THE EFFECT OF METACARPAL STEM CONFIGURATION ON LOAD TRANSFER TO THE LONG-FINGER METACARPAL: AN IN-VITRO BIOMECHANICAL STUDY

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Introduction:
Failures in total wrist arthroplasty (TWA) can be most often attributed to three main factors: improper prosthesis centering, component loosening and soft tissue imbalance (1). Of these, one of the most often reported complications is metacarpal loosening with dorsal protrusion of the stem (2). Abnormal load transfer through the prosthesis is believed to contribute to component loosening (3).

Although a variety of distal stem configurations exist, few studies report quantitative data to justify an optimal stem design (4-7). The distal component of many wrist arthroplasties consists of a single stem for insertion into the long-finger metacarpal. In cases where revision is required or poor bone stock is present, the option for a double-pronged stem is available for insertion into the long and index metacarpals (8).

The purpose of this study was to compare the force transmission to the long-finger metacarpal in response to anterior-posterior (AP) bending applied to a single versus a double-pronged metacarpal stem. The added effect of stem fixation through the capitate was also investigated.

Methods:
A custom designed metacarpal implant was instrumented with strain gauges for measuring load transfer to the long-finger metacarpal (Figure 1). The implant could be connected or disconnected via a clamp to simulate the double or single-pronged configurations respectively. The strain gauge wires were secured with a metal cap and exited the specimen distally.

We tested the metacarpal implant in 10 unpaired fresh frozen human cadaveric specimens (74.2 ± 17.4 years). These were prepared by disarticulating the phalanges at the metacarpophalangeal joint, amputating the first, fourth and fifth metacarpals and resecting the proximal carpal row. The skin and musculotendinous tissues were carefully dissected leaving the distal carpal interosseous ligaments, the carpal-metacarpal ligaments and both the proximal and distal intermetacarpal ligaments intact. The medullary canals of the long and index metacarpals for each specimen were prepared by an experienced orthopaedic surgeon by incrementally enlarging the canal diameter until a tight fit between implant and bone was achieved. The implant was inserted such that the strain gauges were positioned just distal of the carpal-metacarpal joint and oriented to measure the maximum strain value.

Each specimen was clamped at its distal end and AP bending moments of 0.065, 0.130 and 0.196 Nm were applied (Figure 2). Three stem configurations were investigated: a double-pronged stem fixed through the capitate into the long and index metacarpals, a single-pronged stem fixed through the capitate into the long-finger metacarpal alone and a single-pronged stem fixed into the long-finger metacarpal with the capitate removed. Data was analyzed using two-way repeated-measures ANOVA with α = 0.05.

Results:
The bending moment for the double-pronged stem increased linearly with applied bending moment (R^2 = 0.99). Similar relationships were found for all other stem configurations tested (R^2 > 0.98). Removing the capitate caused an approximate 20% load increase to the metacarpal (p < 0.001). The double-pronged stem, however, appeared to offer no advantage in AP bending over single stem fixation (p = 0.875), suggesting a second stem may not be required (Figure 3).

Discussion:
Our findings suggest that the capitate is an important structure in stem fixation, and as a result, we recommend preserving as much of this bone as possible in a TWA. Furthermore, we speculate that the support offered by the capitate, as well as the strong carpo-metacarpal ligaments, may have obscured any small load sharing effects between the double and single-pronged stems. Although it has been suggested that AP bending is the most concerning with respect to metacarpal stem fixation (9), further work is needed to address other loading modes such as torsion.

References:

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