

Personalized knee modeling for the prediction of biomedical impact of TKA on ligament loading

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Introduction

The Total Knee Arthroplasty is a surgical act that became common against osteoarthritis developing in this joint. According to a survey lead in 18 countries, 175 persons out of 100 000 need that kind of procedure [Kurtz, 2011]. The problem is that with a bad position of the prosthesis, it will age faster and another expensive surgical act will be needed [Liau, 2002] with its consequences: loss of mobility and pain for the patient. Nowadays some tools exist to help the surgeon in this procedure, more and more Computer Assisted Surgery are performed [O'Malley 2012] in order to place the knee prosthesis correctly at the first intervention. But this guidance is only based on the geometry of the bones.

This study aims to build a Finite Element model of the knee specific-patient allowing us to predict the biomechanical effects of the surgery. This may allow us to propose an optimal position for the knee implant.

Methods

One healthy 24 year old male volunteer underwent a MRI and an EOS imaging of the right knee. EOS imaging is a low dose X-ray system dedicated to orthopedic imaging [Wybier, 2013]. Several MRI stacks were taken in order to reconstruct the different parts of the knee.

A 3D geometrical model was segmented from the MRI stacks using the software Aviso®. This model is rather complete and includes the bones, the cartilages and the soft tissues of the knee (ligaments, tendons, and meniscus). This model was then meshed and smoothed using a Low Pass filter [Taubin, 2000] for Finite Element Analysis (FEA) (see figure 1).

The model obtained has 150 000 elements, mostly hexahedral. It has been tested with the boundary conditions of a standing position and computes correctly.

Results

To validate this model, its bony structure was confronted with the EOS images with two

methods. First, a statistical bone shape model of the knee was fitted on the EOS images, and the external surfaces of this statistical model were compared with the ones of the FE model. Second, the projected images of the bones were segmented on the EOS images, and then compared with FEA outputs.

The comparison between the model and the EOS images is satisfying. The specific-patient geometry was not lost in the process.

Conclusion

This is only the first step in the study of the optimal position for the knee implant. The FE model has to be tested with more complex boundary conditions.

Along this study, MRIs were used to build a FE model, and then it has been validated with EOS images. The performances of EOS images are very promising; it is quick and easy to process. We can imagine building a generic biomedical model that would be morphed on the EOS images of a patient for its specific model.

References

- Liau *et al*, *Clinical Biomechanics* 17.2: 140-146, 2002.
- Kurtz *et al*, *Int. Orthop.* 35:1783-1789, 2011.
- O'Malley *et al*, *Operative Techniques in Orthopaedics* 22.4: 176-181, 2012.
- Taubin *et al*, *Eurographics State of the Art Reports* 4.3, 2000.
- Wybier, *et al*, *Joint Bone Spine* 80.3: 238-243, 2013.

Figures

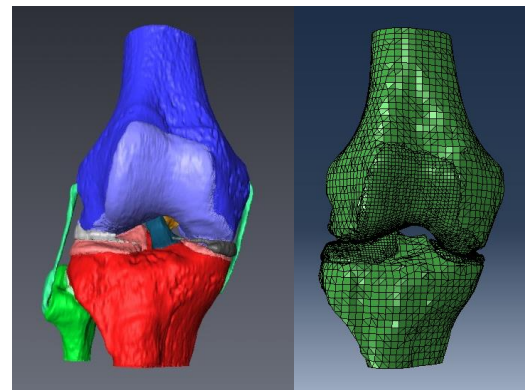


Figure 1: 3D geometrical model segmented from MRI stacks (left), and FE model (right).