

## MECHANICAL PROPERTIES OF CANCELLOUS BONE OF THE DISTAL HUMERUS

<sup>1</sup>Cheryl E. Dunham, <sup>2</sup>Sarah E. Takaki, <sup>1,2</sup>James A. Johnson, and <sup>1,2,3</sup>Cynthia E. Dunning

<sup>1</sup>Departments of Biomedical Engineering and <sup>2</sup>Mechanical and Materials Engineering

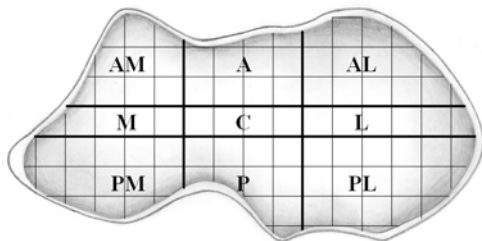
Biomechanical Testing Laboratory, University of Western Ontario, London, Ontario, Canada; email: <sup>3</sup>cdunning@eng.uwo.ca

### INTRODUCTION

Mechanical properties of cancellous bone in the distal humerus are of interest for a number of reasons. An understanding of variations in modulus and strength across several transverse sections may determine optimal fixation techniques and locations for prosthetic components. These results may also suggest optimized surgical procedures to allow better fixation in stronger bone [1,2,3]. An understanding of these mechanical properties is of value in developing finite element models, as well as providing comparative data to validate synthetic bones for implant testing. The objective of this study was to quantify the strength and modulus of distal humerus cancellous bone, and identify any regional variations.

### METHODS

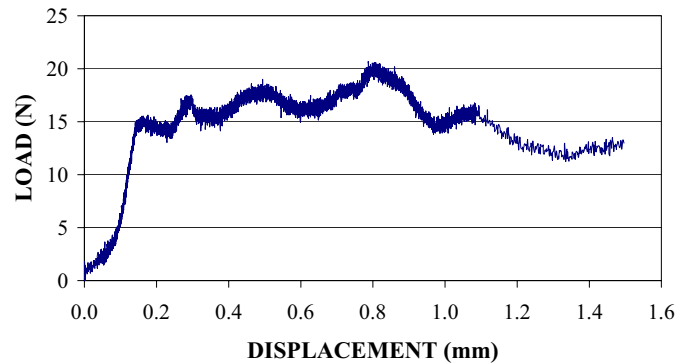
Three consecutive transverse slices (3 mm thick) were sectioned from the distal cancellous region of seven fresh-frozen cadaveric humeri (ages 70-92, mean age 79.4 years). Each slice was marked with a 3x3 mm<sup>2</sup> grid, and subjected to compressive testing using a flat cylindrical indenter (1.6 mm diameter). A servohydraulic testing machine (Inston Corp., Canton, Mass., USA) collected load-displacement data during testing. Indentation modulus and strength were calculated for each test site, and pooled into nine regions defined by anatomical directions (anterior, posterior, medial, lateral and central) for each slice (Figure 1). Results were analyzed using two-way repeated measures ANOVAs to determine differences in strength and modulus among regions and slice levels. All statistical tests were performed with  $\alpha = 0.05$ .



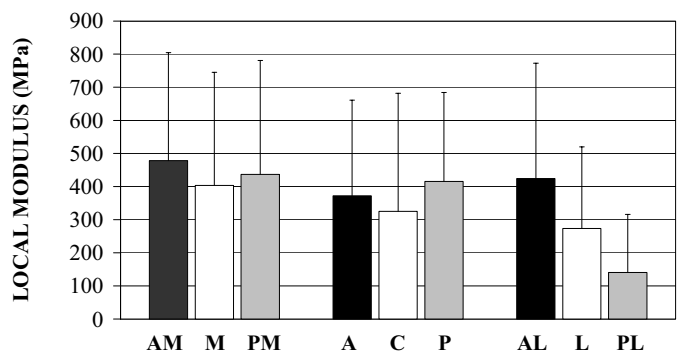
**Figure 1:** Transverse slice showing 3x3 mm<sup>2</sup> test sites and nine regional divisions [defined by anterior (A), posterior (P), medial (M), lateral (L) and central (C) sections].

### RESULTS AND DISCUSSION

Stress-strain curves for the indentation tests were reasonably consistent in shape, with all exhibiting a characteristic yield followed by a slight softening and then a large region of nearly constant load (Figure 2). Mean modulus was found to be 309.8±242.0 MPa (range: 2.9-1041.7 MPa). Yield strength averaged 4.4±2.5 MPa (range: 0.6-16.3 MPa). The highest modulus was found in the distal-most slice ( $p < 0.05$ ). The lowest modulus region was the posterior lateral ( $p < 0.05$ ) (Figure 3). There were no differences in strength among slices or across the nine regions.



**Figure 2:** Representative load-displacement curve for one indentation site.



**Figure 3:** Indentation modulus for the 9 regions of the distal humerus. (See Figure 1 for region definitions.)

### CONCLUSIONS

This study determined the indentation strength and modulus of cancellous bone of the distal humerus at three transverse levels and nine anatomically-defined regions within each cross-section. Mean strength was 4.4 MPa and mean modulus was 309.8 MPa, with large variations both within and among humeri. Cancellous bone modulus decreased with movement from distal to proximal. The posterior lateral region had a lower modulus than the other regions of the distal humerus. The influence of slice depth may be important with regard to the amount of bone removed during prosthetic replacement requiring cancellous fixation. Regional variations in modulus suggest that the posterior lateral region may be an inferior site for screw purchase during fracture fixation.

### REFERENCES

1. Anglin, C. et al. *J. Biomech* **32**, 1091-1097, 1999.
2. Gordon, K. D. et al. *J. Orthop. Trauma* **17**, 285-289, 2003.
3. Batte, S.W.P. et al. *Proceedings of ORS XLII*, Atlanta, Georgia, USA, 1996.