Synchrotron X-ray Tomography Study of Bone-implant Integration

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In the field of orthopedic surgery, implant loosening is a commonly arising problem which often leads to revision surgeries. These surgeries cause a physical, psychological, and financial burden for the patients and their caretakers. To have the orthopedic implants function long-term under various conditions inside the human body, proper integration of the implant into the host bone is required. This integration relies on the quality and quantity of the newly formed trabecular bone around the implant. In this project, it has been assessed whether drug treatments consisting of bioactive molecules improved the quality and quantity of the peri-implant bone.

For this study, 21 polyether ether ketone implants were implanted in the proximal tibiae of rats. Some implants were treated by filling the hollow core of the implants with bioactive molecules, known to promote bone formation. Implants were left to integrate for 6 weeks. After which, the tibiae containing the implants were harvested and subjected to mechanical testing, i.e., incremental pull-out testing. The implants were pulled out of the host bone in a stepwise manner and imaged after every loading step. The images of the bone-implant interface were acquired using synchrotron source computed tomography and resulted in images with a μm resolution. Computed tomography is an X-ray imaging technique used to obtain three-dimensional medical images of parts of the body.

Based on the mechanical tests performed on the bone-implant interfaces, the mechanical properties of the newly generated bone could be evaluated. The images acquired during the testing were used for two different analyses. A first analysis assessed the quantity of bone formed within a defined volume around the implant. A second analysis evaluated the internal strain distribution within the newly formed bone. To that end, digital volume correlation was used. This is a non-destructive experimental technique, which refers to tracking translations of small sub-volumes between two subsequent 3D images.

Failure of the bone-implant interface occurred in similar ways for both treatment groups, and the location of high strains leading to bone damage could be detected using digital volume correlation. The results of the various analyzes showed that there was a trend towards improved mechanical properties, as well as bone quantity for the peri-implant bone of the treated implants. This hinted towards improved implant integration due to the treatment.

Translating these observations to human orthopedic applications will help improve peri-implant bone quality and increase its quantity. This could lead to a reduced number of reoperations, thereby increasing the quality of life of patients and decreasing the financial burden of undergoing orthopedic surgery.

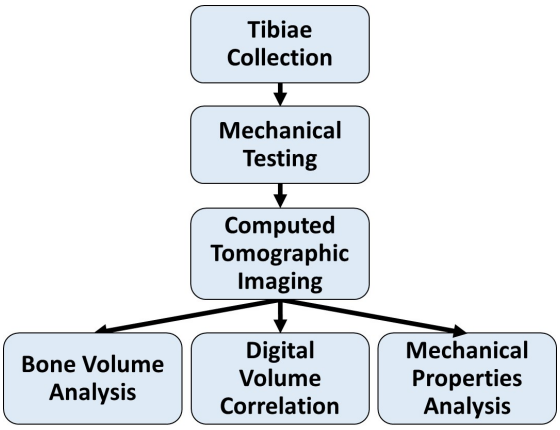

Figure 1. The general flow of the conducted experiments and analyses within this degree project.