An Investigation of Tibial Plate Fixation in Total Knee Replacement

M. Masker[1], K. Hoang[1], L. Anderson, BS[2], C. Tye, MD[3], C. Larsen, PhD[1], V. Moretti, MD[2], T. Tayag, PhD[1,2]

[1]TCU College of Science and Engineering, [2]Burnett School of Medicine at TCU, [3]JPS Health Network

BACKGROUND:

- **Total Knee Arthroplasty** (TKA) is a surgical **procedure treating knee osteoarthritis** by use of a **tibia prosthesis.**
- **Separation of the adhesive** (bone cement) **from** the **underlying sclerotic bone** is a **common failure mode** of TKA.
- **Pilot holes** are **drilled** into **hardened sclerotic bone, thought** to **improve tibia prosthesis fixation.**
- **Simulation studies** informing experimental trial design **need an effectual parameter to define failure** between drilling configurations.

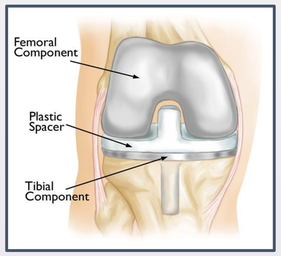

Figure 1. Diagram of Total Knee Arthroplasty

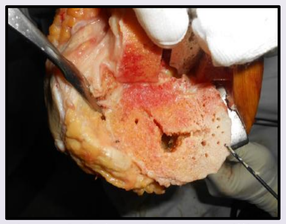

Figure 2. Sclerotic Knee Drilling (reference J. H. Ahn et al, International Orthopaedics …)

Research Question:

Is the percent of cement-to-bone contact area which fails under transverse load an effectual parameter to predict separation of the prosthesis from the tibia in finite element analysis (FEA) simulation?

FEA SIMULATION:

- **Static load** frature mechanic **analyses** were performed using **Finite Element Analysis** (FEA).
- **Factor of Safety (FOS) contours** proposed as **metric of failure.**
- $\mathbf{FOS} = \dfrac{\text{Max. Allowed Stress}}{\text{Applied Stress}}$
- **Percent of cement-to-bone contact area failed (PCBCAF)**: **percent area** of the **cement-to-sclerotic-bone interface** with **FOS less than one.**
- **Experimentally determinined load** at failure with **no holes** drilled to be **simulated**; **PCBCAF** found.
- **PCBCAF** of **no holes mode**l used to **predict** the **load at failure** with **2mm diameter holes.**

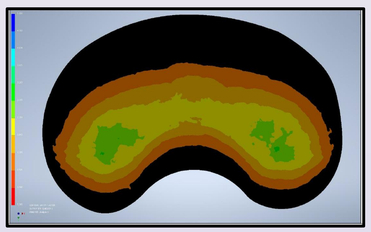

Figure 3. Example FOS Contour of Model Without Holes Drilled (Failed Region Shaded Black)

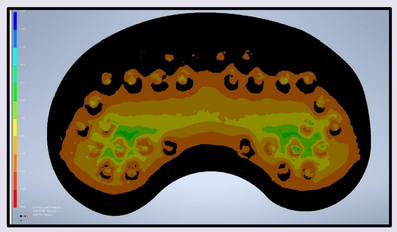

Figure 4. Example FOS Contour of Model With 2mm Diameter Holes Spaced 6mm Apart (Failed Region Shaded Black)

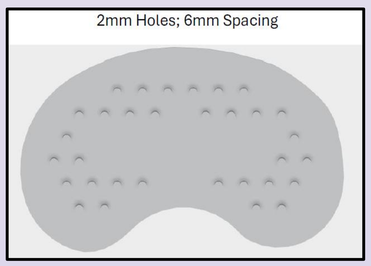

Figure 5. Drilling Configuration Model With 2mm Diameter Holes Spaced 6mm Apart

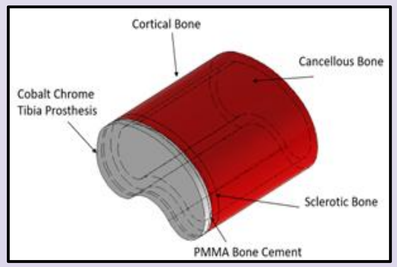

Figure 6. General Model Components (Fixed Components Shaded Red)

PRELIMINARY EXPERIMENTAL RESULTS:

- **Artificial bone models** (Sawbones) used to **replicate tibia bone material properties.**
- **Simplified bone geometry (Fig. 6) minimized trial variability.**
- **Uniformly distributed compressive load applied to tibial prosthesis** transverse to bone axis; bone held fixed.
- **Model without holes average failure load**: **1483 lbf** (n=2).

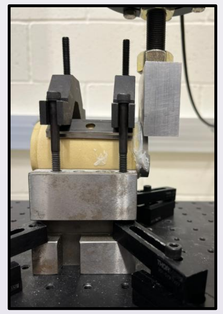

Figure 7. Setup for Experimental Trials

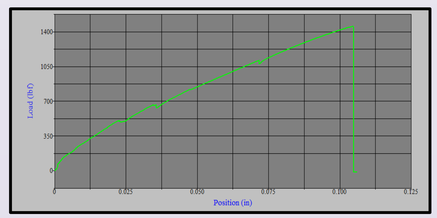

Figure 8. Example Load-Position Curve for Model Without Holes Under Static Loading

CONCLUSIONS/FURTHER WORK:

Experimental Failure Load of Model Without Holes (lbf)	Simulated PCBCAF
1454.9	4.81%
1511.6	5.00%

- **Further work** involves **identifying the loads** at which **drilled configurations match the PCBCAF** of the **model without holes** and **comparing them to experimentally determined failure loads.**

REFERENCES:

ACKNOWLEDGEMENTS:

We would like to thank SERC for all funding, Dr. Charles Withnell for providing scans of tibial plates, as well as Mr. David Yale and Mr. Mark Roegels for all tibia plate modifications, and Mrs. Tammy Pfrang for all material acquisition and remote computer access.