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Abstract

Background: Dense and stiff metallic femoral stems implanted into femurs for total hip arthroplasties produce a stress shielding effect since they modify the original load sharing path in the bony structure. Consequently, in the long term, the strain adaptive nature of bones leads to bone resorption, implant loosening, and the need for arthroplasty revision. The design of new cementless femoral stems integrating open porous structures can reduce the global stiffness of the stems, allowing them a better match with that of bones and provide their firm fixation via bone ingrowth, and, thus reduce the risk of implantation failure.

Methods: This paper aims to develop and validate a simplified numerical model of stress shielding, which calculates the levels of bone resorption or formation by comparing strain distributions on the surface of the intact and the implanted femurs subjected to a simulated biological loading. Two femoral stems produced by laser powder-bed fusion using Ti-6Al-4V alloy are employed: the first is fully dense, while the second features a diamond cubic lattice structure in its core. The validation consists of a comparison of the numerically calculated force-displacement diagrams, and displacement and strain fields with their experimental equivalents obtained using the digital image correlation technique.

Results and conclusions: The numerical models showed reasonable agreement between the force-displacement diagrams. Also, satisfactory results for the correlation analyses of the total displacement and equivalent strain fields were obtained. The stress shielding effect of the implant was assessed by comparing the equivalent strain fields of the implanted and intact femurs. The results obtained predicted less bone resorption in the femur implanted with the porous stem than with its dense counterpart.

Keywords: Diamond cubic lattice structure; Laser powder-bed fusion; Finite element analysis; Digital image correlation; Biomimetic femoral stem; Hip prosthesis