher stiffness than the 3-wire construct, as seen in Figure 2. Mean stiffness of the 1-wire construct was 3.20 N/mm (SD, 0.24 N/mm) and mean stiffness of the 3-wire construct was 0.76 N/mm (SD, 0.15 N/mm). These differences were statistically significant ($P < .001$; 95% confidence interval, 2.18−2.70). The effect size was large (Cohen's $\delta = 12.2$).

DISCUSSION

Although metacarpal neck fractures occur more frequently than shaft fractures, metacarpal shaft fractures are less stable, more prone to functional problems, and slower to heal.[22,23]

Each of the common operative techniques has relative merits, including transverse K-wire pinning, crossed K-wire pinning with or without tension band wiring, interosseous wires, interfragmentary lag screws, locking or conventional rigid plating, IMW fixation, and intramedullary screw fixation.[1−3] No single operative method had been shown to be superior in clinical studies.[2,4−6]

Intramedullary K-wire fixation for transverse shaft or neck metacarpal fractures has several advantages over rigid plating, including smaller incisions, absence