Finite Element Analysis and Preliminary Process Parameter Optimization of Electro-Stimulating Implants for Bone Regeneration and Prevention of Implant-Associated Bacterial Infection Using DC

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Abstract

The aim of this study is to investigate the influence of electro-magnetic stimulation on bone regeneration and the effect on bacterial infection. Electro-magnetic stimulation is a promising technique and a powerful tool for the enhancement of bone regeneration. To optimize the amplitude of the electric field and also the magnetic flux density norm a finite element analysis (FEM) simulation was investigated.

For the simulation, the FEM software COMSOL Multiphysics® was used to compute the electric and magnetic field within the CAD model stimulation chamber (see Figure 1). For the first model, a novel electrode was integrated into an already applied stimulation chamber. The stimulation chamber was built by rapid prototyping technology (IPT, Wismar, Germany) and is composed of Foto Med® LED.A material (Innovation MediTech GmbH, Unna, Germany). The electrode was made from PEEK, VESTAKEEP® PEEK (Evonik Industries AG, Marl, Germany). This CAD model has been extended with two multiturn coils containing each 100 windings, on both sides.

In COMSOL, a Stationary Study and Coil Geometry Analysis Study with an Electric Currents interface and Magnetic Fields interface were created. A voltage of 1 V (DC) was set between the two coils. The mesh was arranged as a free tetrahedral mesh, consisted of approximately 1.63 million mesh cells, the solver achieved an accuracy of 8E-10.

As a result, an almost constant electrical field norm of about 65 V/m arose in the area of interest. In this case, a current of 125 mA (DC) flows through both coils. In the Coil Geometry Analysis Study the magnetic flux density norm generated as a consequence is determined. The magnetic flux density norm on the surface of the area of interest is in the range of 100 A/m and 300 A/m (see Figure 2).

In conclusion, we demonstrate that a simulation of an electro-magnetic stimulation in an already applied stimulation chamber with DC current could generate suitable values.

Future aims include an additional optimization of the magnetic flux density due to the variation of the current. In order to achieve this, a parameter sweep with different diameters of the area of interest will be performed. Thereby, the electrical field norm should remain constant at 65 V/m and the electrical potential between both coils should be flush varies. The next step will be the integration of the ascertained parameter in an applied stimulation chamber to provide the validation of the model concept.

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Figures used in the abstract

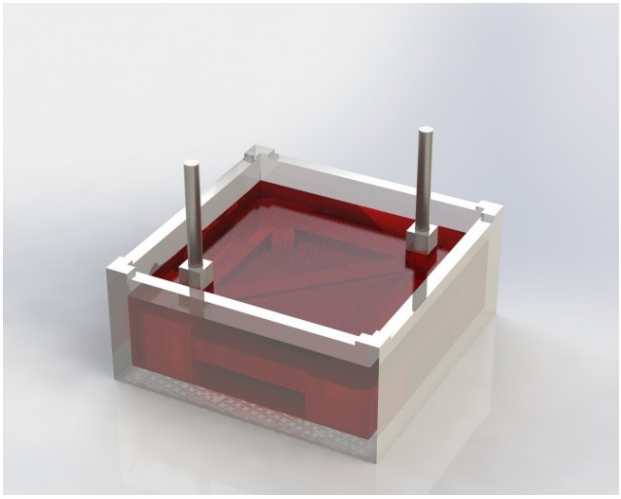

Figure 1: Electrical magnetic stimulation.

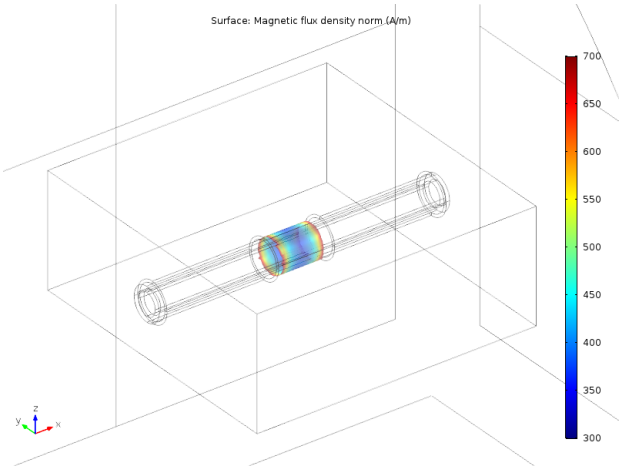

Figure 2: Area of interest magnetic flux density norm.