Intramedullary Threaded Nail Versus Plate and Screw Fixation of Comminuted Metacarpal Shaft Fractures: A Biomechanical Study

Andrew Allen[1], Alexander D Jeffs, Yukun Zhang, Zohair Zaidi, Nathaniel Clark Adams, Bradley John Lauck, Matthew Fisher, J. Megan M. Patterson, Reid W Draeger
[1]Orthopaedics

INTRODUCTION: Indications are expanding for the use of intramedullary threaded nail (IMTN) fixation in metacarpal fractures. While the noncompressive design of these implants theoretically prevents unwanted shortening in length-unstable fracture patterns, the stability of these implants in comminuted metacarpal fractures remains unknown. The purpose of this study was to compare the stability of IMTN to plate and screw fixation in comminuted metacarpal shaft fractures using a cadaveric model. We hypothesized that IMTN fixation would have superior bending stiffness compared to dorsal plate and screw fixation and provide sufficient stability to withstand cyclic loading comparable with early range of motion (ROM).

METHODS: Index, long, ring, and small finger metacarpals were harvested from matched pair cadaveric hands (n=18). In the midshaft of each metacarpal, a 1.75 mm transverse fracture gap was created to simulate a comminuted fracture. Specimens were divided into two groups for fixation with either a retrograde IMTN or dorsal plate and bicortical locking screws. Specimens underwent three-point bend testing with a materials testing system. Each specimen first underwent cyclic loading at 70 N for 2000 cycles to stimulate composite grasp, followed by cyclic loading at 120 N for 2000 cycles to simulate tip pinch. Specimens were then loaded to failure. Outcomes included cycles to failure, bending stiffness, peak load to failure, and location of failure. Failure was defined as catastrophic loss of fixation or fracture causing a sharp decline in the load-displacement curve.

RESULTS: Bending stiffness was significantly greater in the IMTN group compared to the plate group (141.19 ± 30.41 N/mm vs 37.27 ± 14.02 N/mm, $p < 0.05$). Peak load to failure was greater in the plate group, but this difference was not statistically significant (370.44 ± 70.16 N vs 545.17 ± 351.89 N, $p > 0.05$). During the cyclic loading phases, all specimens in the IMTN group completed the 70 N and 120 N loading phases without failure. In the plate group, 2 of 9 specimens progressed to catastrophic failure during the 120 N cyclic loading phase. When loaded to failure, specimens in the IMTN group failed by implant fracture (n=8) or fracture at the bone-implant interface (n=1). Plates all failed by the fracture gap bone ends touching followed by screw cutout (n=2) or propagation of a fracture from the osteotomy site to the screw-bone interface (n=7).

DISCUSSION AND CONCLUSION: IMTN fixation had significantly greater bending stiffness and more consistent load to failure characteristics compared to dorsal plate and screw fixation. IMTN fixation provided sufficient stability in comminuted metacarpal shaft fractures to withstand cyclic forces consistent with early ROM. Plate fixation demonstrated more variable results, with 22% of specimens failing during the 120 N cyclic loading phase.

Figure 1. Representative image of fracture fixed with a dorsal plate and locking screws that failed during LTF by propagation of a fracture from the osteotomy site to the screw-bone interface leading to screw pullout.

Figure 2. Representative image of a fracture fixed with an IMTN that failed during LTF by implant fracture.