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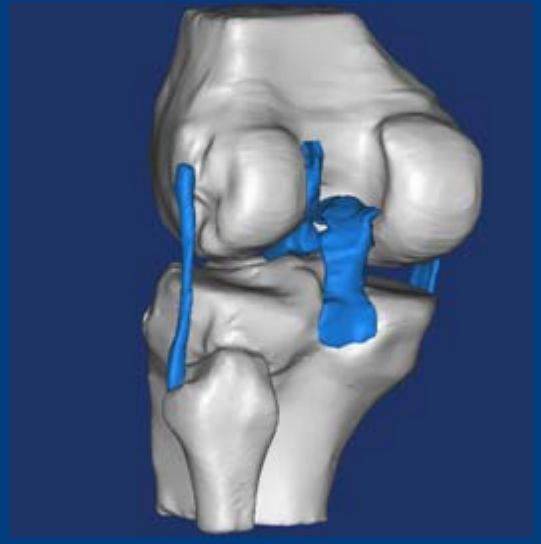
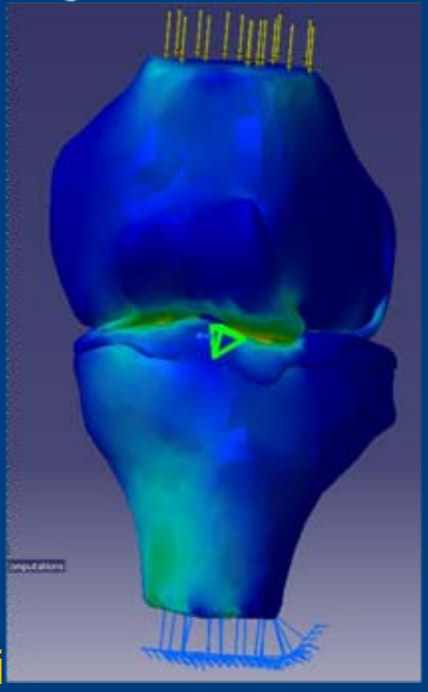


Stress distribution in the knee joint following a high tibial osteotomy

Rajshree Mootanah, Howard Hillstrom,

Carl Imhauser, Rob Walker, Andrew New, Sylvain Mangeot, Emilien Blanc, Cedric Dare, Anthony Burton, Caroline Mouton, Samira Ait Ali



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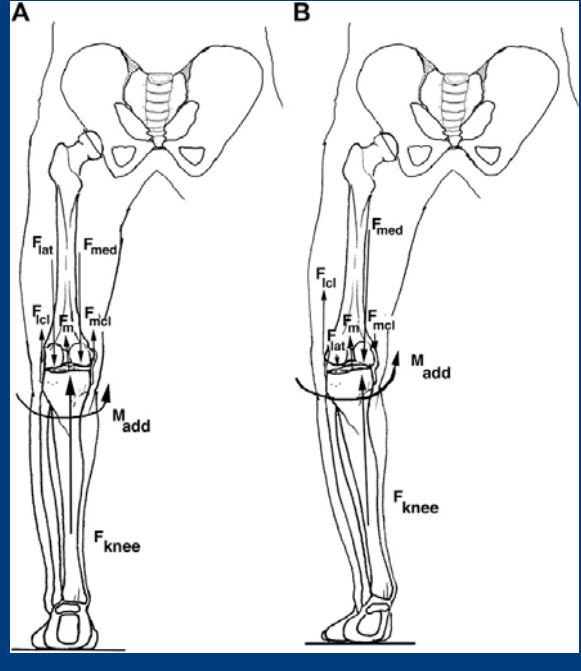
Introduction

- 14.1% of men & 22.8% of women over 45 years show symptoms of OA of the knee
- Knee OA = mal-alignment of the lower limb
- 5 degrees of varus mal-alignment => 70% - 90% increase in compressive loading in knee joint =>resulting in OA worsening.



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Introduction

- Knee arthroplasty is not appropriate for younger patients who wish to return to high level activity.
- High Tibial Osteotomy (HTO) = preservation of bone stock and soft tissue structures.
- Results HTO are unpredictable, which could be due to patient selection or surgical techniques.

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Aim

Use finite element methods to predict the optimum HTO surgical techniques for improved and more consistent HTO surgical outcomes.

By reducing stress in specific regions of the knee it may be possible to slow down or eliminate disease progression.

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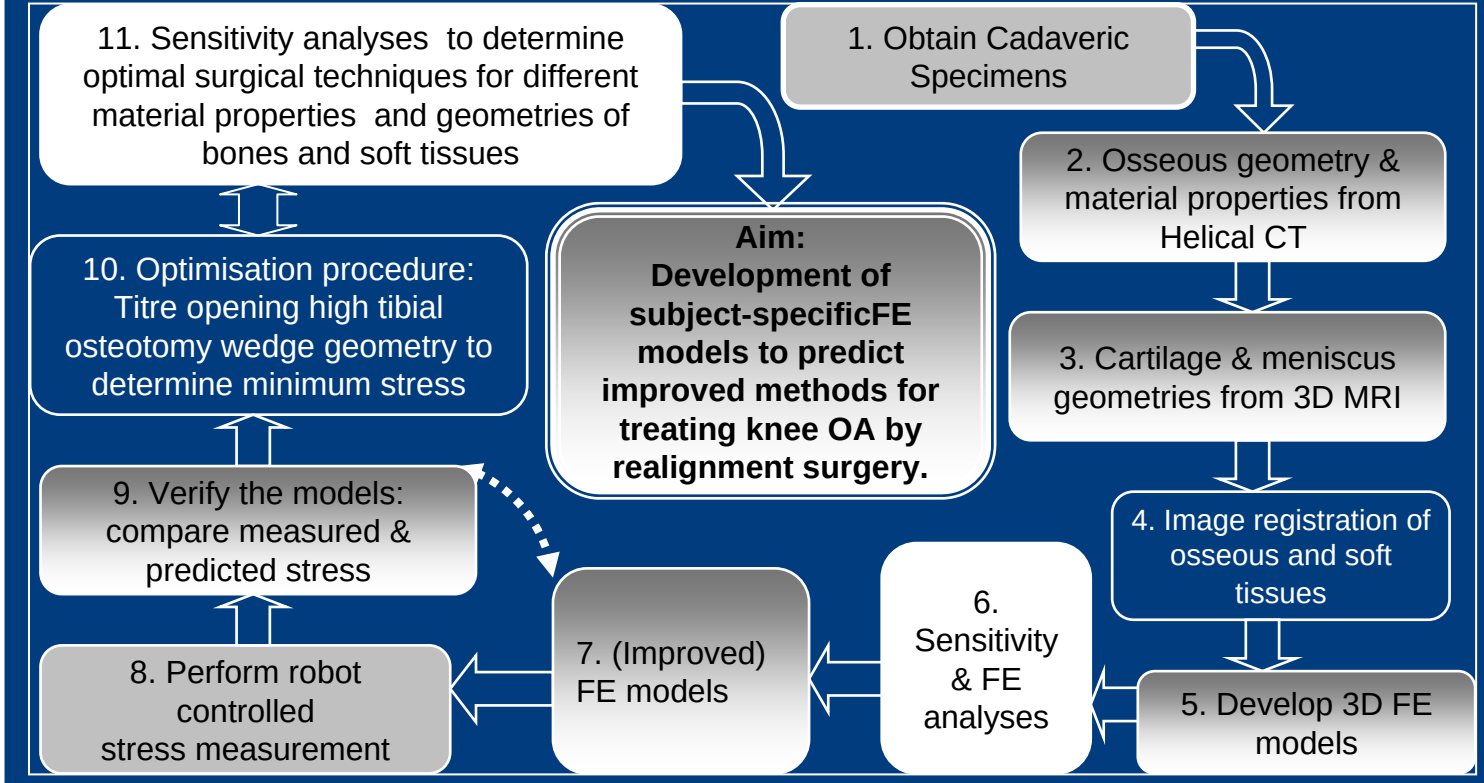
Research Method



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Finite Element Method

Magics Remesh Module

Surface Meshing, smooth surfaces

CT scan images

Materialise modules
Image processing, generation of 3D structure

CATIA

Conversion of surface mesh to solid part & FEA

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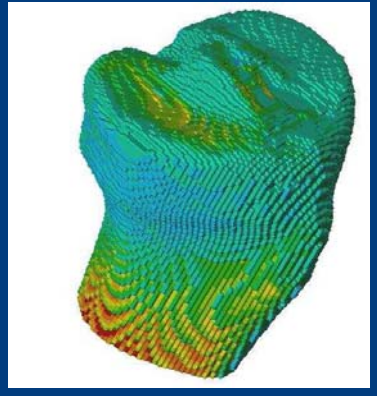
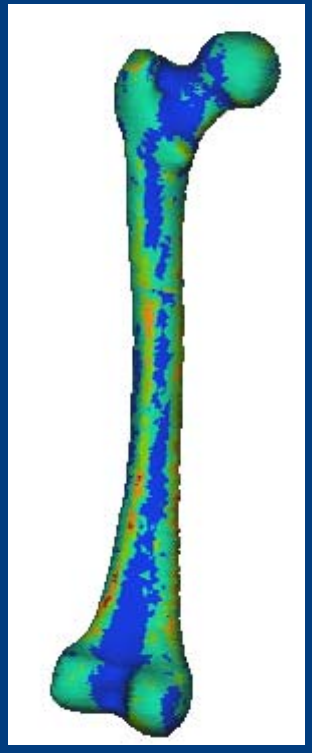
Automatic assignment of bone material properties

Homogenous isotropic

- From literature / Mech Testing

- Unhomogenous anisotropic
  - Grey value / HU
  - Bone Density
  - Young's modulus





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Equation A: Hvid, Bentzen, Linde, Mosekilde, Pongsoipet

$\rho = 0.00120 \cdot HU + 0.101$ $[g/cm^3]$

$E = 2560 \cdot \rho$ $[MPa]$

Equation B: Rho, Hobatto, Ashman (cp. (Eq. 6), (Eq. 7))

$\rho = 1.067 \cdot HU + 131$ $[mg/cm^3]$

cancellous bone:

$E = 0.004 \cdot \rho^{2.01}$ $[MPa]$

cortical bone:

$E = 0.014 \cdot \rho - 6.142$ $[MPa]$

Equation C: Carter & Hayes (cp. (Eq. 2)

$E = 3790 \cdot \dot{\varepsilon}^{0.06} \cdot \rho^3$ $[MPa]$

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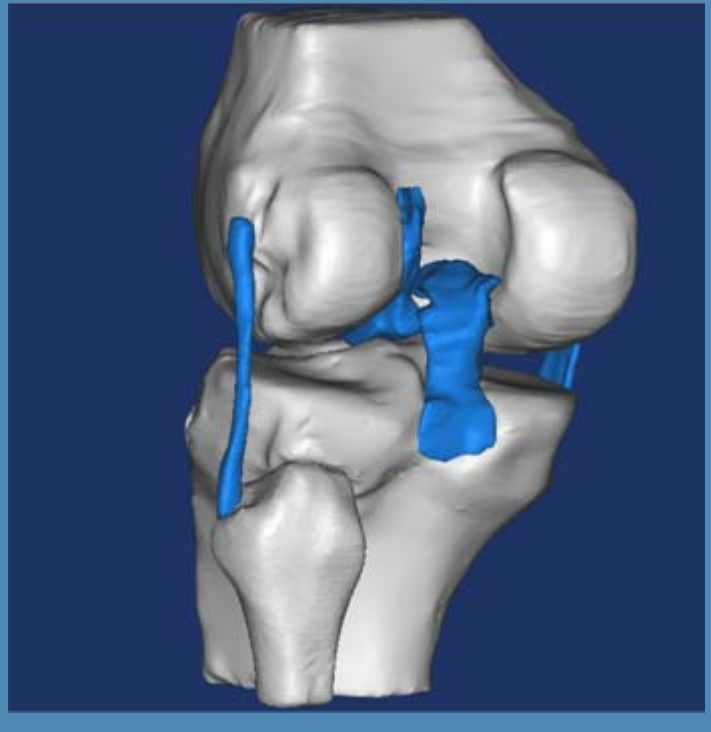
Creating the knee model



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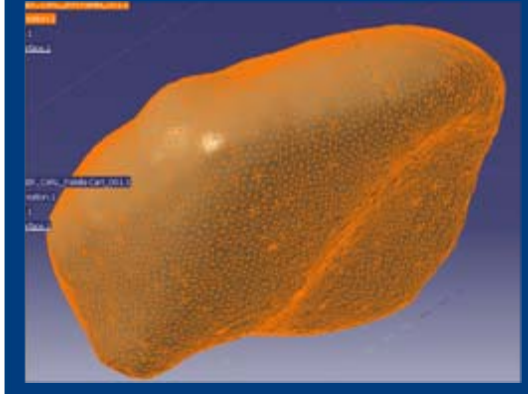
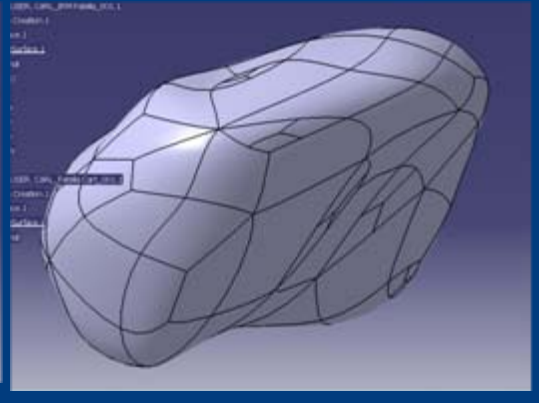
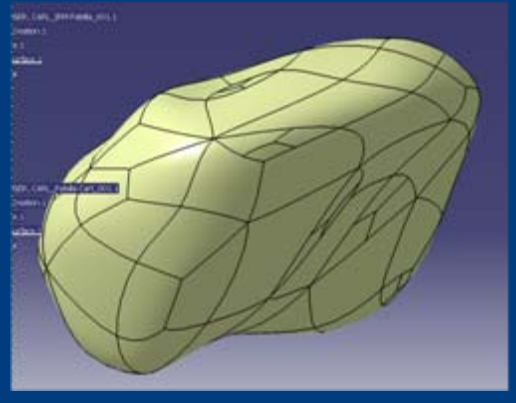
From 3D model to FE model



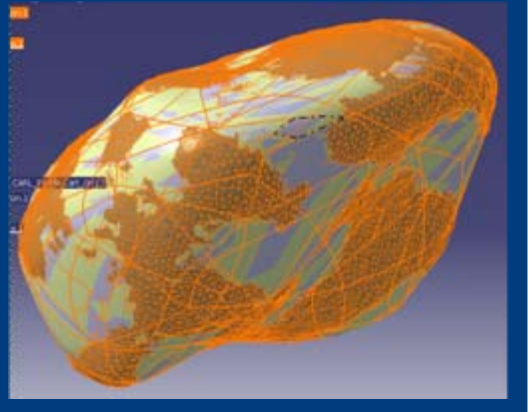
Cloud of points



Surface



Close Surface



FE mesh

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Material properties & Boundary conditions

Cartilage: E = 12 MPa, v = 0.46

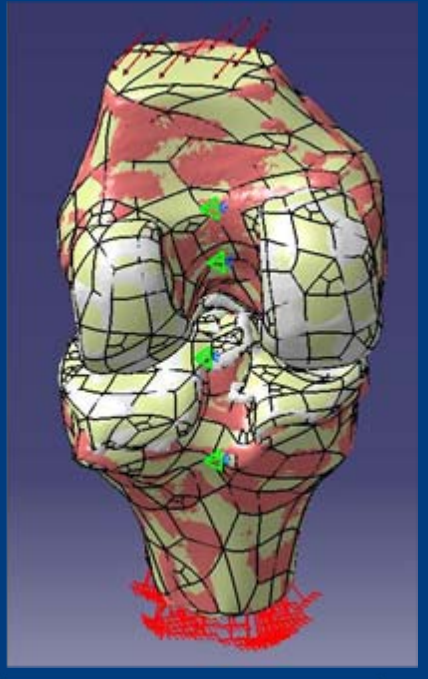
Cortical bone: E = 15 GPa, v = 0.35

Cancellous bone: E = 400 MPa, v = 0.3

Tibia is fixed at distal end

Load = 3 X body weight applied on femur

Elements between bone & cartilage are merged



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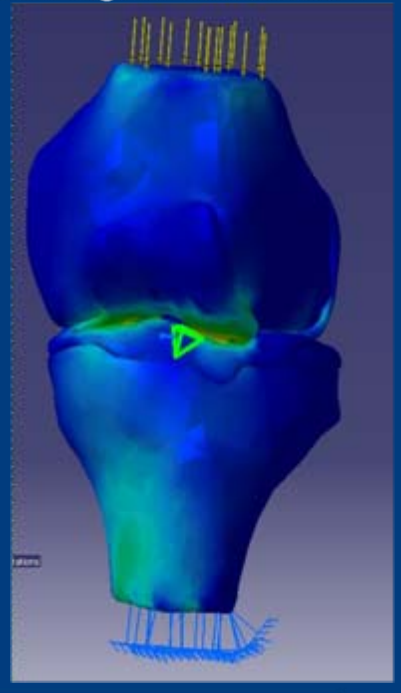
FE results

Peak Principal stress before HTO: 12 Mpa

Peak Principal stress after HTO: 4 MPa

Reduction by 67%



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Conclusion

Our preliminary FE results show that HTO reduces stress in specific regions of the knee and could disease progression.

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Further work

- Include menisci and ligaments in FE model
- Optimise MRI sequence for better thresholding of soft tissues
- Sensitivity analyses on geometry and material properties of bones
  - To eliminate the image registration process
- Corroboration of results with in-vitro studies on cadaveric specimen
- Generalisation of the FE models to predict improved HTO geometry

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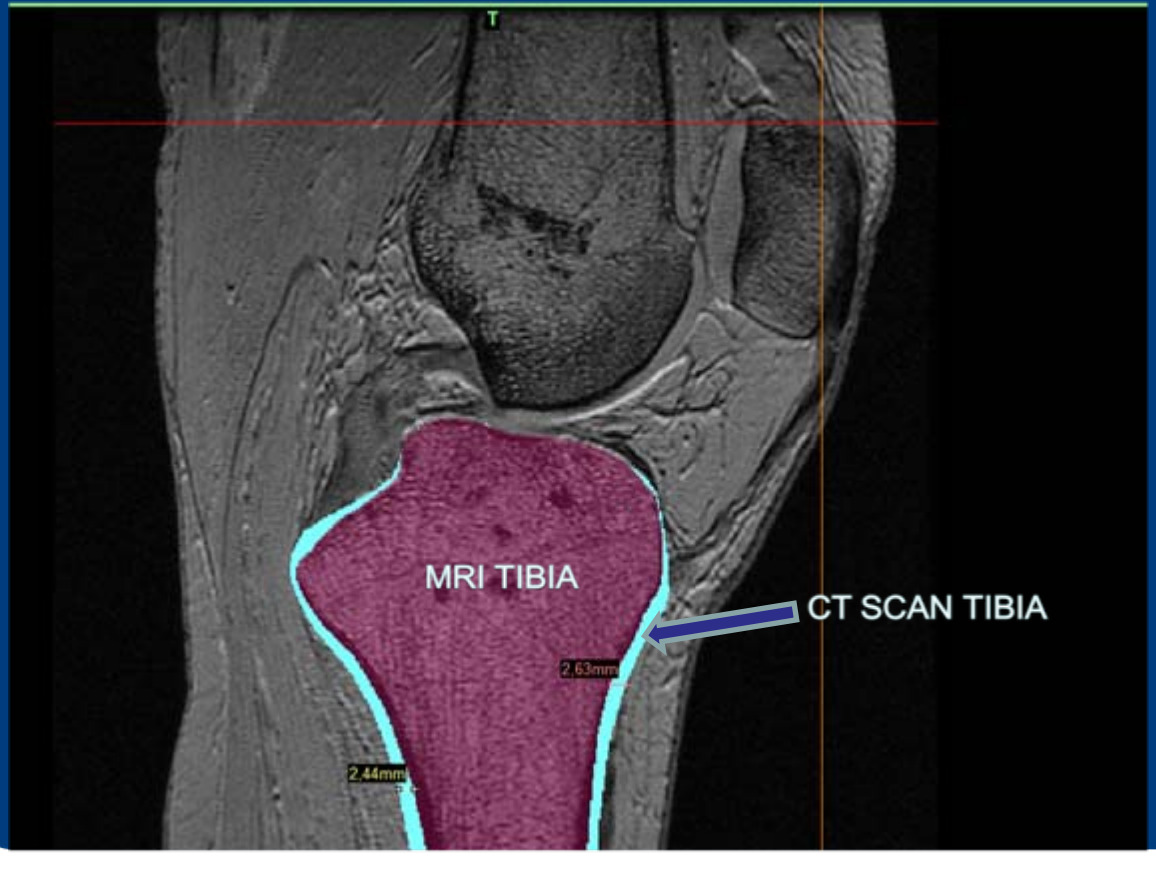

Discrepancy in bone geometry , using CT and MRI images

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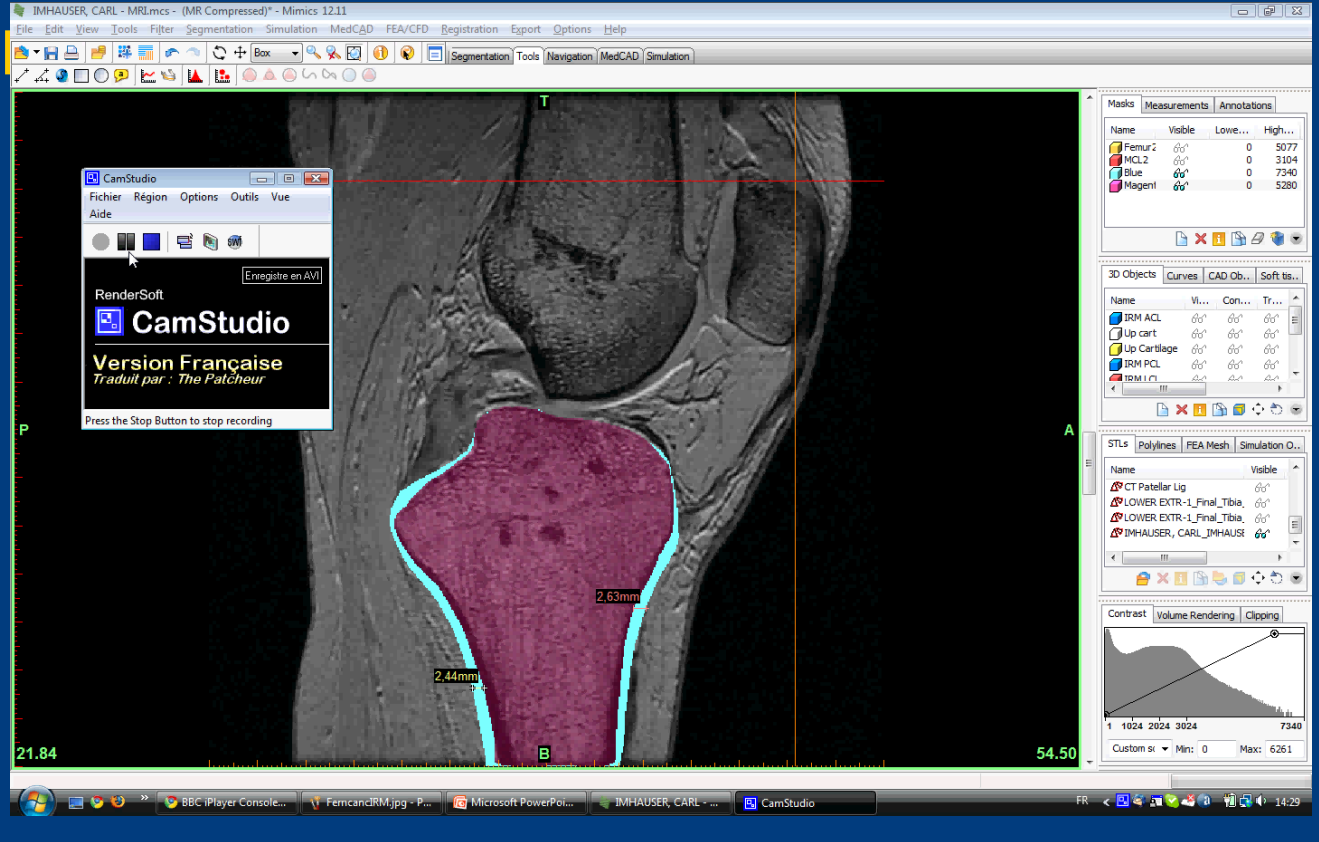

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Q & A