The Response of the Vertebral Endplate to Indentation Fatigue

Introduction:
The indentation test technique has been used to infer structural properties of material at or near the surface. Previous studies have elucidated to regional differences in vertebral endplate stiffness and failure loads. While these two mechanical parameters are of importance, the characterization of the regional variations associated with the vertebral endplate is more clinically relevant if conducted under fatigue loading. The investigators hypothesized that regional biomechanical differences are evident in the superior vertebral endplate and can be manifested by continuous fatigue loading.

Materials and Methods:
Eight bovine lumbar cadaveric vertebrae were tested. The intervertebral disc material from the superior surface of each vertebral body was completely removed from the specimens by fellowship trained spine fellows. A polar coordinate system was established on each specimen comprising of a Inner (I), Middle (M) and Peripheral (P) radii that were adjusted so they each comprised a 1/3 radius of the specimen. Each radius included seven test points, (0°, +30°, +60°, +90°, -30°, -60° and 90°) and the points were selected based on a polar co-ordinate system. In addition, a reference point (O), set at the most posterior edge of the specimen, was used to normalize the resulting deformation from each site within each vertebra. [Figure 1A]

Each vertebral body was placed in embedding plastic and oriented so as to permit an approximately perpendicular surface for contact with a 0.5mm radius indenter, which was mounted to the actuator of a materials testing machine (Bose ELF3200, Minnetonka, MN)[Figure 1B] Upon orienting the vertebral body indentation location with the indenter, the vertebra was secured in place and subjected to cycles of compressive loading from -10N to – 50N at a rate of 1Hz for 130 cycles. Load versus deformation data was taken at cycle 10 and acquired at five cycle intervals thereafter. Deformation changes over the applied load cycles were calculated for each cycle interval for the 22 indentation points on each of the eight vertebrae. Normalization of the deformation data was performed by expressing each testing point deformation (at each cycle) as a percentage of the deformation seen at the respective cycle for the reference point (site 0), labeled 0°, for each particular vertebra. The percentages for each test point were averaged and plotted versus cycle number, then subjected to a linear regression. Parameters resulting from the regression were analyzed using a 1 way ANOVA with a Tukey post-hoc analysis for grouped comparisons within each radius.

Results:
The plot of deformation versus cycle number for each angle is seen in Figure 2A-D. The periphery is usually considered the most stable section of the endplate. Yet one can see that the deformation of the middle radius along the anterior to posterior axis of the vertebra is comparable to that of the periphery. However, as the cycle count is increased, the increase in deformation associated with the middle radius raises relative to that of the periphery. It should be noted that in both the inner and middle radii, the 0 and 30 degree angle locations display a significantly (P<0.01) non-zero rate (slope) with respect to the number of cycles applied. This condition was also seen at the periphery, but only at angle locations of 60° and 90° (P<0.001).

Discussion:
It can be seen that endplate along the 0° angle location can increase deformation near the middle radius due to fatigue. Damage of bone (positive slope) was generally in the middle radius and at the 30° location, indicating that such a region is susceptible to failure. Clinically this would necessitate that preparation of the endplate be performed so as to not damage the surface. Furthermore, the most stable regions in fatique are located in the 60° and 90° locations, regardless of radius. In light of this finding, clinicians should attempt to position intervertebral devices so as to contact these regions