Furthering Orthopaedic Research through Enhanced Remeshing

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A growing number of patients has undergone both a total hip and a total knee replacement in the same leg. Researchers at the Biomechanics section of the University of Leuven wanted to understand whether the distance between the hip and knee implants — the 'interprosthetic gap' — would influence the femoral strength. This required a robust workflow for creating accurate finite element models. Using the Materialise Mimics Innovation Suite allowed the researchers to generate accurate surface and volume meshes based on medical image data.

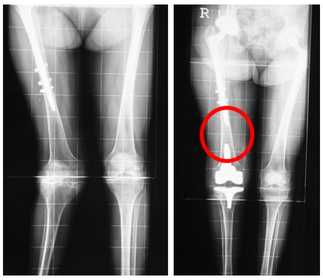

Fig. 1 - Interprosthetic gap shown on an X-ray

Understanding the Interprosthetic Gap

The interprosthetic gap is the distance between a hip and knee implant in the same bone. In conventional implant designs, this distance is very large, but some revision implant designs feature stems that are much longer. This can lead to smaller interprosthetic gaps (Figure 1), which may increase the risk of fractures. The aim of this study was to better understand the role of these gaps on bone strain and to quantify whether they act as stress risers.

Fig. 2 - Initial (grey) and adapted (green) hip prosthesis models

Creating Realistic 3D Bone and Implant Models

To obtain a 3D model of the femur, the researchers imported CT images of a sawbones femur model into Materialise Mimics. The software's thresholding algorithm, based on Hounsfield units, swiftly created multiple regions (masks) corresponding to the cortical and trabecular aspects of the femur. The masks were then converted into 3D models. Next, laser scans of the hip and knee prostheses yielded STL files which were imported into Materialise 3-matic. Materialise 3-matic's design features allowed for the adaptation of the prostheses' stem length (Figure 2), thereby simulating different prosthesis sizes without the need for scanning all sizing options.

To create realistic femur-prostheses models, it was crucial to place all variations of the prostheses in the correct locations. Positioning the femoral head-neck resection and the prostheses themselves was straightforward with the display of the three anatomical planes and the 3D positioning tools in Materialise Mimics. This work yielded anatomically relevant simulations of about 30 combinations of hip and knee prosthesis placement surgeries and their resulting interprosthetic gaps in an efficient way (Figure 3).

> "The Materialise Mimics Innovation Suite is ideal for creating accurate and homogeneously meshed FE models from CT data."
>
> Professor Jos Vander Sloten, Biomechanics Section, Department of Mechanical Engineering, Faculty of Engineering, University of Leuven, Belgium

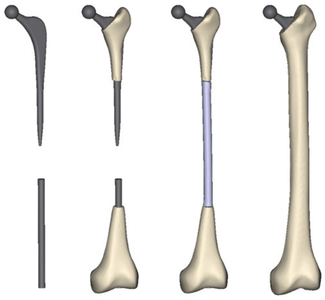

Fig. 3 - Masks – Prosthesis, trabecular bone, cortical bone and intramedullary space

Preparing the Finite Element Models

The masks of the cortical and trabecular bone, implants and filling material were combined into unified models using Materialise Mimics' non-manifold assembly creation function. The advanced remeshing algorithms in 3-matic delivered an excellent uniform mesh quality throughout the assembly (Figure 4), which in turn yielded high-quality tet10 elements in the volume mesh (Figure 5), without the need for manual interaction. Once the assemblies were meshed, they were exported to Abaqus. Material properties were assigned based on the volumes and literature values, and a finite element analysis was performed.

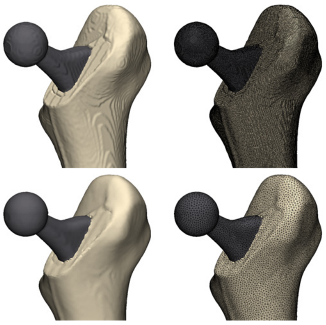

Fig. 4 - Before and after remeshing

Successful Finite Element Simulations

After applying loads representative for walking, it was found that the strains in the interprosthetic gap were higher than those in the surrounding area. However, models with this gap consistently had lower strains than models with only a hip prosthesis. Furthermore, the results indicated that not only the gap size, but also the gap's location influences the strain pattern. However, the interprosthetic gap did not act as an overall stress riser when compared to a bone without implants. The researchers were able to establish a robust FE workflow for the different combinations of implant size variations, using the advanced FE tools in the Materialise Mimics Innovation Suite. Moreover, the manual intervention in creating the assemblies was reduced to a minimum.

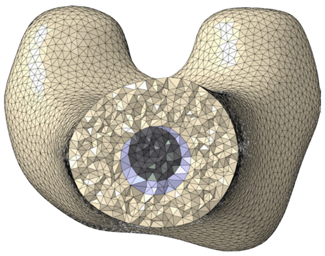

Fig. 5 - Consistent mesh quality in non-manifold assemblies

The Materialise Mimics Innovation Suite's Main Benefits for Finite Element Modeling

- The segmentation capabilities of Materialise Mimics provide you with market leading tools for converting CT images into accurate 3D bone models, including separate masks for cortical and trabecular bone
- Materialise 3-matic helps you save time by eliminating the task of manual model adjustment thanks to the automatic, non-manifold assembly generation with excellent mesh quality
- The export functionality to multiple software packages in their native file format (e.g. Abaqus, Ansys, Comsol) allows you to seamlessly transfer the model to the finite element package of your choice
- With the ability to modify models on mask or STL level, the Suite offers you the flexibility to generate variations of an assembly in any way you desire

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