Utilisation of Finite Element Analysis to Predict Elevated Bone Metabolic Activity in Patients with Painful Total Knee Arthroplasty

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OBJECTIVES

- The aim of this work was to develop patient-specific FEA models of knee joints from Single Photon Emission Computer Tomography (SPECT)/Computer Tomography (CT) scans.
- The models will be used to identify relevant stresses and strains at the bone-implant interface and analyse the effects of deviations from normally accepted TKA alignment parameters on knee pain.

BACKGROUND

- Osteoarthritis of the knee joint is one of the most common causes of disability in the developed world and costs more than USD 128 billion [1] annualy in lost productivity alone.
- Unexplained knee pain after TKA is a significant clinical issue with up to 20% of patients suffering from ongoing pain [2], often without a readily apparent cause.
- Understanding how patient-specific joint geometry and implant placement may contribute to abnormal loadings and thus pain, may give an insight to better understanding why a TKA may result in an unsatisfactory outcome.

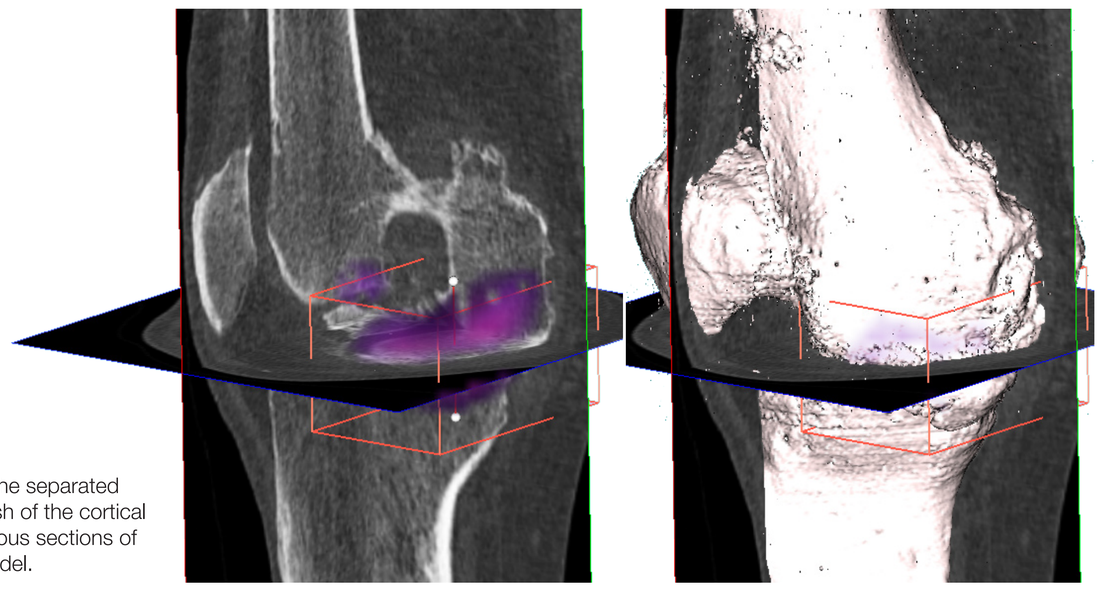

Figure 1. The separated volume mesh of the cortical and cancellous sections of the FEA model.

METHODS

- SPECT/CT scans collected from 100 patients
- Bone metabolic activity (Figure 1) classified using a validated localisation scheme [3].
- CT images rendered into 3-dimensional surface models using Mimics (3D visualisation software).
- Based on the individual postoperative SPECT/CT data set, the operation was mimicked *in-silico* using Rhinoceros (3D modelling software).
- Material properties assigned to bone (Figure 2) based on CT greyscale values [4].
- Relevant physiological forces applied, simulating peak forces during gait.

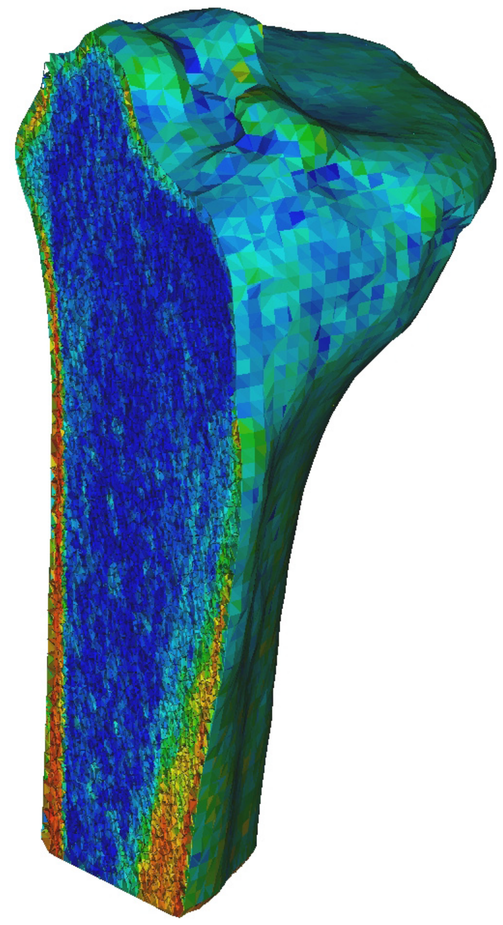

Figure 2. Typical FEA mesh of the tibia created from CT scans obtained from a patient who received a TKA. Every element is assigned heterogeneous material properties derived from the greyscale values of the CT data.

DEVELOPED MODEL

- We have created patient-specific FEA models based on CT scans after TKA surgery. Models contained approximately 100,000 elements for the tibial bone section and 30,000 elements for the implant. Meshes were composed of four-node tetrahedral elements approximately 1.5 mm in edge length. A typical mesh is shown in Figure 2. Stresses at the cortical and trabecular bone-implant interface were simulated given normal gait cycle loadings. The inclusion of a strain adaptive algorithm [5] allowed for time-dependent changes in tibial geometry and mechanical loading, which were dependent upon patient-specific bone geometry and loading cases generated by surgical implant placement. Models predicted areas of potential increased stresses and were subsequently correlated with SPECT outcomes.

CONCLUSIONS

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FUNDING:

RTK gratefully acknowledges funding from the Pro Motio Foundation, Basel (Switzerland).

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