DESIGN OF INITIAL FIXATION IN BONE OF CUSTOMIZED INNOVATIVE HIP RESURFACING ENDOPROSTHESIS BASED ON VALIDATED NUMERICAL MODEL OF THE BIOMIMETIC MULTI-SPIKED CONNECTING SCAFFOLD EMBEDDING IN BONE AND DATA FROM THE HUMAN OSTEOARTHRITIC FEMORAL HEADS µCT ASSESSMENT

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Introduction

The prototype multi-spiked connecting scaffold (MSC-Scaffold) is a new kind of biomimetic fixation for resurfacing endoprostheses [1-3]. This scaffold mimics the natural interface between articular cartilage and subchondral trabecular bone in human joints. The numerical model of the MSC-Scaffold embedding in bone developed in previous studies [4,5] enables simulation of load transfer from the MSC-Scaffold to periarticular bone. The assisted by computed microtomography (µCT) examination of mechanical embedding of the MSC-Scaffold prototypes in periarticular bone has provided insight into the mechanical behaviour of considered system, and allowed for validation of this model [5,6]. Further µCT assessment of subchondral trabecular bone before and after the MSC-Scaffold embedding in human osteoarthritic femoral heads has revealed densification of bone microarchitecture caused by the MSC-Scaffold embedding [7]. Based on the above findings it was attempted to design of initial fixation in bone of customized innovative hip resurfacing endoprosthesis applying the validated numerical model and data from the human osteoarthritic femoral heads µCT assessment.

Materials and Methods

For the design of initial fixation in bone of customized innovative hip resurfacing endoprosthesis there was applied the numerical model validated in µCT-assisted mechanical tests performed on fresh swine femoral heads [5,6]. The subchondral trabecular bone relative area (BA/TA) was measured on binarized images obtained during the uCT assessment (GE phoenix v|tome|x s240) of bone microarchitecture before and after the MSC-Scaffold embedding in human osteoarthritic femoral heads. Then, to determine the mechanical properties of this bone, Young's modulus of bone in the MSC-Scaffold embedding direction E_2 was calculated based on the known from BA/TA measurements apparent bone density ρ, according to the empirically established formula: $E = 1.310\rho^{1.40}$ [8].

Results and Discussion

In TABLE 1 there are presented the calculated values of Young modulus in embedding direction E_2 of subchondral trabecular bone at different levels of the MSC-Scaffold embedding.

TABLE 1. Young modulus in embedding direction E_2 of bone at different levels of MSC-Scaffold embedding.

Level of MSC-Scaffold embedding [mm]	1.0	2.0	3.0	4.0
Young modulus in embedding direction E_2 [MPa]	842	964	1096	1172

FIG. 1 shows the force-embedding level relationship from simulations applying the validated numerical model of the MSC-Scaffold embedding in bone and values of Young modulus in embedding direction E_2 of subchondral trabecular bone, calculated based on µCT assessment of human osteoarthritic femoral heads given in TABLE 1.

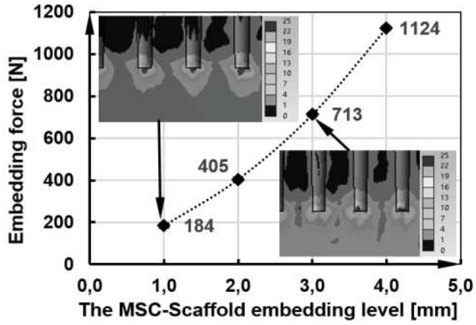

FIG. 1. The force-embedding level relationship from the simulation study of the MSC-Scaffold embedding in bone. Insets show maps of the Huber–von Mises–Hencky stress distribution in peri-impant bone for the considered MSC-Scaffold embedding level.

As seen in FIG. 1, the embedding force increases significantly with the MSC-Scaffold embedding level. This is due to the following two factors: the increase in the contact area between spikes of the MSC-Scaffold and the peri-implant bone, and the peri-implant bone material densification. The obtained results allow to assess efficient embedding level for the MSC-Scaffold initial fixation in human bone of patient with OA, allowing safe postoperative limb loading. Furthermore, based on pre-operative data from QCT assessment of bone of particular patient the geometric features of the MSC-Scaffold can be designed as customized for this patient.

Conclusions

The validated numerical model of the MSC-Scaffold embedding in bone is useful in the bioengineering design of the initial fixation of the customized innovative resurfacing endoprostheses with the biomimetic MSC-Scaffold.

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