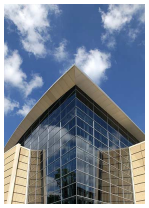
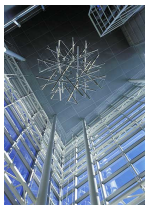


Metacarpophalangeal Joint Replacement



Team Members: Nate Cira, Amanda Feest, Hallie Kreitlow, Kenny Roggow
Client: Ramzi Shehadi, MD, Dean Healthcare
Advisor: Professor Naomi Chesler

Abstract

Existing metacarpophalangeal (MCP) joint replacements require collateral ligament support. The proposed design, an osteointegrated constrained joint replacement, makes it possible to reconstruct MCP joints of patients who do not have functional collateral ligaments. The artificial joint is designed to fail at a replaceable interface, preserving osteointegration and simplifying secondary surgery. Osteointegration is further enhanced by damping effects of the flexible pin. Lack of effective existing designs and an aging population contribute to market potential for this device.

Background

Anatomy and Terminology

Figure 1. Location of MCP joint, proximal phalange, and metacarpal.[1]

- MCP joints fall between the proximal phalange and the metacarpal
- Collateral ligaments connect the metacarpal to the proximal phalange
- The volar plate prevents hyperextension of the finger

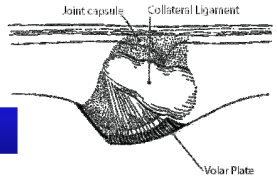


Figure 2. Collateral ligaments and volar plate.[2]

Problem Statement

Figure 3. Example of congenital hand defect (symbrachydactyly).

- Patients who have congenital defects or severe trauma lack collateral ligaments and a volar plate
- Patients with rheumatoid arthritis often lack functional collateral ligaments
- Desired joint replacement should not require collateral ligaments for joint stability

Figure 4. Example of rheumatoid arthritis.[3]

Design Criteria

Client Requirements	Design Specifications
Functional range of motion	20° extension to 90° flexion [4] 40° abduction and adduction at 0° flexion [4]
Lifespan of at least 10 years	Withstands ~310 million cycles at varying movement angles [5]
Withstand physiological loading	70 N pinch grip [6]
Appropriate mode of failure	Lowest factor of safety at the articulation
Biocompatible	Uses materials that are FDA-approved
Osteointegratable	Stems coated with surface treatment

Final Design

Materials implemented:
- Metacarpal component
  - Cobalt chromium (CoCr) plasma sprayed and coated in hydroxyapatite
- Phalangeal components
  - Alumina head
  - CoCr plasma sprayed and coated in hydroxyapatite
  - CoCr pin connection
- Polyoxymethylene (POM) pin

Features of design:
- Fails at replaceable interface
- Damping at flexible pin

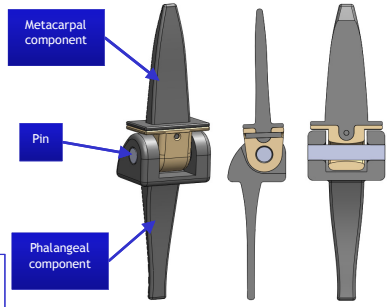


Figure 5. SolidWorks model of final design.

Finite Element Analysis

Component	Applied Load	Yield Strength	Factor of Safety
Metacarpal stem	616 N @ 0°	450 MPa	2.3
Metacarpal stem	616 N @ 90°	450 MPa	1.3
Phalange head	616 N	3,000 MPa	10.5
POM pin	50 N	66 MPa	2.4

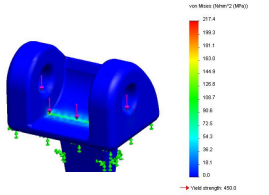


Figure 6. Metacarpal stem loaded at 0° flexion.

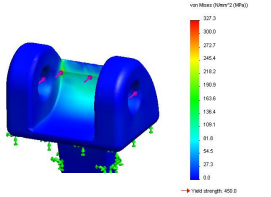


Figure 7. Metacarpal stem loaded at 90° flexion.

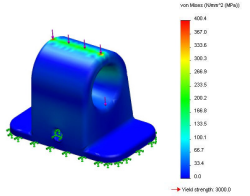


Figure 8. Loading and stress of phalange head.

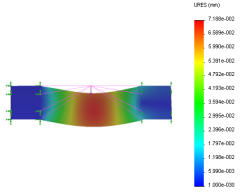


Figure 9. Displacement of POM pin.

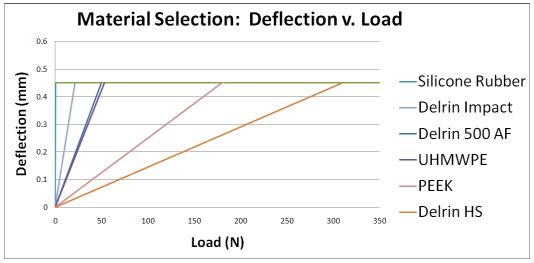


Figure 10. Graphical display of material optimization.

Implantation Considerations

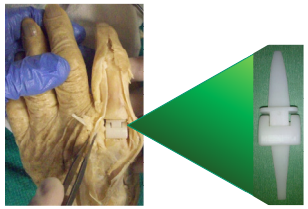


Figure 11. Design implanted into cadaveric hand.

- Alignment aid to prevent scissoring
- Alter bone cut to preserve collateral ligaments
- Custom press-fitting instrumentation

Future Development

- Disclose to WARF for patenting
- Propose to companies
- Premarket approval required for FDA acceptance

Competition/Market

- Market size
  - Estimated 8,700 candidate fingers yearly[7,8]
  - $ 26 Million in potential yearly sales
- Silicone implant
  - 75% of U.S. market[9]
  - Limited stability
  - Micromotion due to inability to osteointegrate
- Semi-constrained implant
  - Does not prevent dislocation under tensile loads

Figure 12. Silicone implant.[10]

Figure 13. Semi-constrained implant.

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- Bill Checovich, PhD-Intellectual property
- Professor Tim Osswald-Materials

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