Development of Patient-Specific 3D Knee Joint Finite Element Model to Optimize Anterior Cruciate Ligament (ACL) Reconstruction

H.H. Rachmat[1], R.L. Diercks[2], G.J. Verkerke[1,4], Nico Verdonschot[3,4]

[1] Department of Biomedical Engineering and [2]Orthopaedic Surgery, University Medical Center Groningen, University of Groningen
[3] Orthopaedic Reseach Laboratory, University Medical Center Nijmegen
[4] Department of Biomechanical Engineering, University of Twente
e-mail: h.h.rachmat@med.umcg.nl

INTRODUCTION

The anterior cruciate ligament (ACL) is the most frequently injured ligament of the knee during sports activity. ACL-reconstruction strives to a full recovery of functionality. However, in 10-20% of cases the reconstruction is not optimal, leading to accelerated cartilage damage. This is probably caused by the surgical plan that is based on the average patient.
Development of a three-dimensional (3D) finite element model of the knee joint of a specific patient will learn the surgeon, how to do surgery for that patient.

RESEARCH GOALS

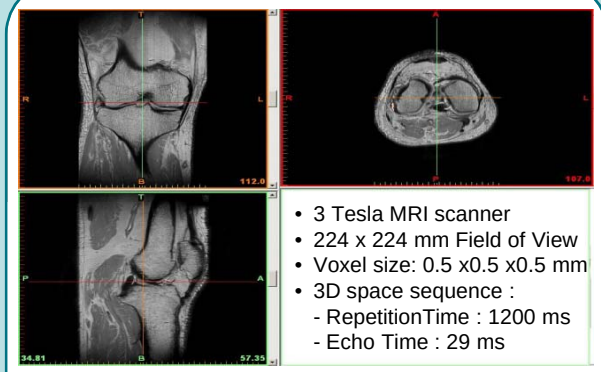
To realise a 3D simulation model to assist a surgeon for determining the optimal location of the graft at femur and tibia as well as optimal length of the graft for successful a subject-specific ACL-reconstruction.

Cadaver leg (66 years old) at full extension position

MATERIAL AND METHODS

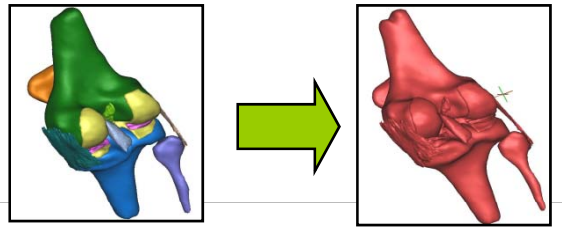
Five cadaver legs were scanned by MRI and used to develop a 3D model of an intact knee including four bones and soft tissues (ligaments, cartilage and menisci) with non-linear material properties to simulate passive knee movements. The 3D knee model is developed including images segmentation using **Mimics software** and 3D solid model construction using **Patran software**. The solid model will simulate the effects of patient specific parameter variations including bone shapes, insertion sites, mechanical properties and variations of surronding tissues on ACL reconstruction through several Finite Element simulations of passive movement using **Marc and Mentat software**.

RESULTS

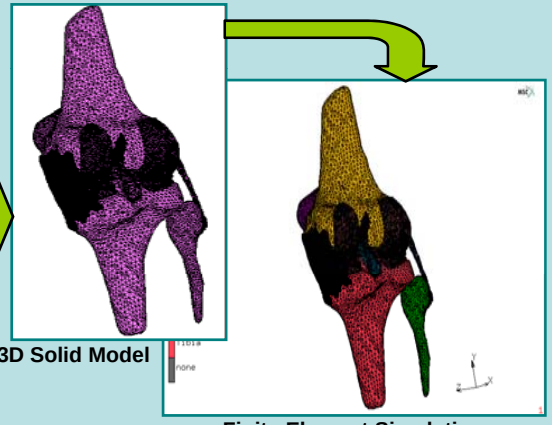


- 3 Tesla MRI scanner
- 224 x 224 mm Field of View
- Voxel size: 0.5 x0.5 x0.5 mm
- 3D space sequence :
  - RepetitionTime : 1200 ms
  - Echo Time : 29 ms

Segmentation Procedure



3D Object Model **3D Surface Mask**



3D Solid Model **Finite Element Simulation**

DISCUSSION

- **A first FE-model of a specific patient has been made**
- **The MRI quality image for soft tissue elements will be improved with different MRI sequence and use CT study to develop knee bone shapes**
- **The geometrical model and the finite element analysis of the 3D knee model will be validated with an experimental cadaveric study**

Orthopaedic Research Lab UMC St Radboud UNIVERSITY OF TWENTE.

Kolff3 - Department of BioMedical Engineering – FB40
University Medical Center Groningen
Antonious Deusinglaan 1
9713 AV Groningen – The Netherlands