Engineering Orthopaedics Through Education and Research

Joint Replacement Surgeons of Indiana Research Foundation

2011 Laboratory Update
Program Overview

The Joint Replacement Surgeons of Indiana (JRSI) Research Foundation is a not-for-profit organization committed to fostering the advancement of orthopaedic patient care through clinical and engineering research and education. The Orthopaedic Biomedical Engineering Laboratory is a partnership between JRSI and Rose-Hulman Institute of Technology in which students gain laboratory experience while participating in timely research focused on improving implant design and surgical techniques.

This program update is an overview of the growth of our program and the achievements of our students since the beginning of the 2010-2011 academic year at Rose-Hulman. Since that time JRSI has facilitated in-depth research experiences to 9 undergraduate engineering students, provided paid summer internships for 5 engineering students in the laboratory and 5 additional students in our clinical research facility, and have sponsored senior design projects for both mechanical and biomedical engineering departments. JRSI led the drive to acquire over $330,000 in state-of-the-art research equipment for Rose-Hulman through National Science Foundation grants. Through this infusion of high-tech instrumentation, our students have made numerous contributions to the orthopaedic community while developing unique skillsets which set them apart from their peers as they enter their careers as young scientists and engineers.
Student Involvement

Summer Engineering Interns
Derek Archer
Ryan Gergely
Kelsey Hughes
Betsy Jones
Amanda Kingman

Academic Year Researchers
Derek Archer  Amanda Kingman
Allan Che      Jordan Oja
Nathan Elder   Hobey Tam
Kelsey Hughes  Andrew West
Betsy Jones

Senior Design Teams
Andrew Roth    Derek Archer
David Sandborn Karah Hickman
Breanne Thrasher Lancer Irwin
Chris Wilson
Lauren Wueremberger
A major goal of our laboratory programming is to recruit, train, and encourage students in the engineering and orthopaedics as a potential future career. To that end, we have worked to expand our outreach activities to local youth. Beginning this past year we have started participating in Rose-Hulman’s Explore Engineering Program to give local middle school students hands-on experience with orthopaedic research. This spring we partnered with Terre Haute South High School to provide senior Erin West with a month-long internship several hours each school day as she participated in research projects and evaluated her plans to enter engineering upon graduation. In the last year we have additionally hosted a group of middle school students on a field trip and sponsored a local science fair project, where 7th grader Emmett Baumgarten investigated how bone thickness correlates to overall bone strength.
“The JRSI Research Foundation has provided me with a unique and exciting opportunity to work in the Orthopaedic Biomechanics Laboratory for my sabbatical leave from Rose-Hulman. My sabbatical experience has been multi-faceted – from accessing computational tools used at the major orthopaedic implant companies to developing new hands-on research skills that I had only read about previously. The lab projects have been diverse, challenging, and full of opportunities to solve new problems and explore the biomechanics of hip and knee replacements using a variety of cutting-edge research techniques. After my experiences in the lab, I am more convinced than ever that the relationship between Rose-Hulman and JRSI is exceptional. JRSI provides high-quality research opportunities for undergraduate student researchers; and the students (with oversight and guidance) provide high-quality results to questions of interest to the JRSI surgeons.” — Renee Rogge, PhD; Associate Professor of Biomedical Engineering
In a collaborative effort between Rose-Hulman and JRSI Foundation, our laboratory was awarded a $335,311 grant from the National Science Foundation for the acquisition of state-of-the-art biomechanics research instrumentation. With the remodeling of our laboratory space to allow for diversified tissue and biomechanical testing, and the installation of this new testing equipment, our laboratory is now equipped to conduct a broad range of orthopaedic investigations while simultaneously creating student educational experiences far beyond the typical undergraduate classroom setting. New capabilities in the laboratory include:

**Intron E-1000 Materials Testing Machine**
This electrodynamic materials testing machine allows for dynamic fatigue testing for small orthopaedic implants, screws, or soft tissue at loads between 0.25 to 225 pounds of force at rates up to 100 cycles per second.

**Tekscan K-scan Contact Pressure Measurement System**
This is a piezoelectric transducer system specifically designed to allow for dynamic, real-time characterization of contact mechanics and wear mechanisms in the natural or
**Instron E-10000 ElectroPuls Axial-Torsional Materials Testing Machine**

One of just 30 systems installed in the United States, this biaxial materials testing machine represents the newest technology in testing equipment. Capable of simultaneously applying 1-ton compressive loads and torques up to 800 inch pounds, 100 times per second, this system enables a full range of physiological testing on both natural tissue and implants never previously possible at Rose-Hulman.

**Vishay System 7000 Data Acquisition System**

A system capable of collecting up to 80 simultaneous strain, displacement, voltage, or temperature measurements.

**Matscan Barefoot Analysis System**

A dynamic contact pressure measurement system allowing for the investigation of patient balance, force distribution in the foot, and gait analysis.
Conference Presentations

The primary aim of the JRSI Foundation is to generate high-quality, peer-reviewed literature in an effort to contribute to the global orthopaedic knowledgebase. Medical journal publications and national conference podium and poster presentations are a key avenue for disseminating findings from our research to surgeons and engineers in the orthopaedic community. In the past year, we presented our research at the following national medical and engineering conferences and journals:

Biomedical Engineering Society Fall Meeting

2010 - Austin, Texas

- High Initial Stability in Porous Titanium Acetabular Cup Designs
  
  Student Author: Leah Howard

- Factors Influencing Tibial Loading Following Total Knee Arthroplasty; Student Author: Susumu Tokunaga

- Acetabular Cup Design and Orientation Affect Periacetabular Loading Distribution; Student Authors: Didem Tunc and Leah Howard

- A Biomechanical Analysis of Implant-Induced Cup Deformation in Acetabular Cup Designs; Student Author: Betsy Jones

2011 - Hartford, Connecticut

- Biomechanical Assessment of Tibial Component Slope in Unicompartmental Knee Arthroplasty; Student Authors: Derek Archer, Amanda Kingman, and Kelsey Hughes
American Association of Hip and Knee Surgeons Annual Meeting  
2011 - Dallas, Texas  
• Cup Deformation in Metal-on-Metal and Conventional Metal-Backed Modular Component Designs; Student Author: Betsy Jones

Orthopaedic Research Society Annual Meeting  
2012 - San Francisco, California  
• The Influence of Bone Resection Depth on Tibial Loading (Accepted for Presentation); Student Author: Susumu Tokunaga

American Academy of Orthopaedic Surgeons Meeting  
2012 - San Francisco, California  
• A Biomechanical Model of Acetabular Cup Deformation in Metal-on-Metal Designs (Accepted for Presentation); Student Author: Betsy Jones
2011 Peer-Reviewed Manuscripts

Accepted/Published

- Metal Backing Significantly Reduces Tibial Strain in a Medial Unicompartmental Knee Arthroplasty Model. *Journal of Arthroplasty*

Submitted/Currently Under Review

- Acetabular Stiffness and Implant Orientation Change Acetabular Loading Patterns in THA. *Journal of Arthroplasty*; *Student Authors*: Leah Howard and Didem Tunc
- Tibial Density Assessment Using Radiographs after Total Knee Arthroplasty at 10-Years Follow-up. *Journal of Arthroplasty*; *Student Author*: Jim Merchun
- High Initial Stability in Porous Titanium Acetabular Cups: A Biomechanical Study. *Journal of Arthroplasty*; *Student Author*: Leah Howard
- Factors Influencing Tibial Loading Following Total Knee Arthroplasty: A Finite Element Study of Metal Backing and Tibial Resection Depth in a Composite Tibia. *Medical Engineering & Physics*; *Student Author*: Susumu Tokunaga
- Towards the Optimization of the Preparation Techniques of Polymethyl-methacrylate Bone Cement. *Medical Engineering & Physics*; *Student Authors*: Ryan Gergely and Betsy Jones
- Validation of Digital Image Correlation Techniques for Strain Measurement in Biomechanical Test Models. *Journal of Biomechanics*; *Student Author*: Derek Archer
- Deformation in THA Press-fit Cup Designs. *Clinical Orthopaedics and Related Research*; *Student Author*: Betsy Jones
Current and Ongoing Research

- Biomechanical Evaluation of Tibial Loading Following Mobile-Bearing Total Knee Arthroplasty

- Analysis and Interpretation of Contact Loading Utilizing a Digital Pressure Transducer

- Biomechanical Analysis of Cup Deformation in Modular Acetabular Components

- Finite Element Modeling of the Tibia Following Unicompartmental Knee Arthroplasty

- Biomechanical Assessment of Tibial Component Slope and Rotational Alignment in Metal Backed Mobile Bearing Partial Knee Arthroplasty
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