Mechanical transduction in a truss lumbar fusion cage: FEA results match mechanically responsive metrics of bone formation.

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Purpose of the study

An interbody fusion device has been developed that provides structural support while optimizing mechanical strain to accentuate bone signaling. Its open configuration was designed to sustain strength without impeding or restricting the potential for bone to grow into, and through the implant. Within a stable spinal cage bone construct, it is well known that mechanically-responsive anabolic modeling is initiated at 1000 to 1500 microstrain (μs), increases until 3000μs, and that above 3000 μs unrepaired microdamage begins to accumulate. Below this range mechanically-controlled disuse-mode remodeling acts. At 17000 μs solid fusion has shown to result, and forces of 25000μs result in bone fracture. Strains between 3000 and 25000ms (0.0030 or 0.0250 strain) are in the pre-fracture region. The purpose of this work was to evaluate the microstrain in the truss elements of the 4Web ASTS lumbar implant under physiologic loading using FEA, and compare this to the microstrain known to induce bone formation. In this work the truss surface is assumed to be smooth.

Materials &Methods

4Web incorporates topological dimension theory in lumbar truss cages to offer low mass structures for bone support and attachment. The implants are designed to offer equivalent or greater static and dynamic compressive and compressive shear strengths, and uninterrupted bone channel volumes when compared to existing spinal cages for the same indications. A series of non-linear static finite element analyses was conducted using Solidworks Professional (Cosmos) finite element software (Dassault Systèmes SolidWorks Corp, Concord, MA) to quantify the strain induced in the lumbar truss (cage) implant in varying combinations of physiologic loading. The Ti6Al4V device was positioned in place of the intervertebral disc within a simplified L3-4 spinal unit bone model. L4 was restrained and physiologic forces were applied to L3. Regions of compressive vs. tensile strain modulated with the load pattern.

Results

The range of 3D element microstrain of the titanium struts was high; however the surface of the implant where the bone cells attach did not exhibit these extremes. The calculated linear microstrain remained below the optimal zone of 1000 to 3000μs under anticipated early post-op loading (2000 N compression), and approached the optimal zone only under high demand loading (5000 N or combined loading including ~15 Nm of bending). The implant surface texture would be expected to have an influence on strain seen by the bone cell. Future work includes evaluation of the role of the implant's surface topology on the surface-bone cell interface microstrain. This analysis suggests that the truss elements in the implant exhibit strain under physiologic load that may stimulate bone remodeling and biologically stiffens the implant-host bone structure at the fusion site.

Conclusion

Regions of compressive vs. tensile strain modulated with the load pattern. The range of 3D element microstrain of the titanium struts was high; however the surface of the implant where the bone cells attach did not exhibit these extremes. The calculated linear microstrain was below the optimal zone of 1000 to 3000 microstrain under anticipated early post op loading (2000 N compression), and approached the optimal zone only under high demand loading (5000 N or combined loading including ~15 Nm of bending). The implant's surface texture is expected to have an influence on strain seen by the bone cell. Future work includes evaluations of the role surface-bone cell topology and microstrain, with particular emphasis on how the microsurface interfaces the macrodynamics of bone formation.