A079: A Patient-Specific Image-Based Computational Model for Biomechanical Evaluation and Design of 3D Printed Polycarbonate Fusion Cages

Elena Provaggi[1], Claudio Capelli[2], Julian Leong[3], Rebecca Goodchild[4], Wayne Austin[4], Deepak Kalaskar[1]

[1]University College London, Department of Surgery and Interventional Science, London - United Kingdom
[2]University College London, Institute of Child Health & Great Ormond Street Hospital for Children, London - United Kingdom
[3]University College London, The Royal National Orthopaedic Hospital, London - United Kingdom
[4]Ceramisys Ltd., Sheffield - United Kingdom

Introduction: Spinal fusion surgery is accepted as the gold standard for the treatment of degenerative disc diseases when a conservative approach fails. The most commonly used devices for this procedure are interbody cages made of metals such as titanium, tantalum or polymers as polyether ether ketone. The mismatch in mechanical properties between the implant and surrounding bone has been largely suggested as a cause of implant subsidence and therefore suboptimal outcomes. While it is largely recognized that the geometry of the interbody cage is crucial in restoring the load patterns, the optimal implant design still remains debatable. Standard implants and instrumentations may be unsuitable for some surgical cases. Hence, patient-specific designs can potentially improve clinical outcome in spinal surgery by creating an optimal match for each anatomy. Recent advances in computational models combined with additive manufacturing technology can be now used to optimize existing device and develop novel implant designs with control over the architecture, which may facilitate cell adhesion and bone in-growth.[1,2] Moreover, 3D printable biomaterials such polycarbonate have recently shown feasibility to spinal cages that provide appropriate mechanical properties to withstand the physiological loading configuration and support the process of osteointegration[2-4]. This study aims to use a particular computational technique such as finite element analyses (FEA) to optimise existing device and design more effective solutions for spinal fusion implants. **Material and Methods:** Standard FEA were set up to simulate different loading conditions such as compression, flexion, extension and bending on a conventional cage design. Furthermore, a novel cage was designed to match the pre-operative vertebrae derived from computed tomography (CT) images of a patient. Two materials were modelled: titanium and polycarbonate. Titanium was used as control materials during the computational analysis, due to its wide applications in spinal implants. Polycarbonate was included as widely available within additive manufacturing techniques. The influence on the performance of four different filling densities (25%,50%,75%,100%) of 3D printed polycarbonate was studied through mechanical testing. Micro computed tomography (CT) was used to assess structural reproducibility and generate 3D models of the additive manufactured polycarbonate porous structures. For each of the cages, all four filling densities were simulated through a patient-specific two-level model of the spine within a physiological load distribution. **Results:** Computational results in terms of stress results showed different mechanical responses when using different materials for the spinal cage, manufacturing technique, cage architecture and filling density. In particular, stresses increased with reducing material density. In addition, stress peak values were lower than the respective risk of failure in all the simulated cases, confirming the feasibility of polycarbonate implants. The patient-specific design showed an even stress distribution consistently within anatomical constraints. **Conclusion:** The process suggested the feasibility of a lighter, affordable and patient-specific interbody cage for spinal fusion. Computational analyses may be utilized to balance the complex

requirements of load transfer and porosity to avoid stress-shielding effects and support implant osteointegration.

References

1. Capelli C, Serra T, Kalaskar D and Leong J. Computational models for characterisation and design of patient-specific spinal implant. *The Spine Journal*. 2016; 16: S53-S4.
2. Serra T, Capelli C, Kalaskar D and Leong J. Feasibility of manufacturing a patient-specific spinal implant. *The Spine Journal*. 2016; 16: S64-S5.
3. Figueroa-Cavazos JO, Flores-Villalba E, Diaz-Elizondo J, et al. Design Concepts of Polycarbonate-Based Intervertebral Lumbar Cages: Finite Element Analysis and Compression Testing. *Applied Bionics and Biomechanics*. 2016; 2016: 9.
4. Serra T, Capelli C, Toumpaniari R, et al. Design and fabrication of 3D-printed anatomically shaped lumbar cage for intervertebral disc (IVD) degeneration treatment. *Biofabrication*. 2016; 8: 035001.