CHARACTERIZATION OF THE MECHANICAL ENVIRONMENT OF A HEALING BONE-IMPLANT INTERFACE

By

Jennifer Ann Currey

An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Biomedical Engineering

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

Examining Committee:

John B Brunski, PhD, Thesis Adviser
Deepak Vashishth, PhD, Member
Jan Stegemann, PhD, Member
Natasha DePaola, PhD, Member
Jill Helms, DDS, PhD, Member

Rensselaer Polytechnic Institute
Troy, New York

December 2006

ABSTRACT

There are three main types of failure modes of orthopaedic implants: accumulation of metallic and/or polymeric wear debris, overloading after a healing period, and excessive implant motion relative to the interface. This thesis work is part of a larger study that is testing the hypothesis that strain fields resulting from implant motion affect the type of tissue present around the implant using a mouse model. The aim of this thesis was to characterize the mechanical environment at bone-implant interfaces being tested in the *in vivo* study.

An implant system with a screw implant or a pin implant with ridges and a motion application system were designed to generate controlled and measurable implant micromotion during healing. This implant system was placed within a mock interface and the strain fields were quantified *in vitro*. An axisymmetric finite element model was developed and validated against the *in vitro* strains and was modified to model the *in vivo* interface in an effort to predict *in vivo* strain levels. The mechanical properties for the FEM of the *in vivo* interface were determined iteratively using the *in vivo* interfacial stiffness values measured for day 1 and day 7.

In vitro analysis of the strain found no difference in the magnitude of strain between a pin and screw implant, however, there was a difference in the distribution of strain. The average *in vivo* interfacial stiffness was found to be 0.01 N/μm and 0.03 N/μm for days 1 and 7, respectively. The mechanical properties of the FEM of the *in vivo* study were determined to be E=1 to 5 MPa and ν=0.3 for day 1 and E=10 to 15 MPa and ν=0.3 for day 7. The FEM predicted high principal strains in the area of the first cortex and at the base of the implant (>50% and <-30%), while lower strains (8%) were predicted within the marrow cavity. This model resulted in the characterization the mechanical environment of the bone-implant interface, thus improving our knowledge of the interfacial strain levels and allowing more detailed tests of relationships between strain and healing responses.