LOAD VS. DISPLACEMENT CONTROL TESTING PROTOCOLS FOR EVALUATING ARTIFICIAL DISC MECHANICS
+*Goel, VK;*Vishnubhotla, S; **Patel, T; ***Biyani, A; ****Grauer, JN; *Matyas, AJ; *Vadapalli, S; *****Panjabi, MM; 
+*Spine Research Center, University of Toledo
Vijay.Goel@utoledo.edu

INTRODUCTION:
The importance of in vitro test protocols and finite element models (FEM) to assist with the design, development, and evaluation of spinal instrumentation for use in fusion surgery is well recognized. Recent publications dealing with the testing of ligamentous spine specimens have used pure moments (“load control”) for flexibility testing with and without preload. Muscle forces can be simulated to improve the validity of such testing. The pure moment based tests allow for comparison of different devices and data from different labs. In recent years interest in motion preservation systems, like the artificial disc, have received increased attention. Being motion preserving systems, it is not clear whether to use pure moments or a “displacement” protocol for evaluation of such devices. This finite element study addresses the issue by highlighting differences in mechanics of spinal segment following disc replacement (Charite) and will initiate the much needed discussion on this topic.

METHODS:
A 3-dimensional, non-linear, ligamentous, experimentally validated, FEM of the intact L3-S1 segment was used (Figure 1). Charite artificial disc was placed at L5-S1 level by modifying the intact model. The Charite endplates were ‘tied’ to the adjacent vertebrae, and the middle slip core was allowed to ‘slide’ on these bearing surfaces. The models were constrained at the S1 vertebra. A flexion/extension moment of 10.6 N-m and a preload of 400 N were applied at the top of L3 vertebra (Pure Moment case). Then the same model was loaded in small increments with pure moments until the global motion of the L3 vertebral body matched the intact model in flexion/extension (“Displacement” case). The loads required to achieve these were noted. The relevant biomechanical parameters, like moments, forces across facets, motion, etc were computed and compared among three models (intact, “Moment” case, and “Disp” Case).

RESULTS:
With 400N preload and 10.6Nm of moment, the motions for the “Moment” and “Disp” disc models when compared to the intact model were as follows. For the “Moment” case at L5-S1 in flexion, Charite disc had a 27% increase in motion, and in extension a 93% increase. The adjacent level motion decreased by 1.5%, 3.3% at L3-4, and 7.3%, 8% at L4-5 in flexion and extension, respectively.

DISCUSSION:
The load control results indicate that the Charite disc restores the normal motion of the spine in flexion. In extension it moves more than the intact spine at the instrumented segment, due the dissection of the anterior longitudinal ligament. The effects across the adjacent levels were minimal. The facet load across facets in extension increased. On the other hand, in the displacement control case, the disc placement leads to a decrease in the motion at the adjacent levels while the increase in facet loads across the segment with disc is minimal.

In real life, we do not know whether the spine, while bending over for example, executes the task under “load” or “displacement” control. The present finite element study indicates that the mechanics of the segment is quite different for the two cases. If the motion is executed using a load control strategy then facets at the segment with artificial disc might show accelerated degeneration. On the other hand, a displacement control motion may show abnormal (decrease) motions at the adjacent segments. This could mean that the back muscles may do less work in facilitating the motion. Such subtle differences can be best addressed through clinical follow-ups and EMG studies. Additional investigations are needed for other disc designs to gain an in-depth understanding of the issues at hand.

ACKNOWLEDGEMENTS
Work supported in part by a grant from DePuy Spine, Inc.

AFFILIATED INSTITUTIONS FOR CO-AUTHORS:
**Commonwealth Orthopaedics, Fairfax, VA.
***Medical College of Ohio, Toledo, OH
****Department of Orthopaedics and Rehabilitation, Yale University School of Medicine, New Haven, CT