Use of Rapid prototyping to optimise surgical planning and decision support for Total Hip Replacement

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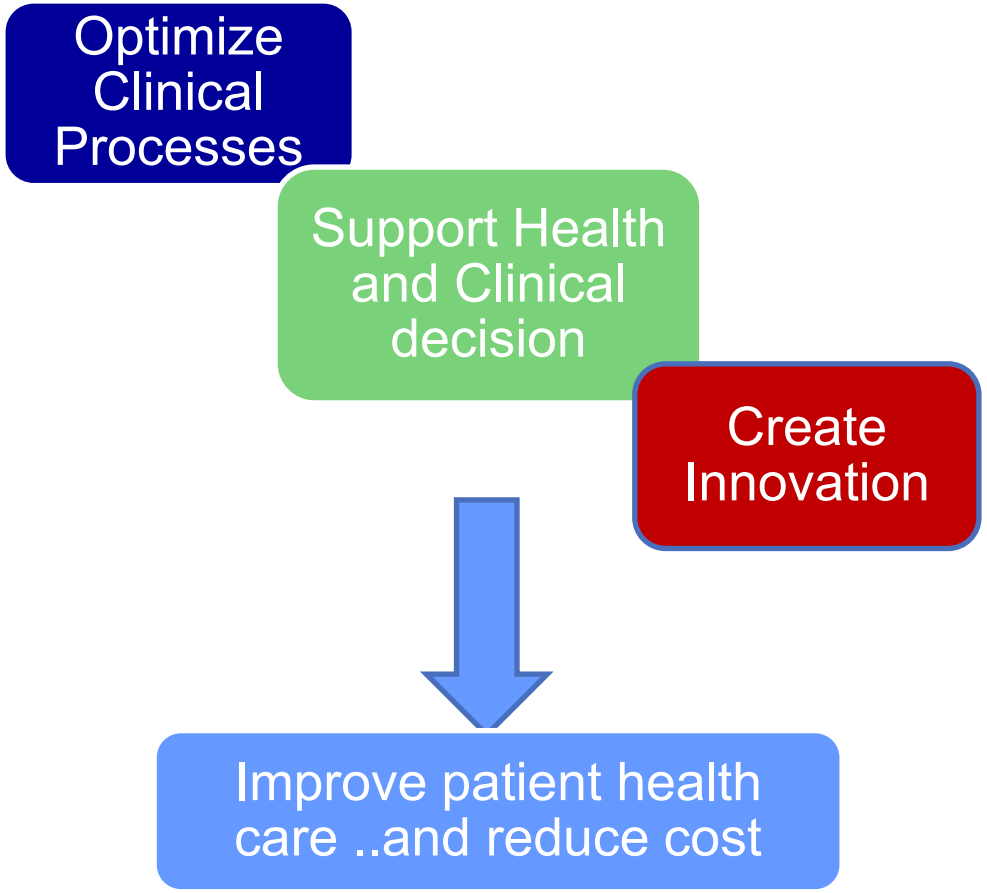
Skýrslutæknifélag Íslands

Summary

- Clinical evaluation score for Total Hip Replacement planning and post-operative assessment
- Integrated Medical Modeling and Rapid prototyping Service

IT @ Health care @ BME



Clinical evaluation score for Total Hip Replacement planning and post-operative assessment

Develop a monitoring techniques based on Gait analysis and bone density changes to assess patient recovery after Total Hip Replacement (THR).

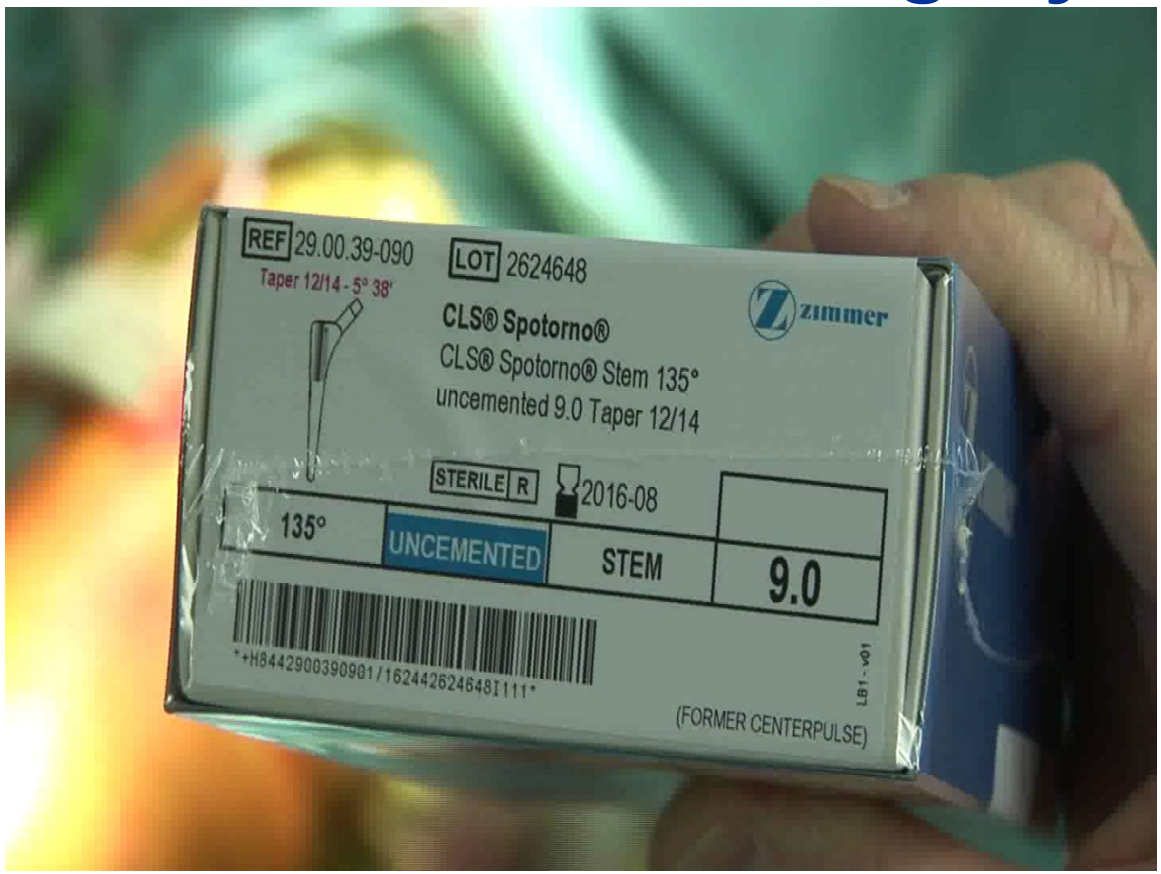
Validate computational processes based on 3D modeling and Finite Element Methods (FEM) for optimizing decision making in THR and selecting the optimal surgical procedure.

Cement vs. Uncemented




		Type	Number	Therapy cost	Dpt cost
Total Hip Replacment cost year 2012	Primary €	Cem	159	**3200**	**2150**
		Unc	105	**3100**	**1600**
		Total	264		
	Revision €	Cem	16	**7800**	**4200**
		Unc	5	**5700**	**1600**
		Mixed	6	**10500**	**2350**
		Total	27		

Uncemented Surgery



Clinical Trial & time plane

•GaitRite sensor carpet and control station
• KinePro videocamera + LED markers, wireless EMG and control station

Pre- surgery	Surgery	6 Weeks Post- surgery	1 year Post- surgery
•Gait measurments		•Gait measurments	•Gait measurments
•Kine view	•Spiral CT	•Kine view	•Kine view
•GaitRite		•GaitRite	•GaitRite
•Spiral CT			•Spiral CT

Load distribution changes

Pre op

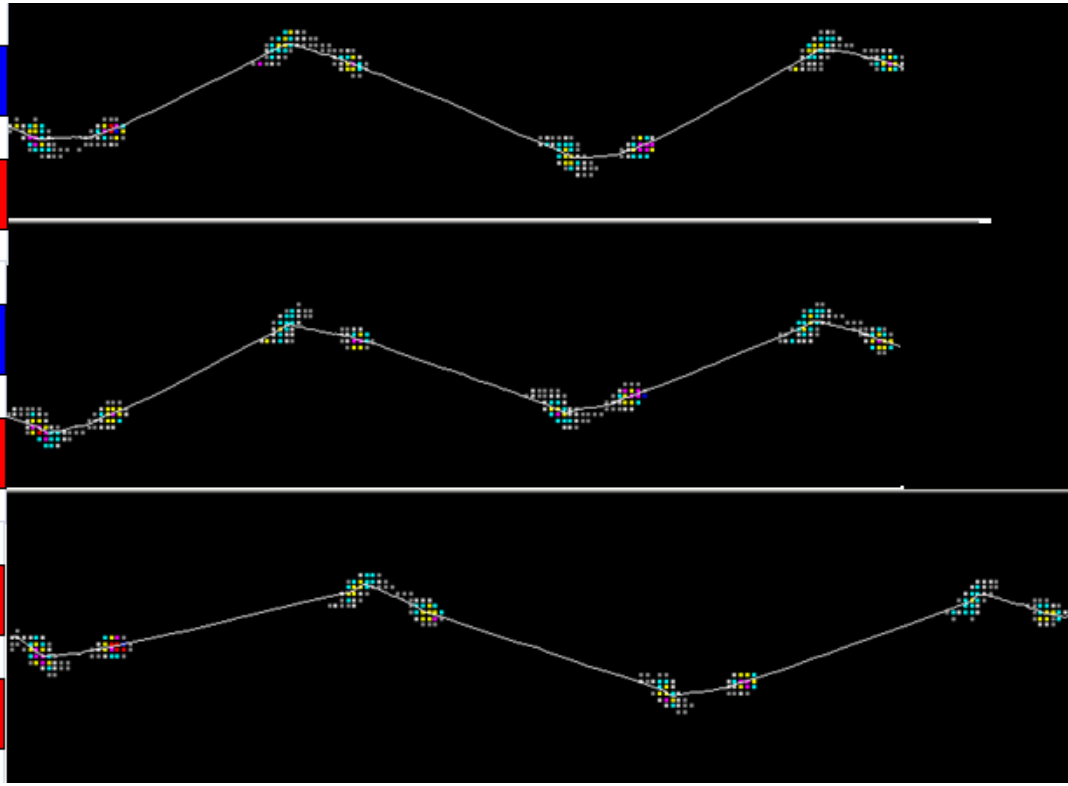
OP	39,5%	9,5% / 0,5%	50,6%
H	44,7%	0,9% / 11,8%	42,8%

6 weeks Post op

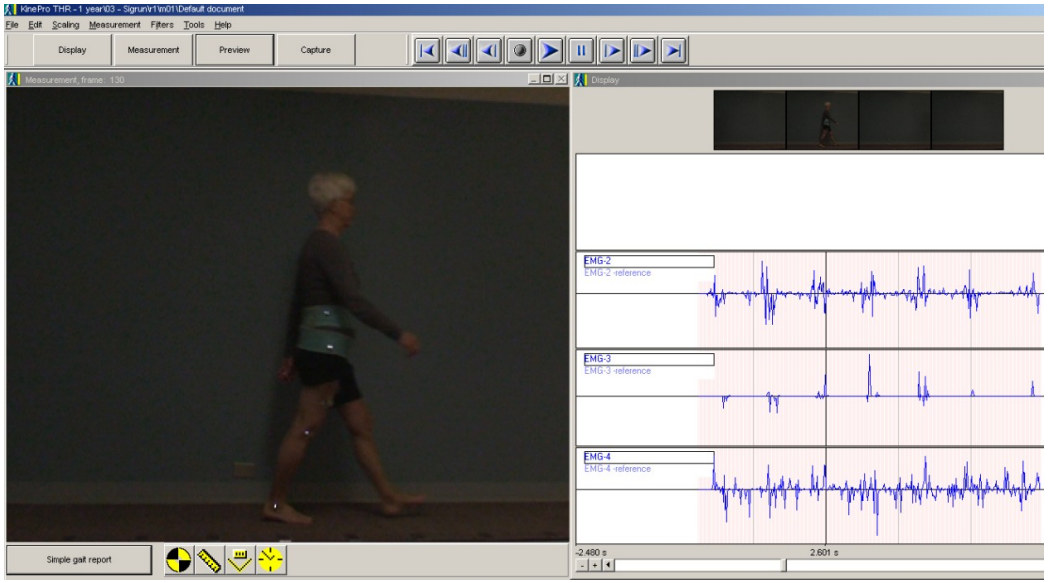
OP	38,4%	8,2% / 0,5%	53,1%
H	43,1%	0,6% / 14,0%	42,4%

1 year post op

OP	46,7%	8,4% / 0,0%	44,9%
H	45,6%	1,0% / 10,5%	43,0%



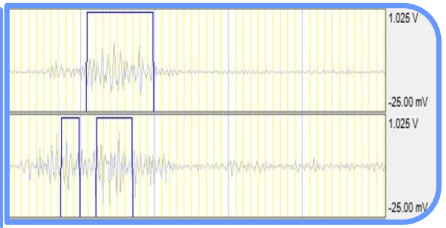
EMG Analysis



Emg Mesaurement by KinePro©

Export Data

Emg OnSet/OffSet detection

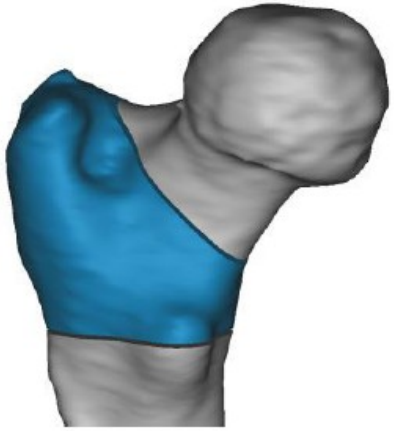


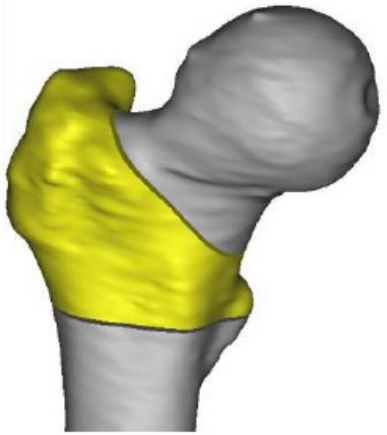
Report statistics of all data

- Evaluation of the imbalance between Healthy & Injured leg. Pre Vs Post 1 Year surgery.

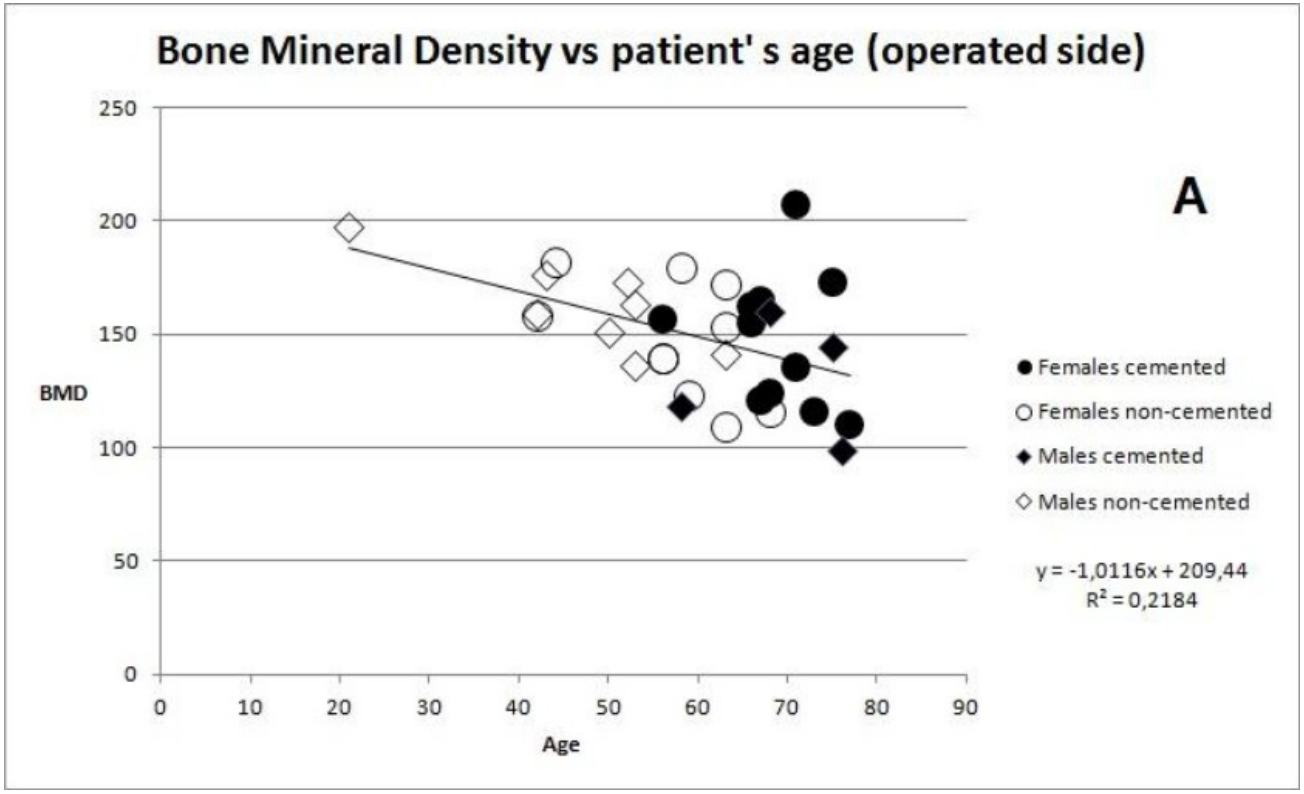
BMD analysis: / Region of interest

- Femoral bone thresholding and segmentation is performed in MIMICS
  - 3D masks of femur are created
- BMD is calculated from proximal femur in the region between femur head and lesser trocanter, as shown in the figure
- A linear relationship between HU and BMD values has been determined with CT scan device calibration

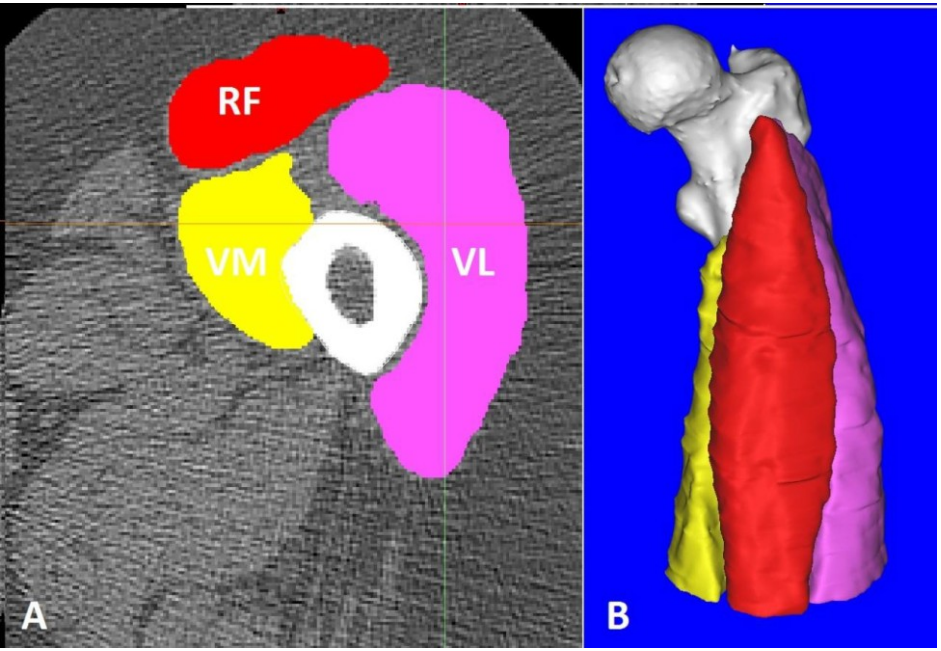


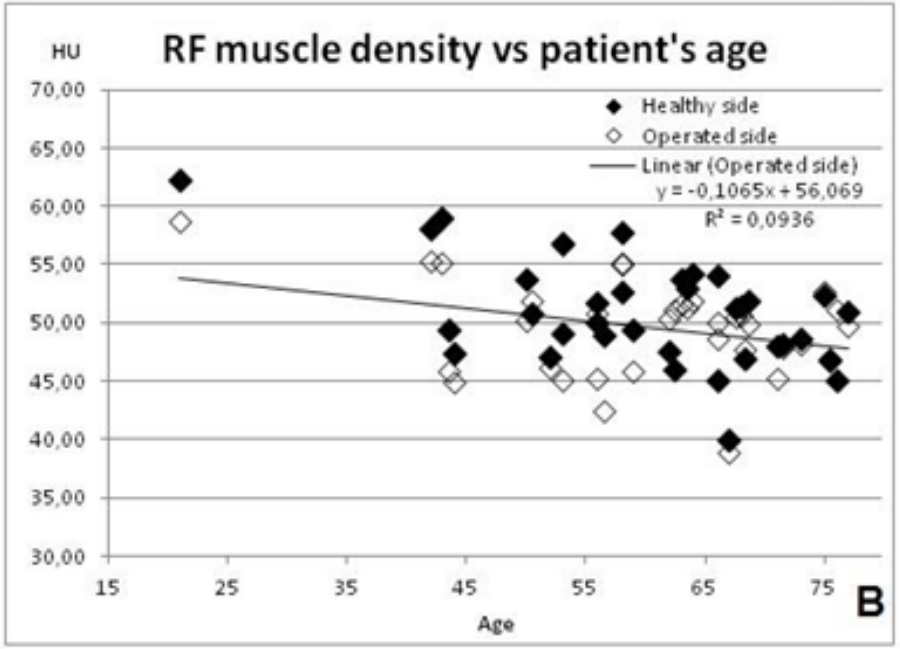


Bone Mineral Density: pre op

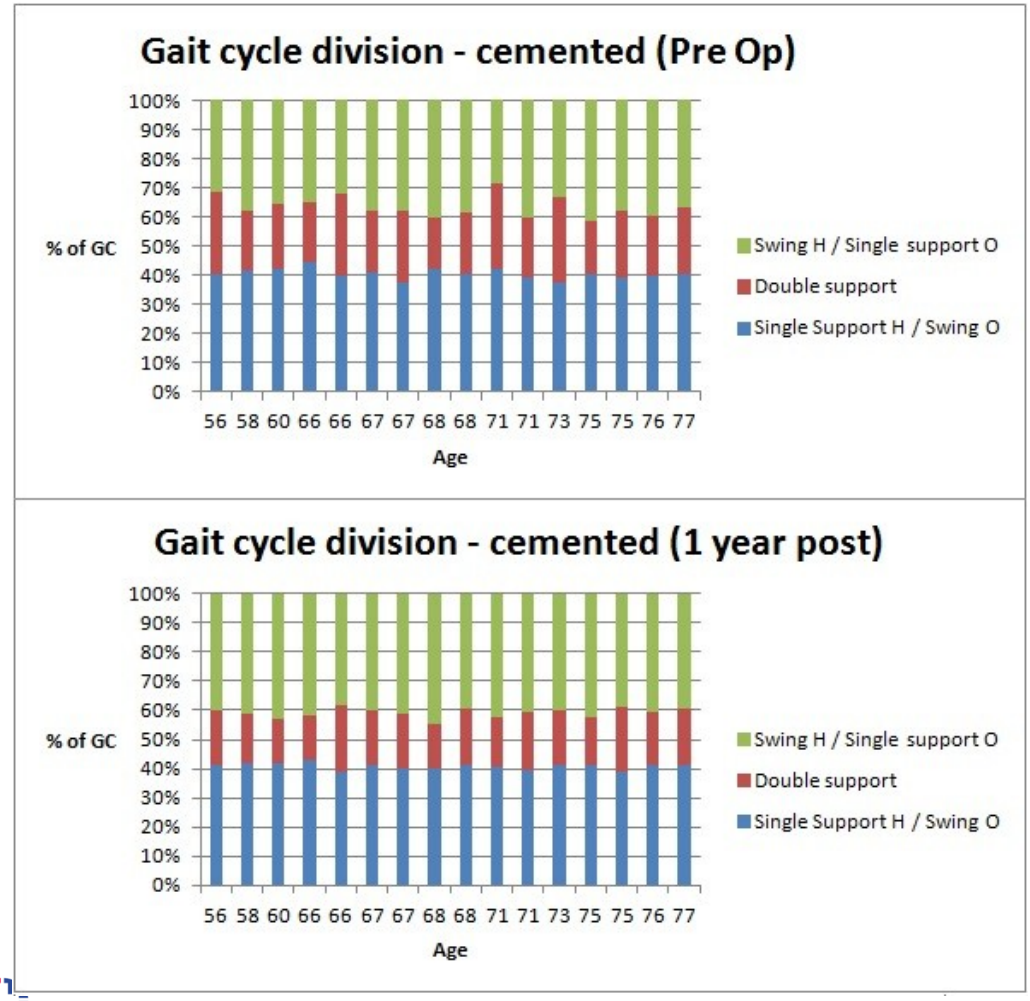


Muscle Density: Pre op



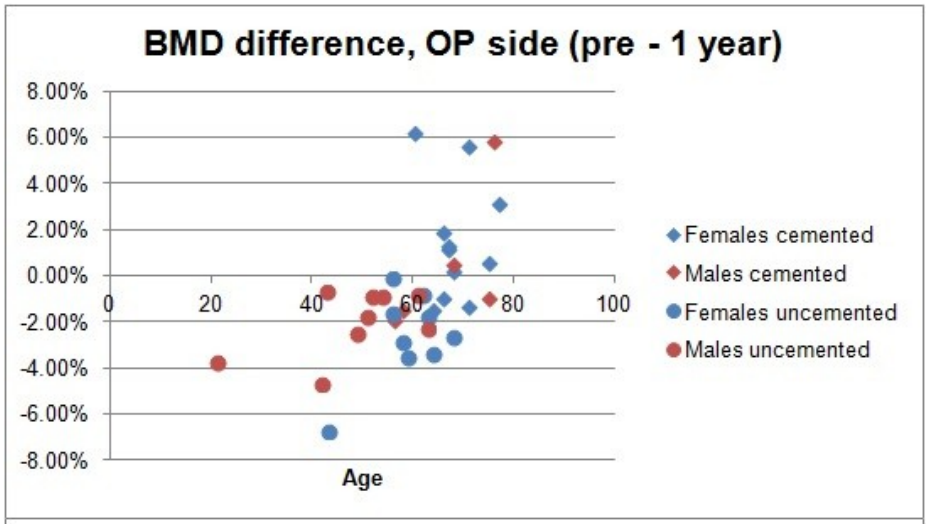


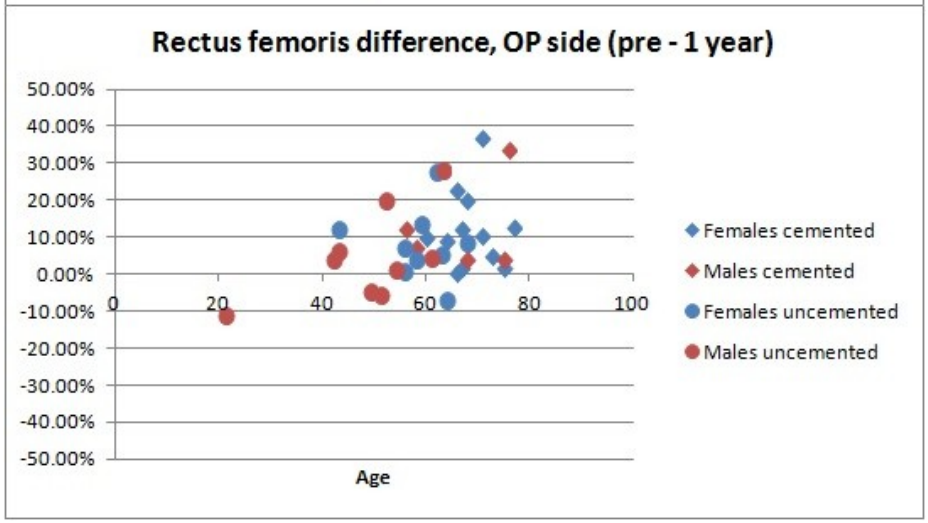
Gait Analysis assessment after 1year



- Gait measurements useful in post-op assessment
- Recovery after surgery varies between patients
- Indicate that cemented patients recover faster

Bone and muscle assessment after 1year





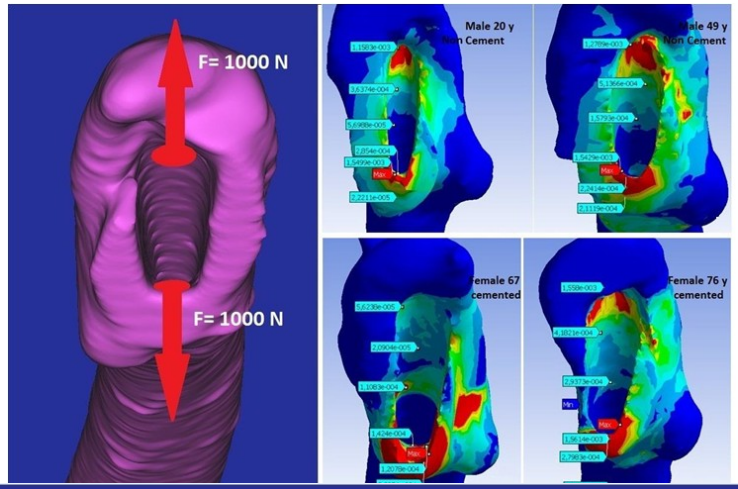
- BMD measurements are valueable pre-op- and post-op assessment
- Muscle density (RF) assessment useful in post-op assessment
- Both types of measurements indicate faster recovery of cemented patients

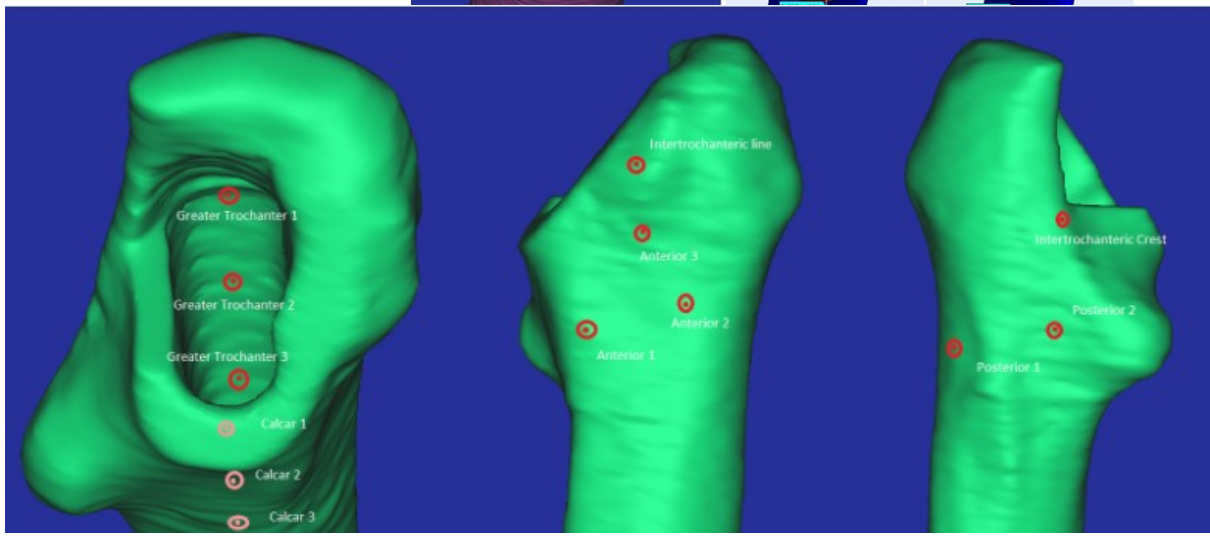
Fracture risk assessment pre op

- The bone fracture risk index (FRI) expresses the risk for structural failure as a ratio of compressive stress (load per unit area) to estimated failure stress

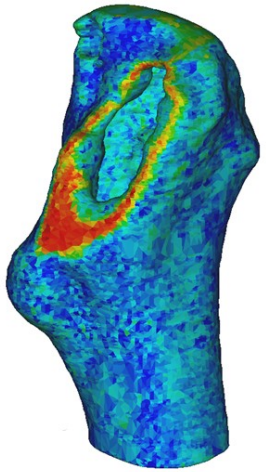
$$FRI\% = \frac{\varepsilon_{max}}{\varepsilon_{yield}} * 100\%$$

Strain distribution

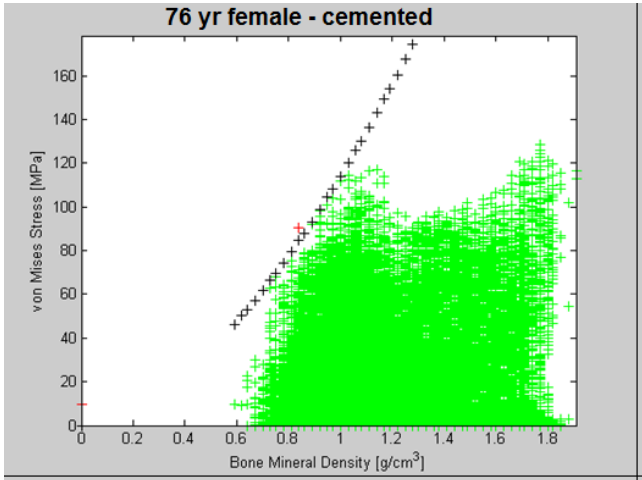


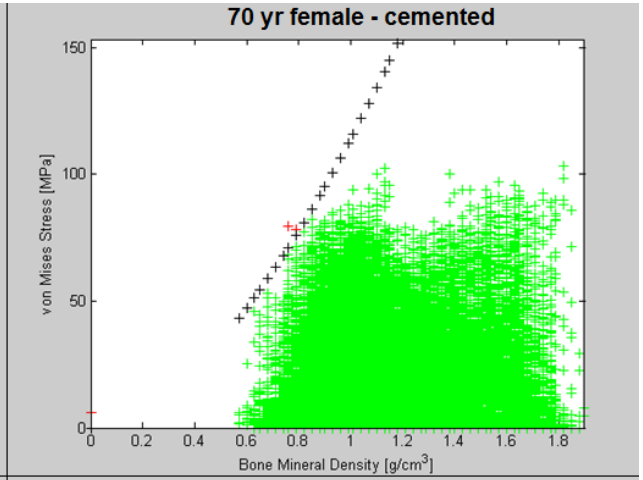


SAFE CASES...



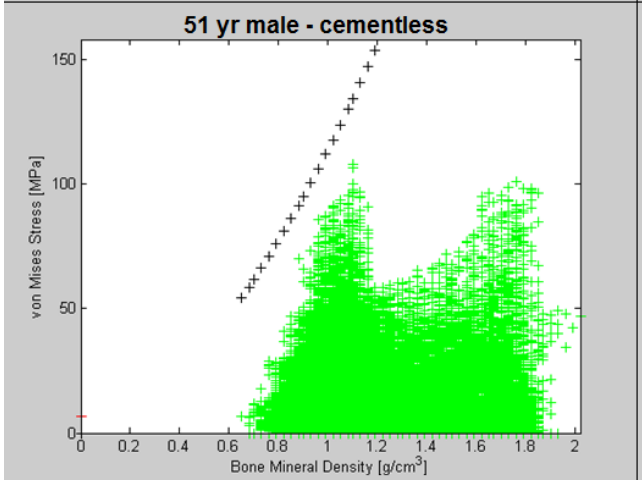
Mean FRI =13.55%
0.070% over 80% FRI

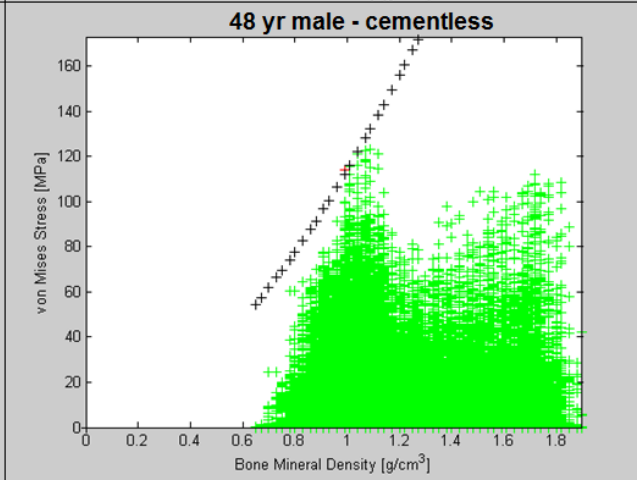




Mean FRI =12.01%
0.044% over 80% FRI

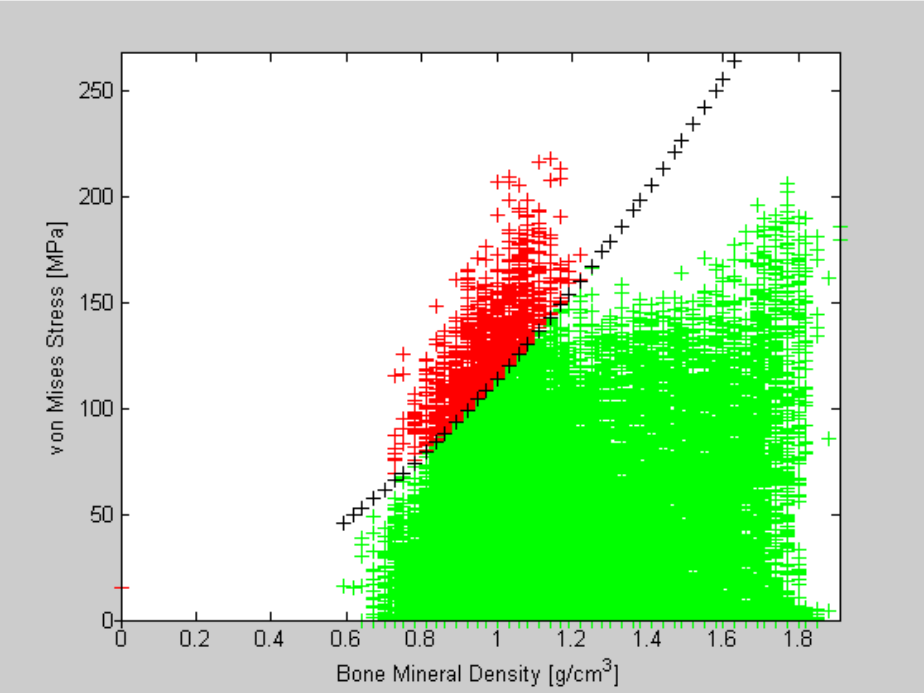
Mean FRI =9.92%
~0% over 80% FRI

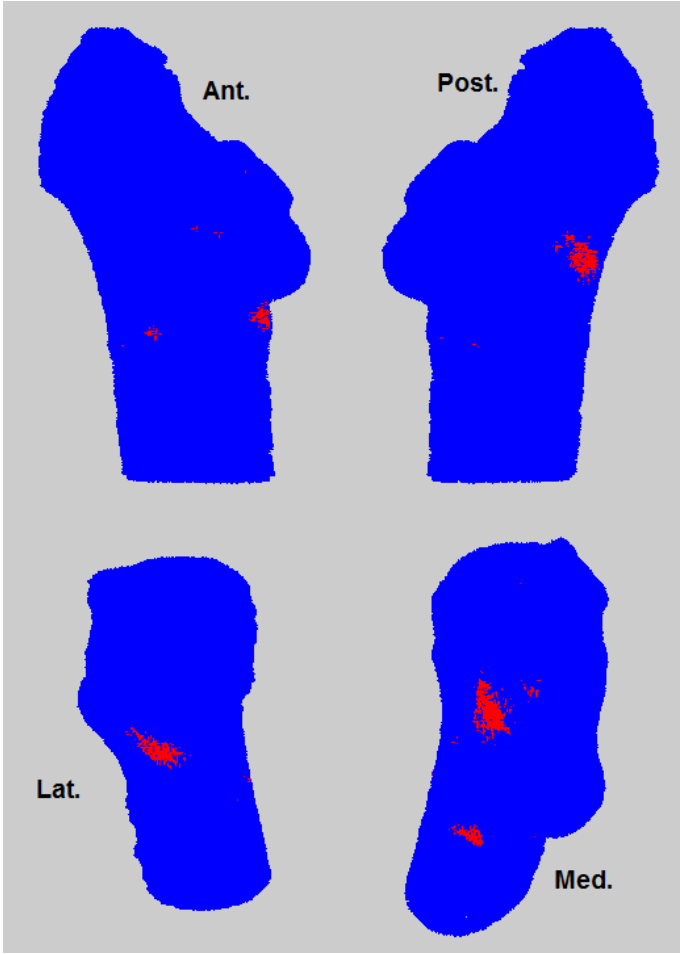




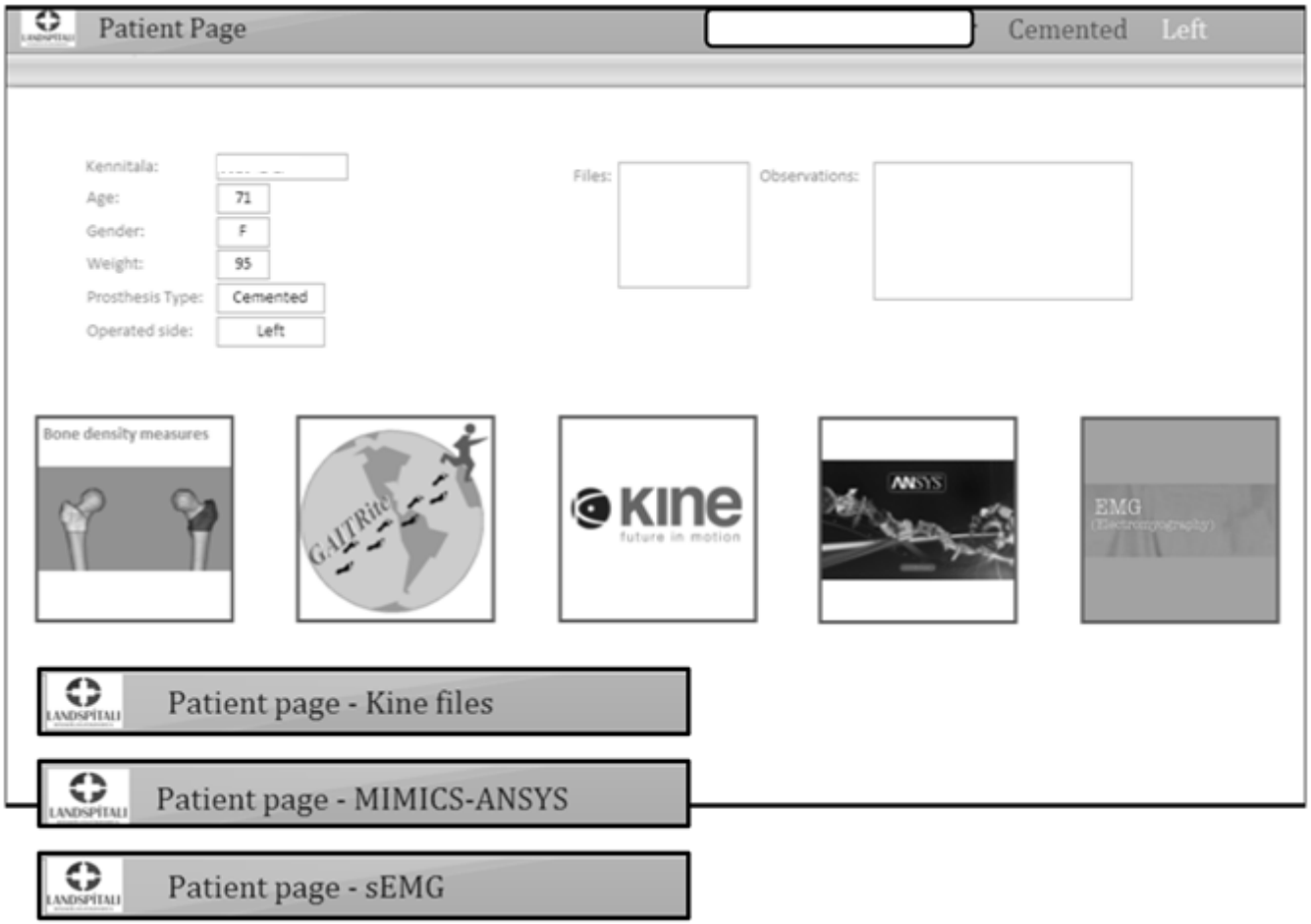
Mean FRI =10.05%
0.022% over 80% FRI

RISK CASE
76 yr old female





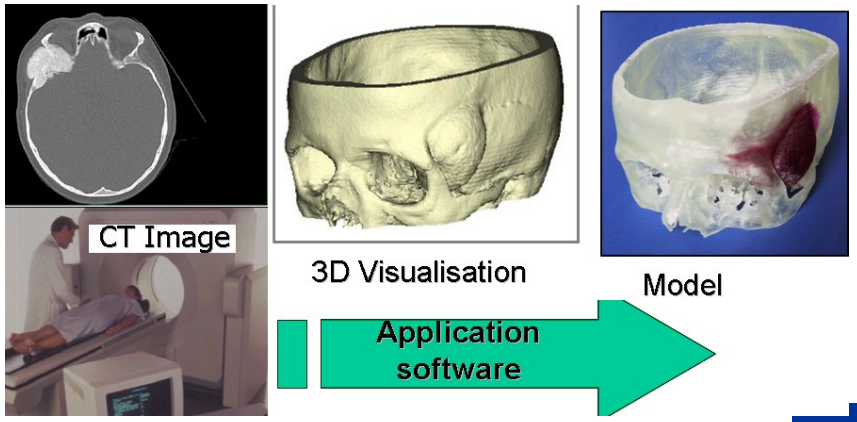
Information exchange and Data base



Integrated Medical Modeling and Rapid prototyping Service

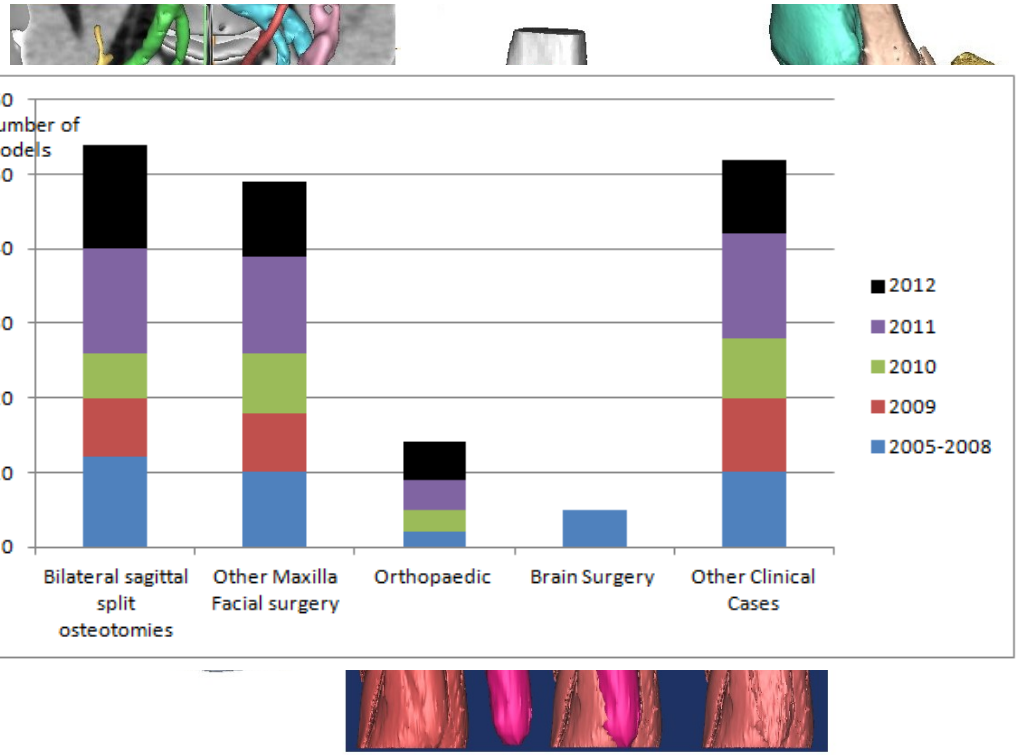
Background

- Rapid Prothotyping: technique that allow the 3D image to be accurately reproduced in a few hours as an acrylic model which can be handled by the surgeon, allowing an immediate and intuitive understanding of the most complex 3-D geometry and can be used to accurately plan and practice an awkward operative procedure. (McGurk, M., et al., 1997)
- Rapid prototyping isn't a new process, it was introduced in the 1980's to define new techniques for the manufacturing of physical models and was originally introduced in industry to improve design and reduce product development time.
- Applications in medicine of RP technologies as support for surgical planning are seen already in 1994 (Mankovich N. et al., 1994)



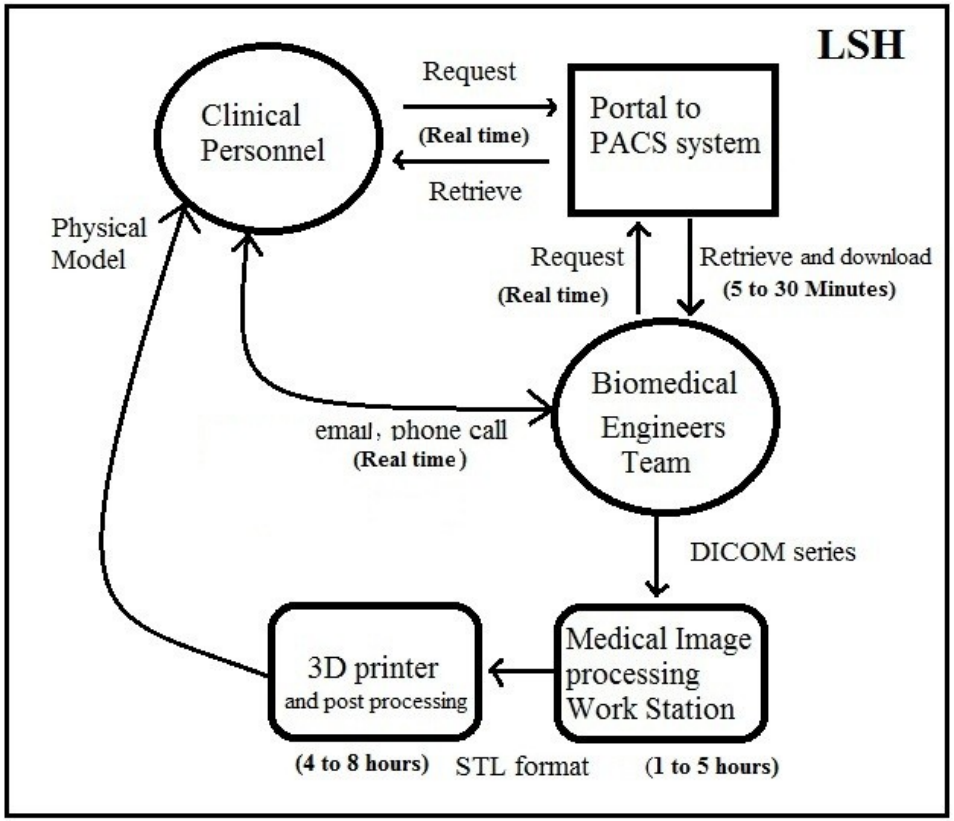
Clinical Applications

- Diagnostic: supporting pathologist with visualization of difficult anatomical case
- Planning surgery in complicate orthopaedic and maxilla facial operation
- Patient follow up in craniofacial trauma, studying structural changes in bone and soft tissue
- Patient compliance providing computer simulating in maxilla lengthening
- Complex hearth surgery planning
- Brain surgery@ navigation systems
- Prosthesis design

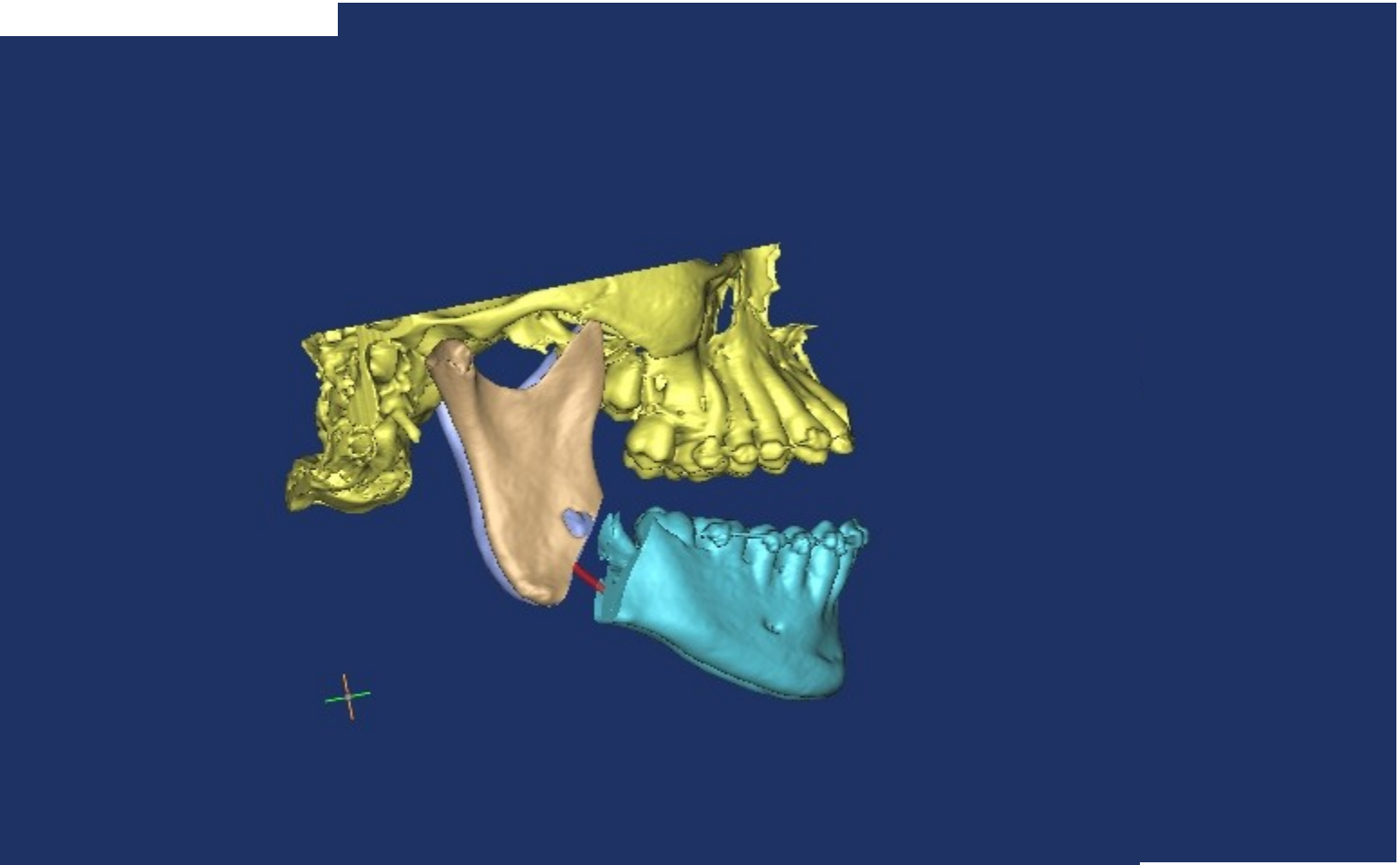


Implementation and Integration in Clinical Processes

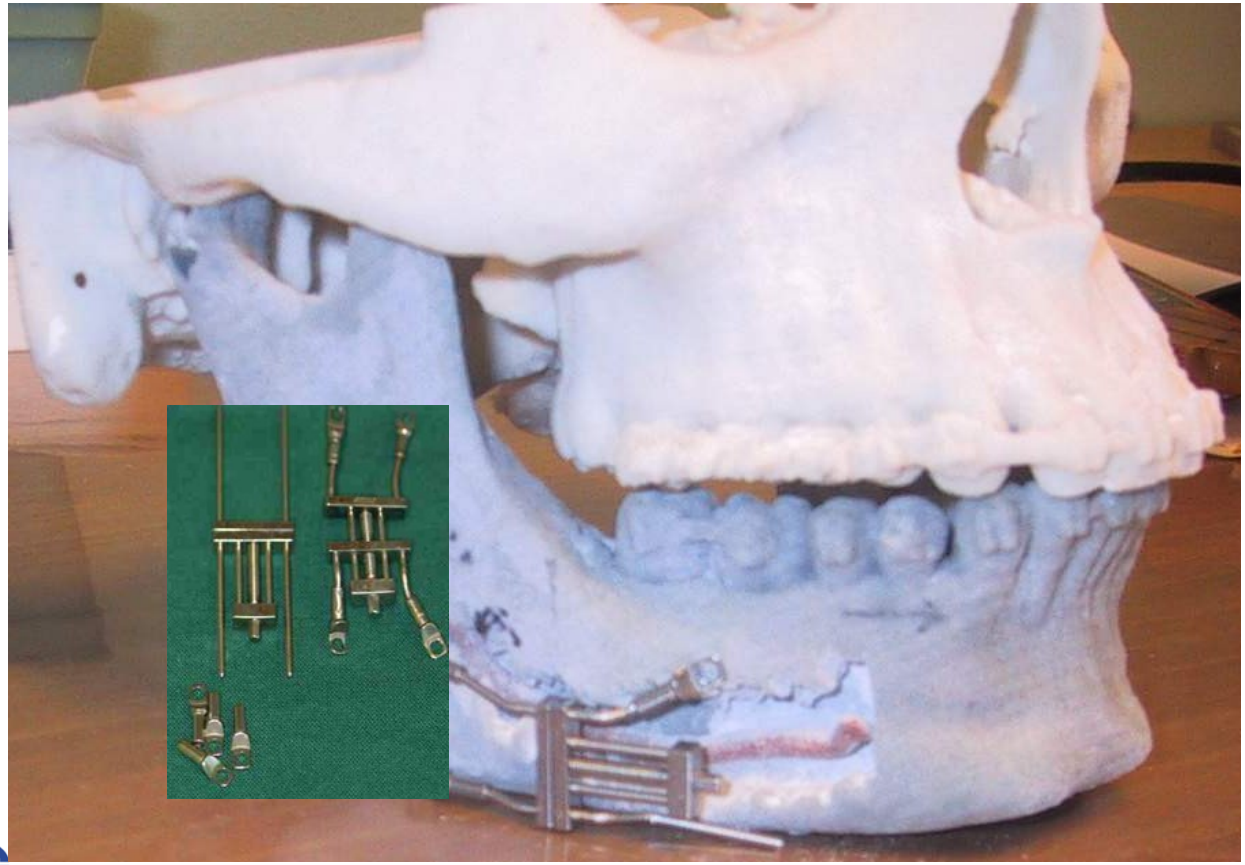
Steps	*Actions to implement a Medical Modeling Process*
1	Select the optimal medical modality to provide best visualization of the anatomical structure of interest (CT or MRI)
2	Set the appropriate scanning protocol for the region of interest
3	Retrieve the scan data from the Hospital PACS
4	Import the scan data to a medical image processing software and segment the region of interest
5	Import the segmented model to 3D Print software and start printing
6	Deliver the model to clinical personnel



Planning Mandible Lengthening surgery

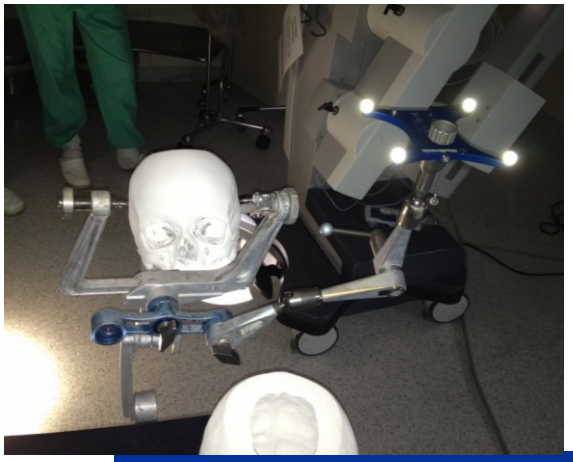


Planning Mandible Lengthening surgery

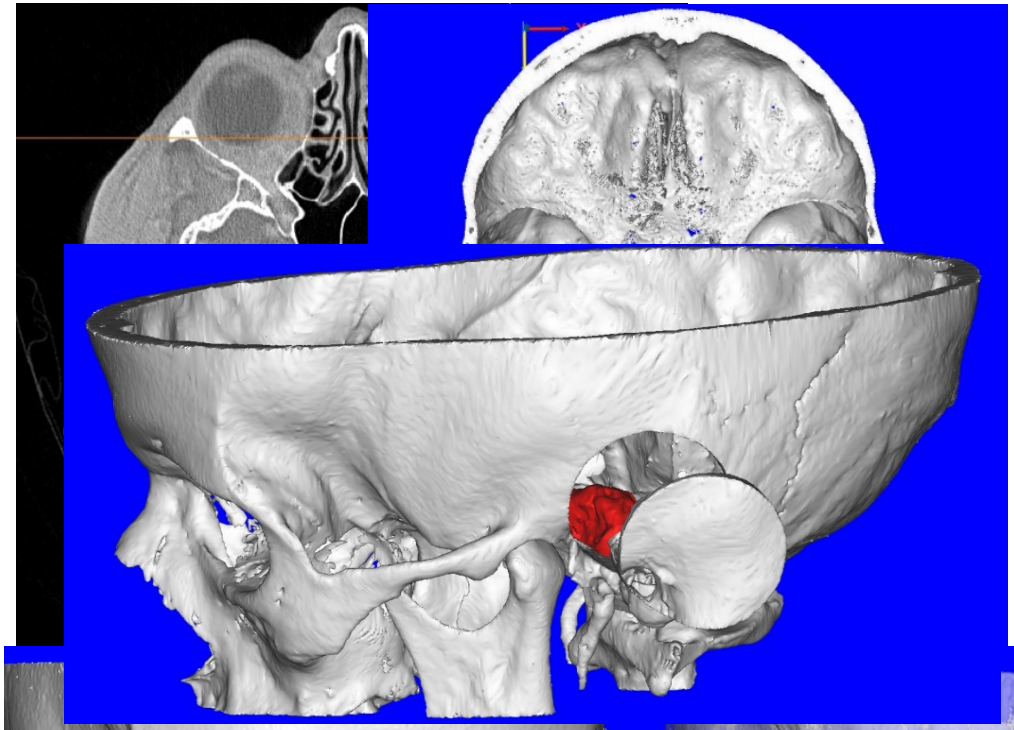


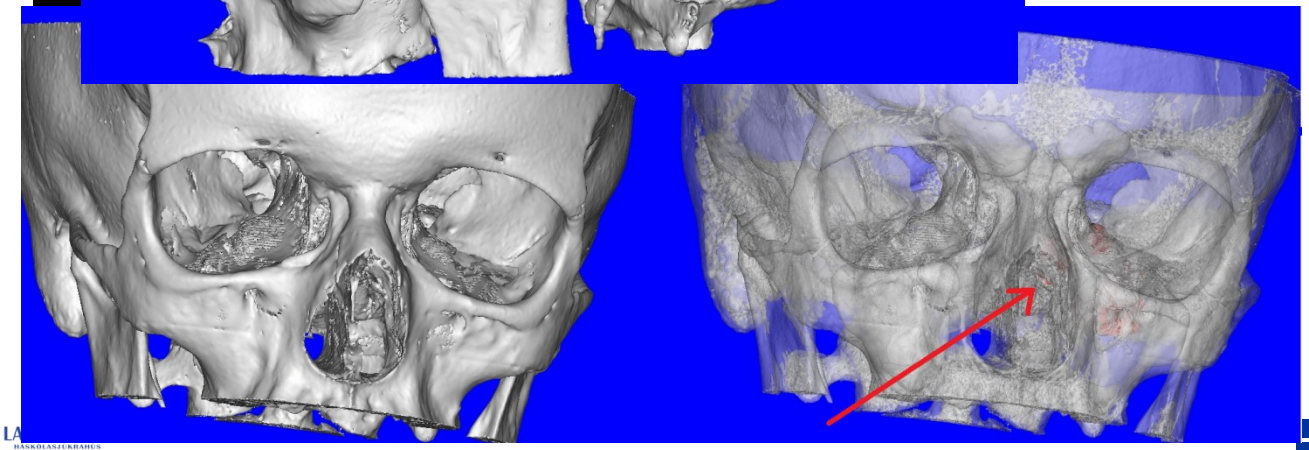
Combined use of Rapid Prototyping techniques and navigation system for brain surgery planning

A navigation system allow surgeons to visualize the patient's anatomy in 3D prior to and during surgery while also seeing the exact location of their surgical instrumentation



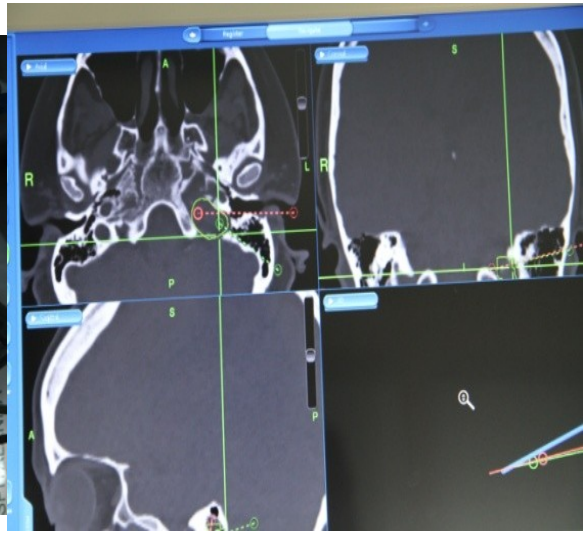
Study Case: Chalesteatoma Removal



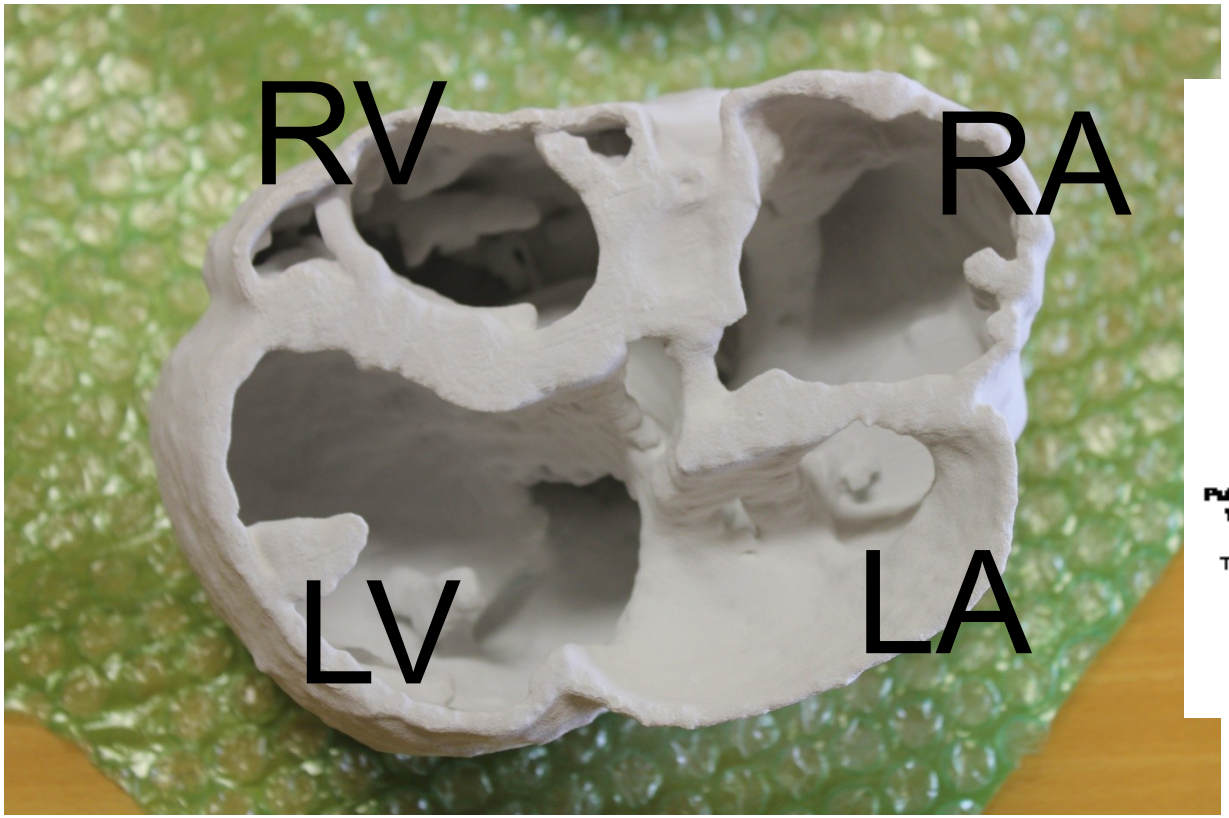


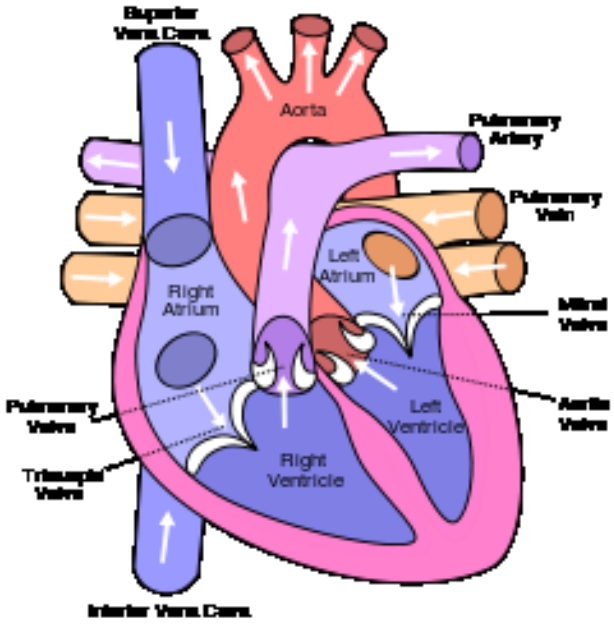
- 42 years old patient with a cholesterol granuloma in a very complicate position, wrapped between the middle ear bones

Surgical Plannig based on the 3D-Model

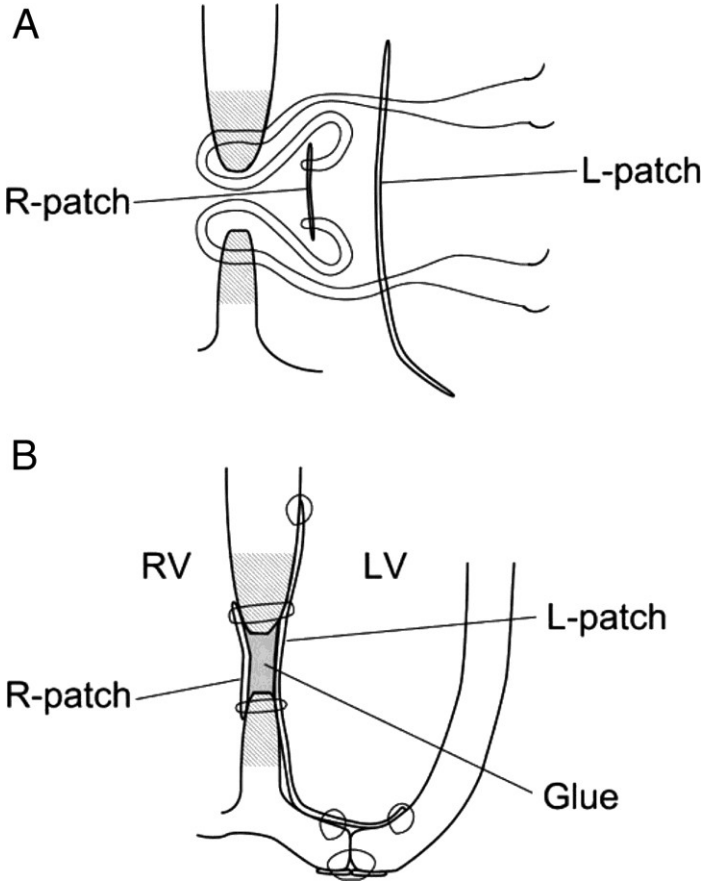


Emerging applications: Cardio Surgery planning

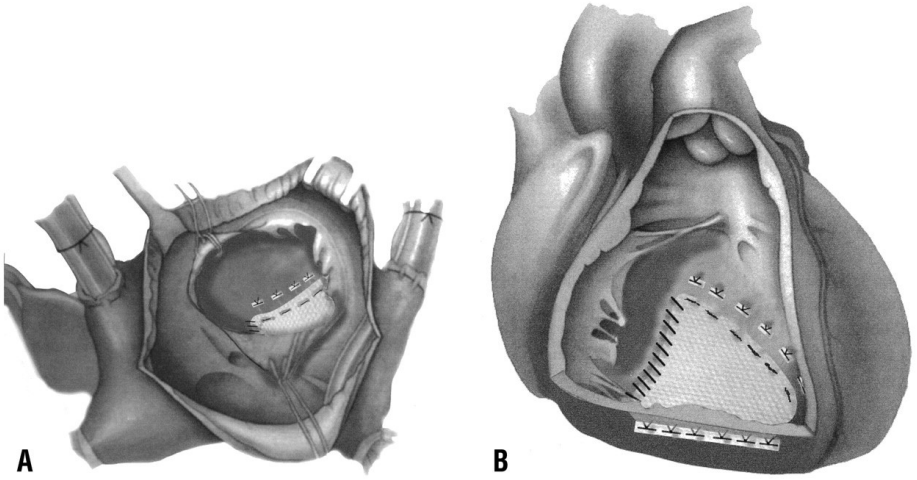




Modelling Ventricular Septum Defect for surgery planning

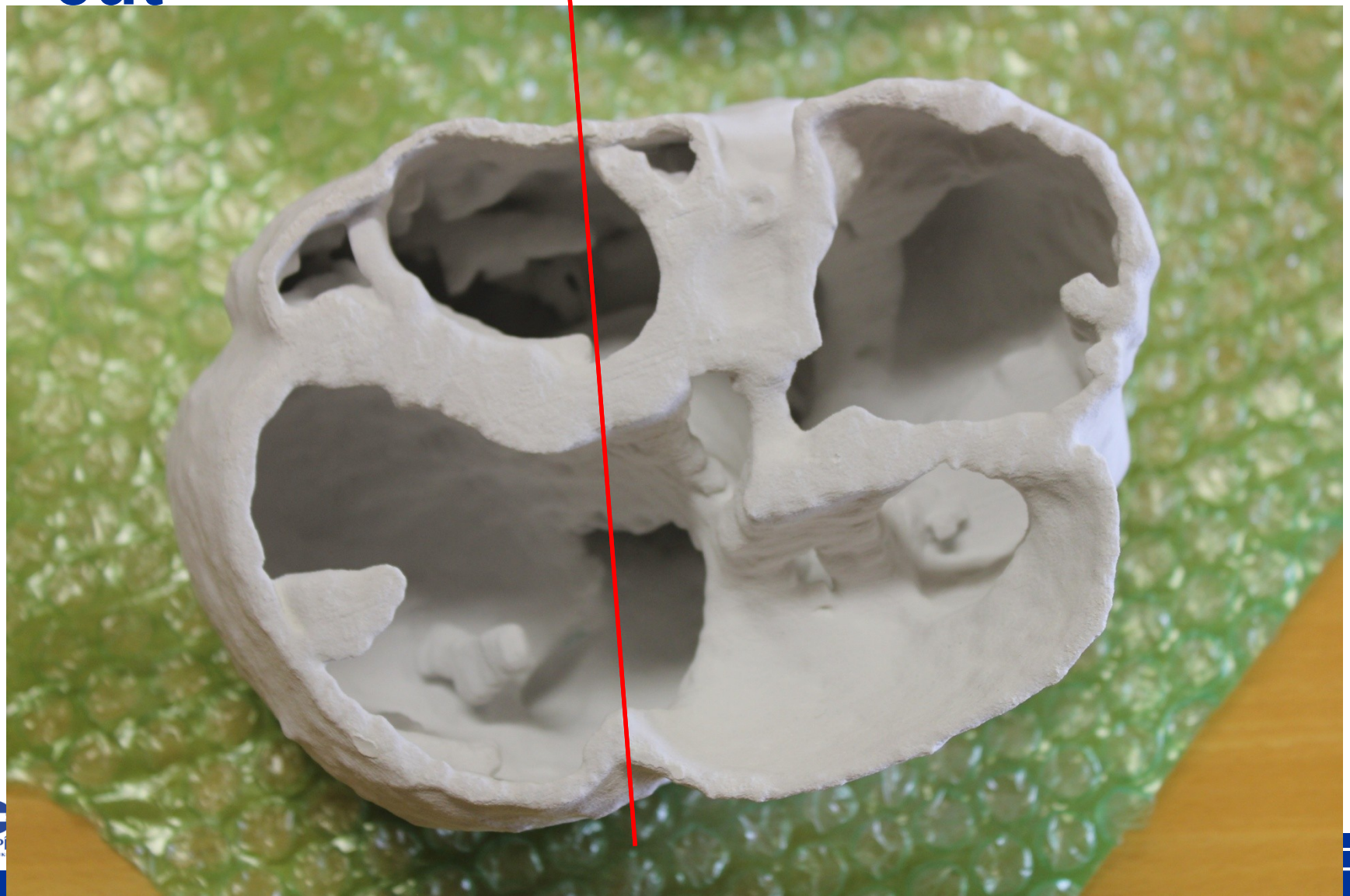


Takahashi S et al. Interact CardioVasc Thorac Surg 2012;14:353-355

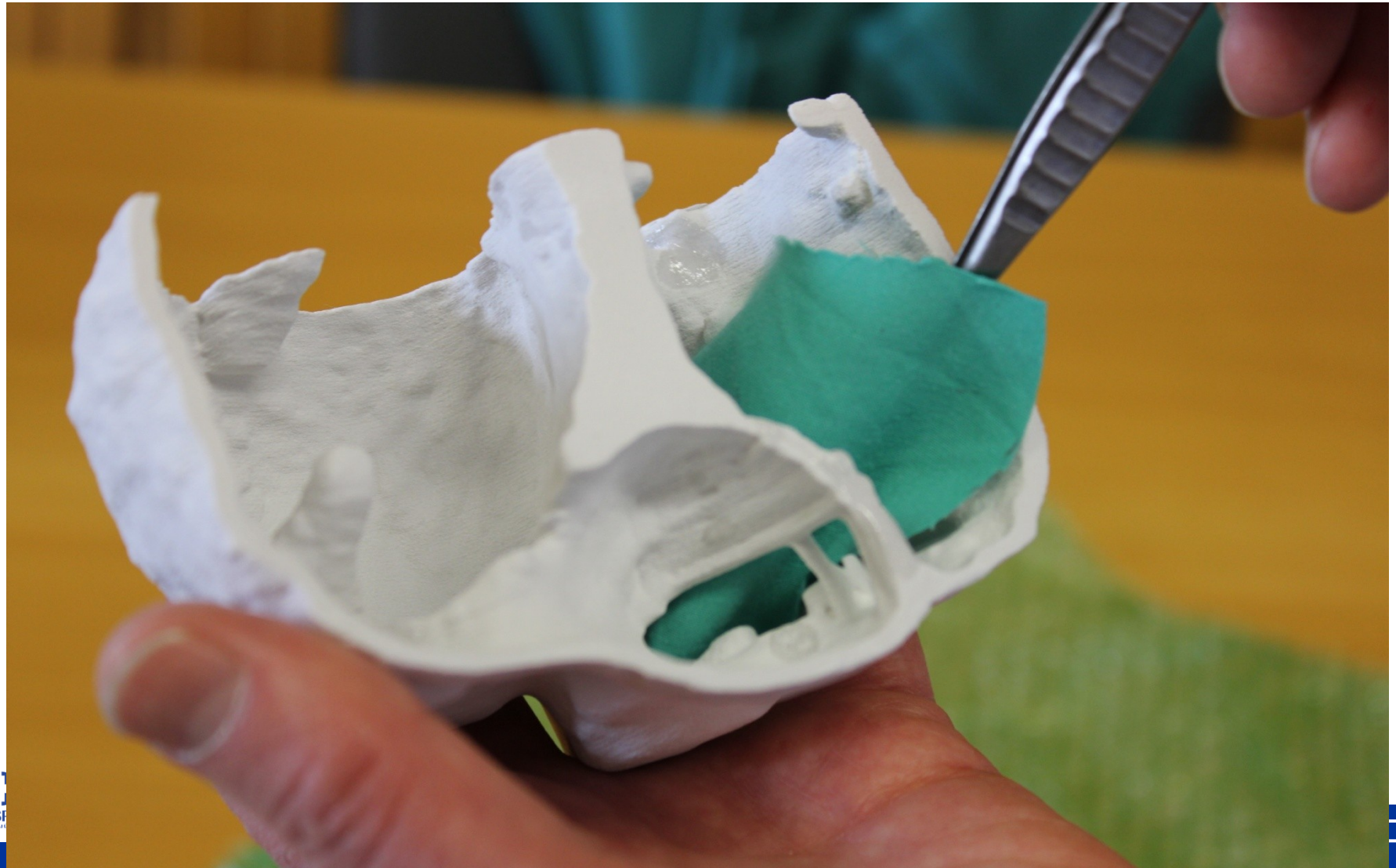


Massetti M. et al.; J Thorac Cardiovasc Surg 2000;119:784-789

cut



Patch Scale model 1:1 in RV



Patch Scale model 1:1 in left V

Economic and social benefits

- **Reduction operation time:** According to Hagdeild LSH, the operation cost per minute for the surgeries that have been supported u 4000 to 7000 ISK per minutes. Us up 90 minutes.
- **Avoid unnece** rom the surgery type, but addi ociated department co less than 5 millions/surgery
- **Improve patient outc aving patient life ...**

THANKS!