An Automatic Modeling Approach for Optimized Positioning of an Electrostimulative Implant in the Human Femoral Head

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Abstract

Introduction

Electromagnetic stimulation is a common therapy to support bone healing in cases of avascular necrosis or pseudarthrosis. An electrostimulative screw implant (Asnis III s-series screw in Figure 1) is used to stimulate bone regeneration in the treatment of femoral head avascular necrosis. To enable positive outcome of the treatment, optimal positioning of the electric implant is critical. The aim of the present study is to optimize the implant position by an automatic modelling approach regarding optimum distribution of the electric field.

Materials and Methods

Optimization was accomplished using a specific software tool (iSIGHT) combined with a finite element solver (COMSOL Multiphysics®). A numerical simulation model of the proximal femur (Fig. 2) was reconstructed from pre-operative patient MRI data according to the procedure described [1]. A typical patient who suffered from avascular necrosis (Steinberg stage III C [2]) was chosen for the optimization approach of the screw implant position. The objective was to find the screw position that delivers the maximum volume of tissue activated (VTA) in the femoral head of the patient's, which was calculated by COMSOL LiveLink™ for MATLAB®. The optimal electric field for bone tissue activation was considered between 5-70 V/m according to Kraus [3].

Results

When comparing the calculated optimized screw position to the initial position derived from real patient post-operative MRI data, we found differences of 0.7 mm, 2 mm and -6.1 mm in the X, Y and Z directions respectively. The largest effect on VTA in the human femoral head was found to be due to the axial position of the screw.

Conclusions

This new modelling approach is a potential tool to optimize the position of electrostimulative implants in order to enable positive outcome of the treatment. It is also applicable for optimization of the implant design and parameters for patient-specific electric stimulation.

Reference

[1] D Kluess , R Souffrant , et al., A convenient approach for finite-element-analyses of orthopaedic implants in bone contact: modeling and experimental validation, Comput Methods Programs Biomed, 295(1), 3-30 (2009).
[2] M E Steinberg , D R Steinberg, Classification systems for osteonecrosis: an overview. Orthop Clin North Am, 35(3), 273-283 (2004).
[3] W Kraus, Magnetfeldtherapie und magnetisch induzierte Elektrostimulation in der Orthopädie (Magnetic induced electrostimulation in orthopadis), Orthopäde,13, 78-92 (1984).

Figures used in the abstract

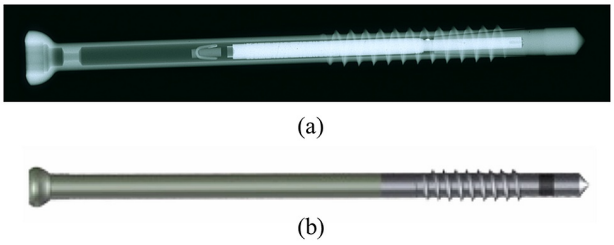

Figure 1: Figure 1. The ASNIS screw. (a) X-ray of implant, and (b) real implant.

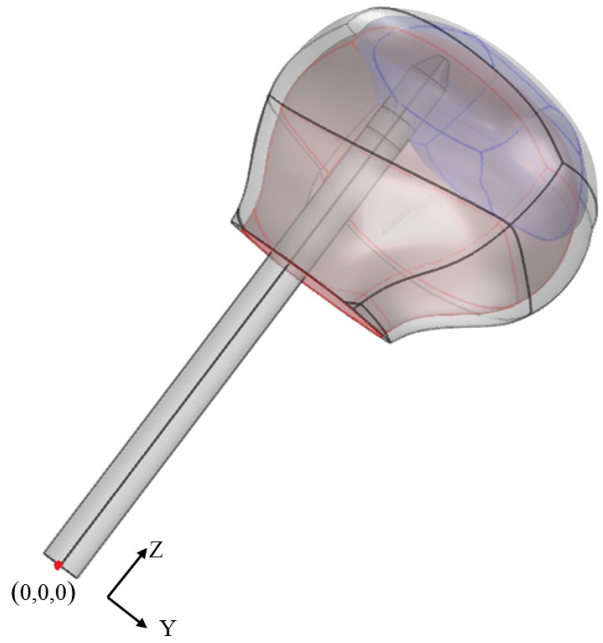

Figure 2: Figure 2. Patient femoral head model. Femoral head with lesion and screw implant, in which the (0, 0, 0) point is the bottom centre point of the implant.