Finite element analysis

The finite element method (FEM) is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations. It is also referred to as finite element analysis (FEA). It subdivides a large problem into smaller, simpler parts that are called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses variational methods from the calculus of variations to approximate a solution by minimizing an associated error function.

Indications

Finite element analysis (FEA) is increasingly used to investigate the brain under various pathological changes. Although FEA has been used to study hydrocephalus for decades, previous studies have primarily focused on ventriculomegaly.

Nucleus pulposus replacement technologies are a minimally invasive alternative to spinal fusion and total disc replacement that have the potential to reduce pain and restore motion for patients with degenerative disc disease. Finite element modeling can be used to determine the biomechanics associated with nucleus replacement technologies.

A study focuses on a new nucleus replacement device designed as a conforming silicone implant with an internal void. A validated finite element model of the human lumbar L3-L4 motion segment was developed and used to investigate the influence of the nucleus replacement device on spine biomechanics. In addition, the effect of device design changes on biomechanics was determined. A 3D, L3-L4 finite element model was constructed from medical imaging data. Models were created with the normal intact nucleus, the nucleus replacement device, and a solid silicone implant. Probabilistic analysis was performed on the normal model to provide quantitative validation metrics. Sensitivity analysis was performed on the silicone Shore A durometer of the device. Models were loaded under axial compression followed by flexion/extension, lateral bending, or axial rotation. Compressive displacement, endplate stresses, reaction moment, and annulus fibrosus stresses were determined and compared between the different models. The novel nucleus replacement device resulted in similar compressive displacement, endplate stress, and annulus stress and slightly higher reaction moment compared with the normal nucleus. The solid implant resulted in decreased displacement, increased endplate stress, decreased annulus stress, and decreased reaction moment compared with the novel device. With increasing silicone durometer, compressive displacement decreased, endplate stress increased, reaction moment increased, and annulus stress decreased. Finite element analysis was used to show that the novel nucleus replacement device results in similar biomechanics compared with the normal intact nucleus [1)].

1)

Coogan JS, Francis WL, Eliason TD, Bredbenner TL, Stemper BD, Yoganandan N, Pintar FA, Nicolella DP. Finite Element Study of a Lumbar Intervertebral Disc Nucleus Replacement Device. Front Bioeng Biotechnol. 2016 Dec 1;4:93. PubMed PMID: 27990418.