

FINITE ELEMENT MODELING OF PERIACETABULAR LESIONS AND ACETABULOPLASTY

Zuoping Li¹, Neha B. Butala¹, Herrick J. Siegel², Jack E. Lemons³, Alan W. Eberhardt¹

¹Department of Biomedical Engineering, University of Alabama at Birmingham, Birmingham, AL

²Division of Orthopaedic Surgery, University of Alabama at Birmingham, Birmingham, AL

³School of Dentistry, University of Alabama at Birmingham, Birmingham, AL

Zuoping Li, Hoehn 361, 1075 13th St. S., Birmingham AL 35294, Tel:205-975-4963, Fax:205-996-6946, lizp67@uab.edu

INTRODUCTION

Percutaneous acetabuloplasty (PCA) has been reported to alleviate pain and restore function in a majority of patients with periacetabular bone metastases [1]. There are limited data available, however, describing the biomechanical consequences of metastatic lesions on pelvic biomechanics and the restorative effectiveness of PCA.

MATERIALS AND METHODS

Experimental tests were performed using an apparatus that simulated single-legged stance on a male cadaver pelvis [2]. The pelvis was cleaned of soft tissues except the pelvic ligaments. A 15.8 cm³ defect was created by an orthopedic surgeon (Siegel) using a dremmel tool. The defect site involved the posterior column and superior dome without violation of the subchondral plate. This defect was filled with bone cement (PMMA + ~25% BaSO₄) to create the "cement" condition. Cortical bone strains were measured at three locations under three conditions: intact, periacetabular defect and cement-filled.

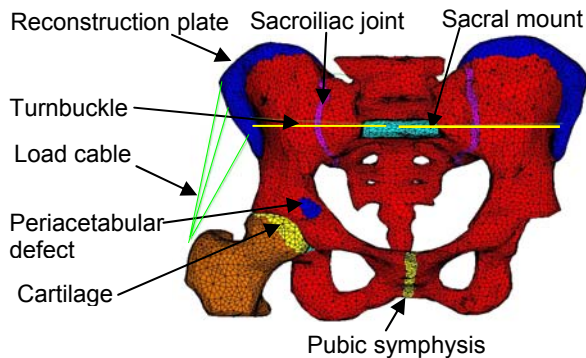


Fig. 1 FE model of experimental setting

Finite element (FE) models (Fig. 1) were developed from computed tomography data using Amira and Hypermesh software, and validated against the experimentally measured cortical bone strains. The segmented components were meshed into hexahedral elements by splitting one tetrahedron into four hexahedra using an indirect hex meshing method. Additional FE models were created with different defect sizes and locations, and varying levels of cortical bone involvement at two sites superior to the acetabular roof: i) posterior column and ii) superior rim. The femur was fully constrained at the mid-diaphysis. The abductor force of 756 N was applied through the load cables and a reaction force of 855 N was loaded vertically at the sacrum, consistent with the experiments. Surface contact was defined between the femoral head and acetabulum. The cemented FE models were run with variations in cement elastic modulus of 0.87 GPa and 2.2 GPa. Intact, defect and cemented FE models were analyzed using ANSYS 9.0 to investigate how variations in defect size and location, cortex penetration

and cement-filling altered pelvic cortical bone stresses and strains, and hip joint contact pressures.

RESULTS AND DISCUSSION

FE models were validated against experimental strain data with differences less than 13% at all gage locations. Compared to other pelvic regions, the FE simulations indicated that the superior rim of the acetabulum exhibited the highest stress levels under the present single-legged stance loading. Peak stresses were affected by defect size, cortex involvement and cement modulus (Fig. 2). The defect location and level of cortex involvement were found to be more critical than defect size alone. Cement filling was shown to restore cortical stresses towards intact values, dependent on cement modulus and defect features. Peak acetabular contact pressures increased for all simulated defect conditions and were reduced to levels below intact following cement filling, depending upon elastic modulus and cortex involvement (Figure not shown). The present lesion models are limited due to differences in geometry, bone density and microstructures as compared to real metastatic lesions. This study demonstrates potential for use of FE modeling in prediction of bone fracture risk associated with periacetabular lesions. Clinically, model applications may require consideration of specific features of the defects in cancer patients.

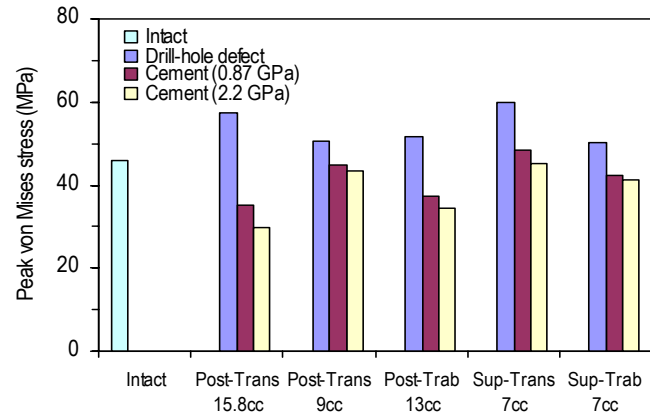


Fig. 2 Effects of defect size, cortex involvement and cement modulus on model predicted von Mises stresses at the superior rim of the acetabulum. Transcortical and trabecular defects at the posterior column and superior rim are abbreviated as Post-Trans, Post-Trab, Sup-Trans, and Sup-Trab, respectively.

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REFERENCES

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