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HOMOGENIZED FINITE ELEMENT ANALYSIS OF THE BONE-IMPLANT INTERFACE: ROLE OF PRESS-FIT, DAMAGE AND FRICTION

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Summary: Introduction
Primary stability is important to prevent failure of implants in osteoporotic bone. Homogenized finite element (hFE) models account for non-linear material properties of bone, for frictional contact at the bone-implant interface and may be instrumental in exploring the determinants of primary stability. The objective of this study is to simulate a previous experiment of insertion and cyclic overloading of an implant in trabecular bone using hFE analysis.
Methods
The FE model consists of a cylinder made of continuous, homogenized, low-density (BV/TV=10.9 %) trabecular bone with a drilled hole in the centre. Trabecular bone was modelled as an orthotropic, linear elastic, perfectly plastic material exhibiting damage and densification. The insertion of a rigid cylindrical implant (ø 3.5 mm) was studied under three different press-fit conditions namely, soft (2 mm hole), dense (3.2 mm hole) and intact (3.5 mm hole). A cyclic displacement along a tilted direction of 30° with respect to the implant axis was then imposed. Frictional contact with small sliding was used at the interface.
Results
The damaged boundary of bone reduced from 1.68 mm to 1.12 mm when changing from soft to dense protocol. The change of friction coefficient from 0.05 to 0.3 increased the initial stiffness and ultimate force. The initial stiffness computed for soft, dense and intact were 390, 560 and 860 N/mm, respectively, while the median experimental values for soft and dense protocols were 500 and 550 N/mm, respectively. The computed ultimate loads were 32, 31 and 35 N, respectively, while the experimental values were 32 and 28 N.
Discussion
The high induced damage in soft protocol at implantation results in lower stiffness and less maximum force in the first cycle thus lowering the primary stability. The ultimate loads computed for the different protocols compare favourably with the experiment, but the simulated stiffness values seem more sensitive to the damage history of implantation. hFE proves to be a promising approach for the investigation of implant primary stability as reproduces successfully the key biomechanical features of the insertion and the cyclic overloading of the implant.
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