COMPUTATIONAL MECHANICS 2018
34th conference with international participation
Srní
October 31 - November 2, 2018

Hydroxyapatite coating influence on performance of bone-implant contact in cranioplasty: Finite element study

J. Chamrad [a], D. Kalasová [b], P. Marcián [a], T. Zikmund [b] and J. Kaiser [b]

[a]*Department of Solid Mechanics, Mechatronics and Biomechanics, Brno University of Technology, Technická 2896/2, 616 69, Brno, Czech Republic*
[b]*CEITEC – Central European Institute of Technology, Brno University of Technology, Purkyňova 123, 612 00 Brno, Czech Republic*

Reliable connection of bone-implant-fixation system, see Fig. 1, is necessary for patients with cranial defects. In case of implant or mini-plate failure, the re-operation is worse than the first operation. It leads to focus on finding the best way of fixation either current procedures or using favourable properties of materials for example using of Hydroxyapatite (HA) coating.

Coating is used in case of improving unsatisfactory properties or performance of a technical material. HA coating increases osseointegration between bone tissue and implant material with coating due to its bioactivity and porosity [2]. It is sprayed by plasma on implant surface, which is in contact with bone. Implant has to be manufactured from material, which can be 3D printed and which can withstand high temperatures (e. g. Titanium alloy – Ti-6Al-4V).

The aim of this study is to analyse mechanical performance of cranial Titanium implant with and HA coating and to compare it with ordinary used implant materials (PMMA, PEEK and Titanium alloy without coating) using computational modelling.

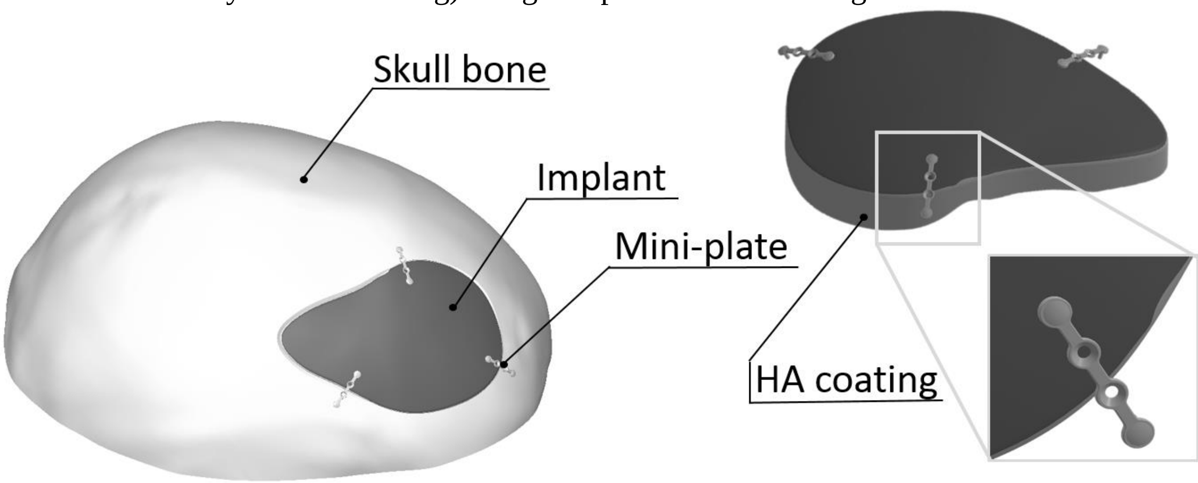

Fig. 1. Cranial bone with implant and fixation mini-plates including HA coating on bone-implant contact (BIC)

Cranial geometry was based on computed tomography (CT) dataset of undamaged skull. The defect was added artificially. Material properties of all components were modelled as homogeneous linear isotropic materials. The only load, applied to the skull and implant, was physiological intracranial pressure (ICP) of value 15 mmHg (2 kPa) [1]. The skull was fixed with fixed support sufficiently far from the implant location. Gradual process of osseointegration was modelled using two different types of contact, bonded and frictional. From the beginning, the BIC was modelled as frictional (friction coefficient was 0.05). Then, gradually 13 calculations were performed and small parts of coating in the locations of lowest implant displacements changed to contact type bonded (due to HA bioactivity). Number of elements and nodes were approximately 510 000 and 1 530 000 respectively.

Maximum values of total displacements of implant and mini-plates for all analysed implant materials were between 0.055 and 0.070 mm. However, implant with coating did progress due to its bioactivity. In case of 30 % osseointegration BIC, the displacements for implant decreased to 0.010 mm and for the most stressed mini-plate to 0.007 mm.

Similar situation occurred in case of von Mises stress. The maximum values of stresses decreased when the osseointegration ratio on BIC increases, as shown in Fig. 2.

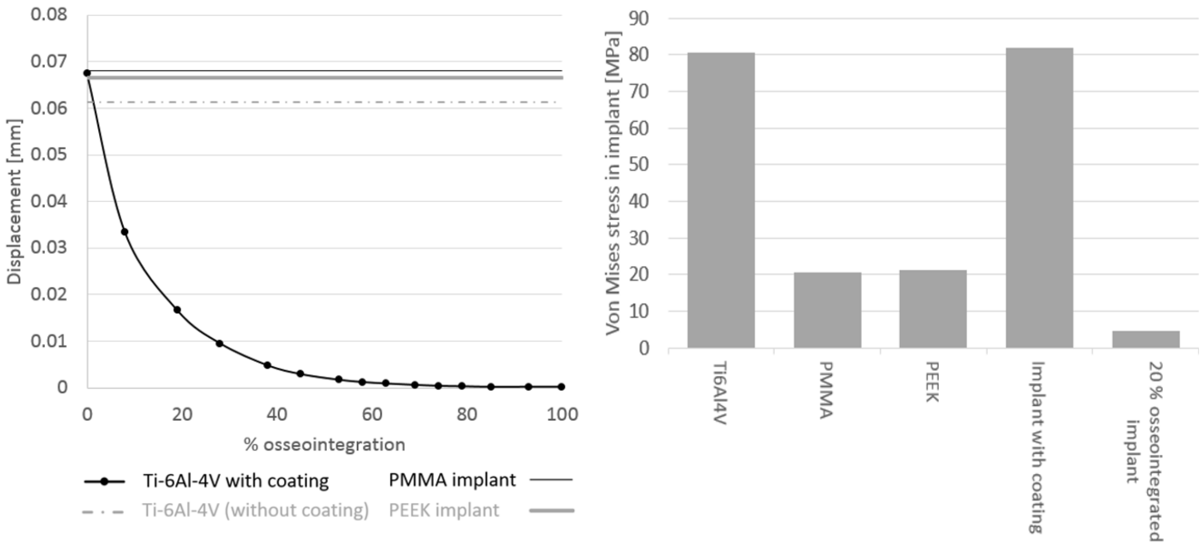

Fig. 2. Comparison of HA coating influence on maximum values of total displacement (left) and von Mises stress of implant to ordinary used biomaterials

In this study, influence of HA coating on cranial implants was investigated. Due to HA bioactivity and based on results from FE analyses, using coating appeared to be beneficial. However, the description of bioactivity has to be investigated more.

Acknowledgement

The work has been supported by the research project FSI/STI-J-18-5337.

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