CHRONIC STRESS EXPOSURE FOLLOWING INTRA-ARTICULAR ANKLE FRACTURES

[1,2]Jane K. Goldsworthy, [1,2]Donald D. Anderson, [2]Kiran H. Shivanna, [2,1]Nicole M. Grosland,
[1,2]Douglas R. Pedersen, and [1,2]Thomas D. Brown
Departments of [1]Orthopaedics and Rehabilitation and [2]Biomedical Engineering, The University of Iowa,
email: don-anderson@uiowa.edu, web: poppy.obrl.uiowa.edu

INTRODUCTION

Post-traumatic osteoarthritis (OA) is a frequent outcome following intra-articular fracture. Residual incongruities have long been associated with aberrant articular contact stress distributions [1]. While these atypical stresses likely play a role in predisposing an articular joint to post-traumatic OA, little is known concerning the relationships between altered surface anatomy and associated contact stress. With the advent of patient-specific finite element (FE) modeling techniques comes the ability to address this issue objectively. Here we present work characterizing aberrant contact stress exposure following intra-articular ankle fractures in a clinical series.

METHODS

CT studies from a series of 6 patients with intra-articular ankle fractures were obtained following a standard orthopaedic protocol. Models were generated from both the fractured and intact contralateral ankles. Tibial and talar subchondral bone surfaces were segmented to yield geometric surface descriptions. An experienced ankle surgeon then used a medical data visualization program (Data Manager (beta2)) to bring these surfaces into apposition to match their weight-bearing radiographic appearance (Figure 1).

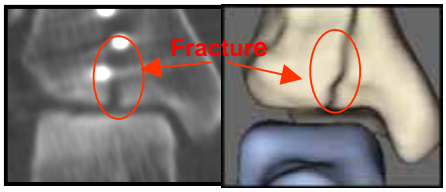

Figure 1: Post-operative CT image of fractured ankle (left) and resulting apposed surfaces (right).

Rigid bone surfaces were defined, and 1.5 mm layers of articular cartilage (E=12MPa, ν=0.42) were meshed onto them using a ray projection-based in-house computer code. Apposing cartilage surfaces were defined as deformable contact pairs with a frictionless interface. FE simulations (ABAQUS (v6.4)) entailed solving a sequence of 13 loading cases to simulate the entire stance phase of gait [2]. The tibia is rotated about a flex/extension axis, while the talus is free to rotate as required by the tibio-talar articulation. Articular cartilage contact stress exposures were characterized by multiplying computed nodal contact stress values by their resident time in the gait cycle, then summing the result over the 13 loading increments and scaling to steps per year.

RESULTS AND DISCUSSION

Computed contact stress distributions for the intact joint were continuous and relatively uniform, while distributions for fracture cases were discontinuous, and more heterogeneous (Figure 2). All 6 fracture cases showed similarly

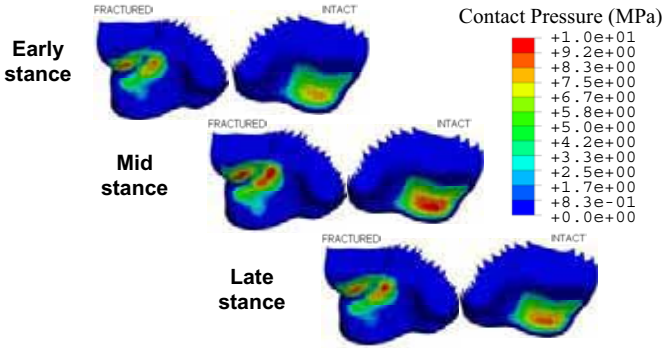

Figure 2: Anterior views of contact stress for a fractured versus intact ankle.

discontinuous and heterogeneous pressure distributions (Figure 3). From these patient-specific contact stress predictions, site-specific chronic stress exposures are

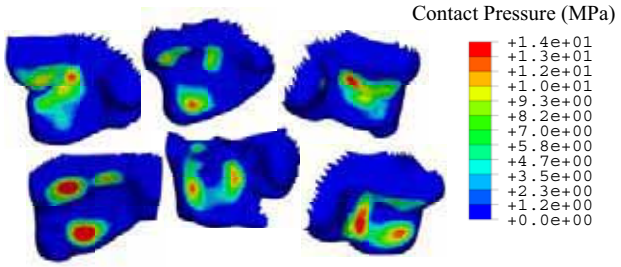

Figure 3: Anterior views of contact stress distributions for individual fractured tibias.

computed for each patient with appropriate time scaling. Comparing the chronic exposure to known chronic stress tolerance levels affords prediction of the likelihood of onset of post-traumatic OA in a given injury.

CONCLUSIONS

These patient-specific FE models of ankle loading during the stance phase of gait provide insight into the contact stress histories which articular cartilage experiences over many cycles each day. This opens new possibilities in studying the link between chronic stress exposure and the onset of post-traumatic OA in an actual clinical population.

REFERENCES

1. Fitzpatrick D, et al. (2004). *J Orthop Trauma,* 18(5):271-8.
2. Anderson D, et al. (2004). *ASB Annual Meeting,* Podium 7.
3. Stauffer R, et al. (1977). *Clin Orthop*, 127:189-96.

ACKNOWLEDGEMENTS

Supported by grants from the NIH (AR46601 and AR048939), with technical help from J.L. Marsh, and Y. Tochigi. F. Taddei and M. Viceconti (Istituti Ortopedici Rizzoli) provided assistance with Data Manager software.