Marco? POLIO! The Search for the Ideal Hip Implant

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Integrated Biomedical Engineering & Health Sciences

Patient Summary

Frieda Pinto

- Experienced flu-like symptoms at an early age
- Loss of muscle function, adversely affecting mobility
- Shorter left leg
- Relies on crutches in day-to-day movement
- Recently worsened pain in the left hip

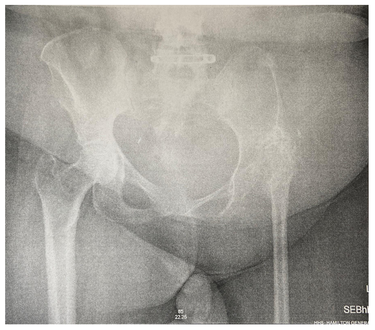

Figure # 1: Pelvic radiograph from a frontal view

Figure # 2 CT Scan of left femur and acetabulum

Medical Imaging Observations

- A narrower synovial cavity and presence of acetabular cysts indicating arthritis
- Significantly reduced thickness of left femur
- Thicker outer part of bone suggests healthy bone density, ruling out osteoporosis

Diagnosis: Poliomyelitis and Secondary Arthritis

Need Statement

Design a hip replacement for Freida Pinto to provide hip support and resolve the pain caused by friction against the deformed socket due to her polio. The replacement should alleviate the pain in her left hip and allow her to live a more independent lifestyle.

Our Design

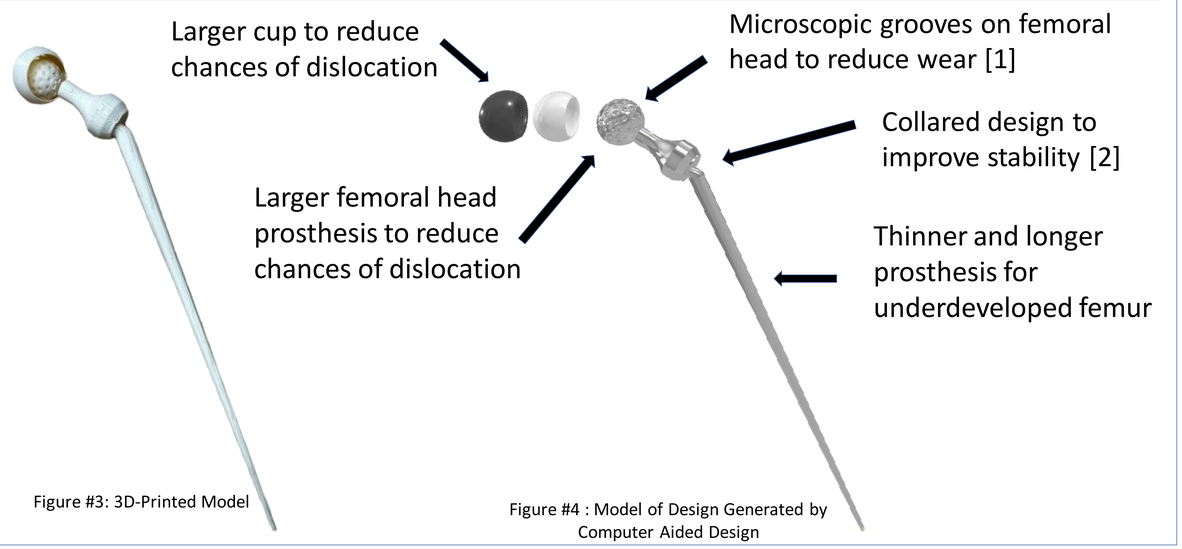

Figure #3: 3D-Printed Model

Figure #4 : Model of Design Generated by Computer Aided Design

Materials

Femoral Prosthesis

Femoral Stem: Functionally Graded Chrome-Cobalt (Cr-Co)

- Inner porous cellular structure and distributing volume fractions to improve flexibility [3]
- 48% lighter and 60% more flexible than traditional fully dense stems

Femoral Head: Oxinium (Oxidized Zirconium)

- Relatively lower hardness than CoCr and Ti alloys
- External surface more resistant against abrasive scratching [4]

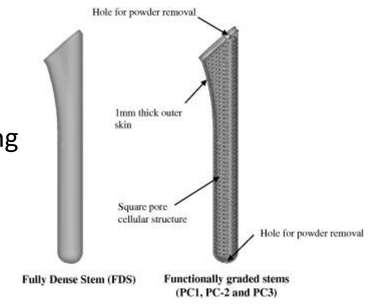

Figure #5. Fully Dense Stem vs Functionally graded Cr-Co stem with square pore cellular structure [3]

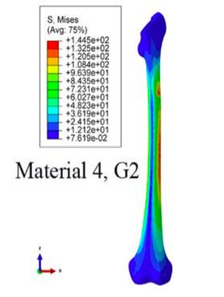

Figure #5. Measured von Mises stress distribution in femur and femoral prosthesis in functionally graded Cr-Co-HA material [3]

Acetabular Prosthesis

Acetabular Cup: Cemented polyethylene

Liner: Highly cross-linked polyethylene (XLPE) [5]

- Reduced fracture risk
- Oxidized zirconium on XLPE reduces wear debris, limiting osteolysis and increasing the longevity of the implant

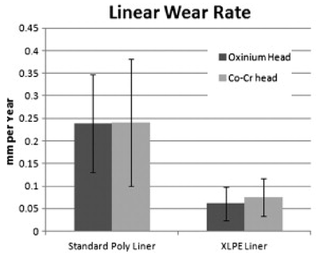

Figure #6: Linear wear rate of Oxinium vs Co-Cr femoral ball with standard polyliner and XLPE liner [6]

Coating

Polyetheretherketone (PEEK)/ Hydroxyapatite (HA)

- PEEK minimizes stress shielding by improved load transfer to bone [7]
  - Cancellous bone stress increased from 81% to 91% when PEEK coating was used

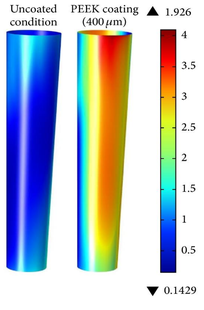

Figure #7: Measured von Mises stress at uncoated vs PEEK-coated cancellous bone [8]

Why Our Design?

- Minimizes stress shielding
  - Emphasized as she deals with polio
  - Implant material is not stiff, transferring stress
- Longer collared stem that goes farther into the femur
  - Makes up for the lack of diameter
  - Provides more stability for the implant
- BMP Cement and HA+ PEEK coating promotes the bone growth (5, 9)
  - There is significantly less existing bone for integration
- Priority between pain, and mobility
- Taking into consideration her age, and the reason behind surgery

Surgical Fixation

- Remove and store healthy bone tissue from femur
- Remove existing cysts and fill with healthy bone tissue
- Insert prosthesis and cement in place

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