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Effect of implant design and material on subsidence following dynamic loading of intervertebral devices

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ABSTRACT

Introduction: Subsidence is not the consequence of a single loading event. More specifically, subsidence may be interpreted as the continuous sinking due to continuous loading. As such, a single static load may not be appropriate. Few studies involving cage subsidence have employed continuous cyclic loading. The goal of this study was to address the mechanical subsidence performance via prediction of the final subsidence depth and the rate of subsidence. It is hypothesized that those spacer designs, which engage the stronger vertebral body periphery, enable endplate stress distribution through increased contact area, and reduced stress concentrations would display more favorable performance characteristics with respect to subsidence.

Materials and Methods: Three intervertebral spacer designs were evaluated; threaded titanium, endplate-sparing titanium, and Polyetheretherketone (PEEK). Devices were randomly but equally assigned to porcine L4 and L5 vertebral bodies with endplates prepared as per recommended surgical procedure. Specimens were loaded from –50 N to –350 N at 1 Hz for 600 cycles with continuous load versus deformation acquired at cycle 10 and at 25 cycle intervals thereafter. For each cycle interval, the net deformation between the maximum and minimal applied load (or subsidence) was computed. The deformation for all six samples of each design were averaged across each cycle interval and subjected to a nonlinear exponential analysis. More specifically, the subsidence is represented by the independent variable Y. Initial subsidence is calculated at the 10th loading cycle and was represented by the variable Y_0. From the subsidence versus cycle data, the rate of subsidence (K) was determined as well as the plateau, or asymptotic limit, of the subsidence. All parameters were compared using a one way ANOVA with a Tukey posthoc test for determination of statistical difference ($\alpha < 0.05$) between designs.

Results and Discussion: All implants displayed an exponential relationship with respect to the number of applied cycles. Significant differences among all three designs were determined for initial subsidence Y_0 ($P < 0.001$) and subsidence limit (plateau) ($P < 0.001$). For both parameters, the endplate-sparing titanium device displayed the least subsidence when compared with the other designs. The subsidence rate K displayed a statistically reduced rate for the endplate-sparing titanium device when compared with the threaded or PEEK designs ($P < 0.001$). Clinically, such a condition results in a slow and gradual settling of the titanium implant upon the endplate surface. The PEEK implant displayed a more rapid and greater subsidence than either the endplate-sparing or threaded titanium designs.

Conclusions: Under continuous loading, an endplate-sparing titanium device displayed significantly reduced initial and final subsidence and subsidence rate when compared with threaded and PEEK designs. The clinical implication of these results is that implant material modulus is not the sole determinant for subsidence.

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