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Preoperative Simulation of the Hip-Stem Osseointegration based on the Physiological Loading Conditions

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Abstract

Individualized approach and quality assurance remains a challenge in endoprosthetics. Computer-aided simulation of the mechanical loading of bones and bony integration of the implant as well as the preoperative prognosis of the longevity of the implant has high clinical and socioeconomic impact. The finite element method provides a precise tool for the analysis of the stress distribution in the bone with and without stem under any given loading conditions. Thus, the determination of the loading conditions, which correspond to the real loading of the bone, is utmost important for the prediction of the osseointegration.

The presented investigation is devoted to the biomechanical investigations of the osseointegration of a titan stem for the hip-joint replacement using the physiological loading determined for the human femur based on the bending-minimization principle. Using the physiological stress levels for different bone types determined for the intact bone in two cases of human locomotion, the osseointegration area of the stem is calculated based on the comparison of the stress distribution in bone before and after virtual implantation as well as on the analysis of the relative micro-motion on the bone/implant interface.

The results of the FE simulation correlate well with the measurements of the osseointegration areas on several explanted stems available for the present investigation as well as with some clinical data. The present work provides a foundation for the simulation and preoperative prognosis of the long-term stability of the total joint replacement and, furthermore, allows an individualized approach to the analysis of endoprostheses.