NOVEL DESIGN OF AN INTERVERTEBRAL DISC REPLACEMENT UTILIZING FINITE ELEMENT METHODS

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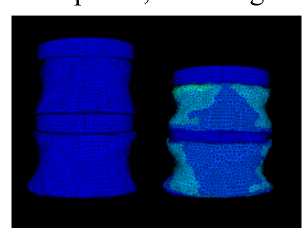
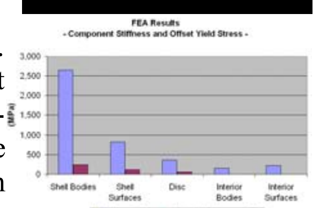
The occurrence of intervertebral disc degeneration disease (DDD) is an affliction of the body that affects a large proportion of the population. As the body begins to age, there is a growing incidence of spine related ailments, such as DDD, causing pain, discomfort, and a reduced quality of life for patients of all walks of life. Current treatments of DDD include non-invasive physical therapy, varying degrees of discectomy, spinal fusion, and most recently disc replacement. However, as a result of the infancy of the disc replacement procedure, a large proportion of the patients for whom non-invasive therapy is not successful undergo spine-fusion procedures. Despite the popularity of spine fusion, and more recently disc replacement, for the treatment of lumbar ailments, these treatments have shown clinical evidence of complications, such as mechanical failure, instability, implant resorbtion, and the generation of particulate debris. Based on the high incidence of surgical treatment for lumbar DDD, there is a justifiable demand for attention to be given to the development of alternative methods to treat lumbar disc-degeneration with fewer clinical complications.

To meet this demand for the development of alternatives to existing disc-replacement and fusion therapies, a novel design was developed to combine the technologies of both spine-fusion and disc-replacement treatments, in conjunction with computer-aided-tissue-engineering principals. This design was based on the idea of developing a replacement intervertebral disc (IVD) with the mechanical properties of vertebral bone, combined with a scaffold-like structure to support biological development, rather than current designs which utilize artificial metals and polymers. As a result, an implant would be developed with the ability to avoid the complications associated with current designs and treatments, yet take advantage of tissue engineering principals, biologically fusing the vertebral bodies over a period of time. By developing such an implant, the symptoms of DDD can be treated by replacing the degenerated IVD, simultaneously fusing the two vertebras together via cell attachment and biological in-growth into the surrounding vertebral endplates, resulting in maintained stability of the spine, without the complications of current treatments.





To test and validate the design of this replacement IVD, a two level vertebral finite element model was generated using Abaqus, based on human lumbar CT scans. The model contained six components, consisting of the loading platen, IVD, the vertebra interior components, representing the trabecular interiors, and the vertebra shell components, representing the cortical shells. Using a non-linear computation method and tissue material properties as described in the literature, stress and deformation analyses were generated and analyzed for the entire model. Based on these results, it can be seen that not only was a functional implant developed with the material characteristics of vertebral bone, but its simulated in-vitro mechanics indicate that the IVD successfully accommodated the loading of the spinal column, maintaining spine stability, and undergoing deformation, rather than implant resorbtion, as illustrated by the comparative stiffness and offset yield stress of both the vertebral bodies (interior and shell) and endplate surfaces. In summary, this finite element model suggests that an alternative IVD can be developed that is more suited for the accommodation of the loads and mechanical behaviors of the spine, with fewer clinical complications than current treatments. Such a device would be extremely valuable to the medical community, providing more options to clinicians, such that patients can receive the most appropriate and most effective treatment for their needs.