

# Regional Mapping of Vertebral Endplate Response Under Dynamic Loading

Mottole N,<sup>1</sup> Turner J,<sup>2</sup> Forton CR,<sup>2</sup> Valdevit A.<sup>1</sup>  
<sup>1</sup>SEA, Ltd., Columbus, OH; <sup>2</sup>Acuity Surgical, Irving, TX  
 Email of Presenting Author: avaldevit@sealimited.com

**Disclosures:** Mottole N (N), Turner J (3A), Forton CR (3A), Valdevit A (5)

**INTRODUCTION:** It has been reported that the removal of the endplate decreases the surface strength and thereby increases the likelihood of subsidence, with the effects most notable in the posterior region. However, based upon the indentation studies, the weak central region of the endplate does not exhibit a substantial mechanical role and it has been surmised that removal of this region may promote graft incorporation. Such a practice could be viable provided that the intervertebral device to be used displays a footprint that takes advantage of the mechanically stronger endplate located at the periphery of the vertebra. Devices that reside upon the periphery and demonstrate a large contact area with the endplate will generate a reduced stress distribution pattern. Studies that have investigated endplate mechanics have been predominantly static in nature, employing a compression to failure profile under displacement control. However, the use of a stress relaxation type of loading regimen as compared to a continuous and linearly applied axial loading may be more fitting and clinically applicable. Stress relaxation in bone has been described empirically. A secondary, short response, relaxation has been elucidated that is on the order of <2-3 seconds and has been linked to the material properties of bone. This suggests that a low frequency indentation fatigue evaluation may be appropriate.

**METHODS:** The mechanical evaluation of the endplate is depicted in Figure 1. The concentric boundaries of Inner, Middle, Outer and Periphery were subdivided into angular positions identified as 0°, 30°, 45°, 60° and 90°. Each location was subjected to 500 cycles of continuous compression from -2.5 N to -25 N. A specially designed fixture permitted the orientation of the vertebral test location to be placed in a near perpendicular alignment with the loading axis (i.e., parallel with the test face of the indenter). A posterior location on each vertebral body was identified as the origin and used to normalize the response to loading for a given vertebral body to pool the results. For each test site, a non-linear exponential regression was performed that provided clinically relevant parameters of Yo (Initial Deformation), Plateau (Asymptotic Deformation Limit), Span (Total Subsidence), and K (the deformation per unit cycle). The visual representation of the mathematical response is seen in Figure 2. Each of the resulting parameters were averaged over each concentric region, for each vertebral body, and over all five spines. The fitted parameters were subjected to a 1-Way ANOVA with a Tukey post-hoc test for determination of statistical differences between concentric regions.

**RESULTS:** The mechanical response of endplate loading with a given region is seen in Figure 3. In the case of Yo, Plateau, Span (or subsidence) and K, statistically significant differences were observed based on the region and are represented in Figure 4. Some clarification regarding the data from the Plateau or Asymptotic Limit seen in Figure 4 is needed. At first observation, it appears that the Periphery displays a deflection limit that is significantly increased relative to the Inner region. Recall that the cyclic loading curves in Figure 3 are decreasing. Therefore, the greater magnitude limits seen for the Periphery are the consequence of settling at an increased absolute displacement above the vertebral endplate. The result is best exemplified by the Span data where the bars represent the total change from the initial Yo deflection to the Plateau or Asymptotic Limit. This can be considered as a measure of the subsidence in a region. From the graphs in Figure 4, it appears that statistically significant differences in mechanical response can be observed in moving from the Inner region toward the Periphery.

**DISCUSSION:** The proper placement of intervertebral spacers between endplates is generally an acquired feel gained through experience. It would be intuitive to place the spacer in the posterior region of the endplate to minimize the risk of expulsion. However, this study suggests that this posterior inner radius region is the most vulnerable to compressive fatigue failure. Ensuring contact with the outer endplate rim will increase support for devices. The sinusoidal loading rate of 1Hz is in keeping with the short viscoelastic response of bone to loading which is on the order of 2s to 3s. Loading at this rate would not interfere with the natural viscoelastic response of bone material to loading and may be the rationale for generating distinguishable regression parameters between sites.

**SIGNIFICANCE/CLINICAL RELEVANCE:** The cyclic loading employed in this study may be a more clinically relevant method for the evaluation of regional endplate integrity. Based upon fatigue loading from this study, the mechanical integrity of the endplate may be less limited in area than previously observed under static conditions.

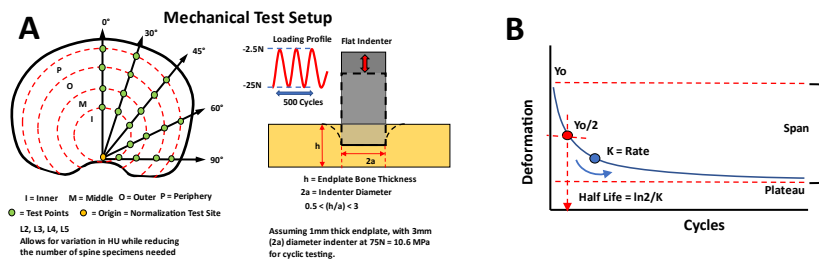


Figure 1. A) Mechanical testing. Each Region of Interest (ROI) was subdivided into angular sections. Cyclic compression was applied to each location using a flat indenter. B) Non-linear fitting and resulting parameters from the cyclic compression were computed for each location.

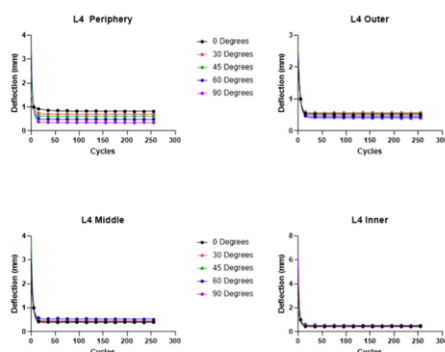


Figure 2. Representative curves for spine specimens at the L4 level across the ROI. Resulting parameters from nonlinear fitting were computed for each ROI at each location for each vertebral level.

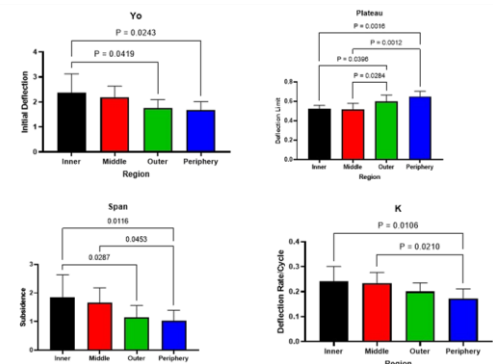


Figure 3. Fitted parameters over the ROI across all spinal segments and specimens. ANOVA resulted in statistically significant differences for the Yo, Plateau, Span and K parameters.