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Research paper

Mechanical characterization and numerical simulation of polyether–ether–ketone (PEEK) cranial implants

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Cranial implants have experienced a significant evolution in the last decade in different aspects such as materials, method of fixation, and the structure. In addition, patient-specific cranial implants have recently been started to be developed. To achieve this objective, efficient mechanical characterization and numerical modeling of the implant are required to guarantee its functionality on each patient as well as to facilitate further developments. In this work, mechanical characterization and numerical models have been performed for patient-specific Polyaryletherketone (PEEK) scaffold cranial implants. Mechanical characterization has been performed at the scaffold and the whole implant levels under displacement control tests. Two different implant designs for the same patient but with different scaffold structure were experimentally characterized, and finite element models of the implants were developed within the framework of linear elasticity. Two types of finite element models were developed: a detailed finite element model with the actual scaffold geometry, and a solid shell-like model with effective material properties. These effective material properties were obtained by means of the Asymptotic Expansion Homogenization (AEH) theory which accounts for the periodicity of the underlying structure of the material. Experimental results showed a linear response of the material and the implant up to failure, therefore supporting the use of linear elastic models for simulation. Numerical models showed excellent agreement with experiments regarding load–displacement response. Models also showed a very consistent behavior with regard to the location and the value of the maximum principal stress in the implant when subjected to the maximum load of the experiments. The two numerical models were compared. The homogenized model gave results that were very close to those obtained with the detailed model, while reducing the number of degrees of freedom by 90%, and therefore the overall computational burden. The results showed that the models are able to reproduce experimental results conducted on actual implants, offering a valid alternative to be used in the design of customized cranial implants with a scaffold structure.

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