Analysis of Implants and Wood Based Products from CT-Data

Festkolloqium Parallel Computing: Algorithms, Applications and Architectures

on the occassion of the 60th birthday of Prof. Marian Vajteršic.

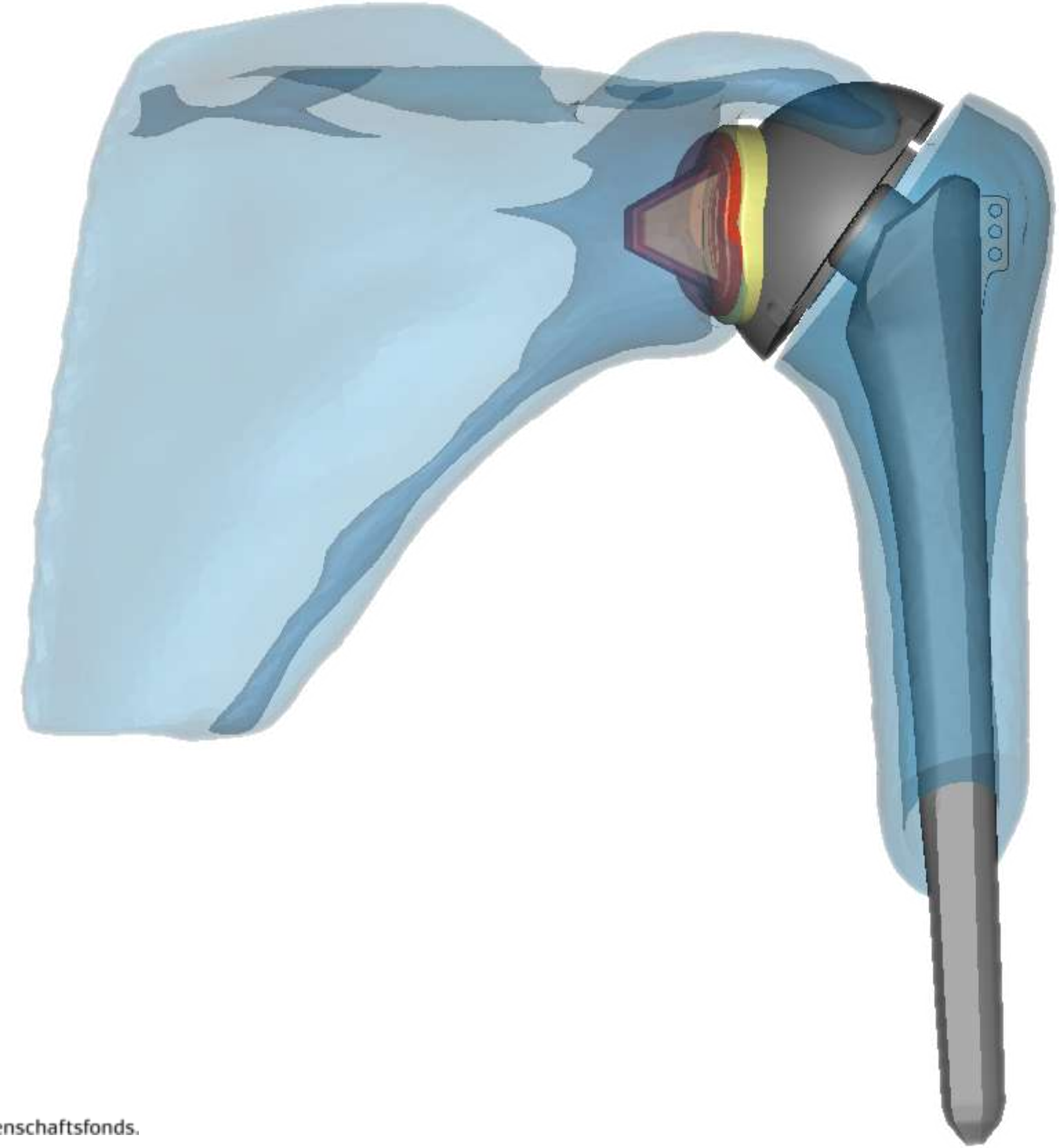
Karl Entacher

fhs Fachhochschule Salzburg

FWF

Content

- Some personal comments
- Analysis of Implants
  - Shoulder Prosthesis
  - Dental Applications
- Analysis of Wood from CT-Data
  - FEA of Wood
  - Wood Based Products



fhs Fachhochschule Salzburg

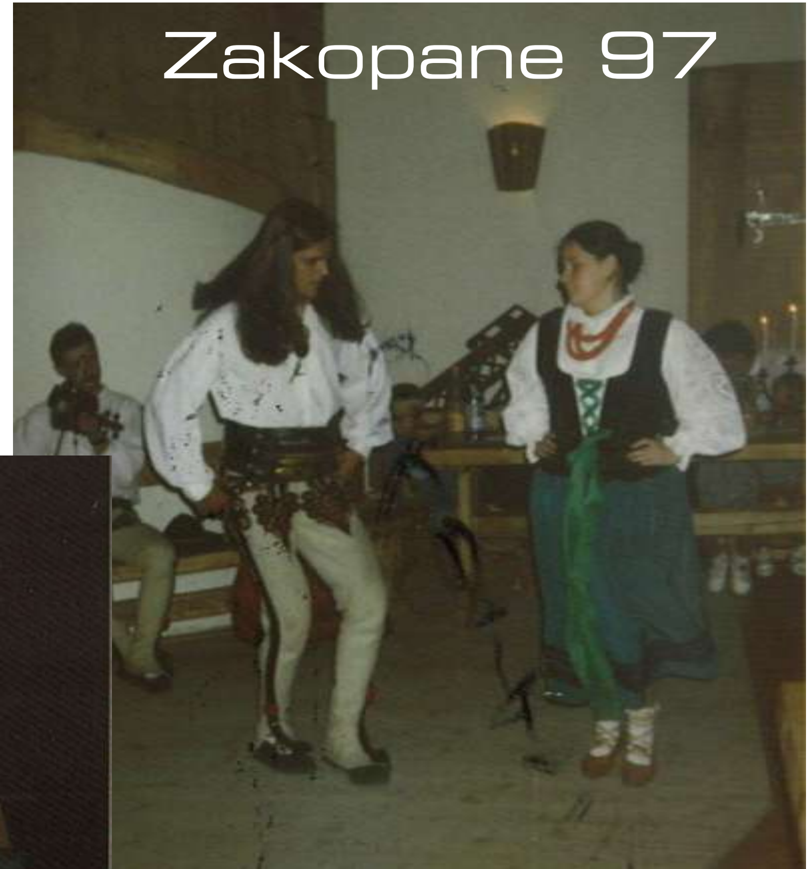
FWF Der Wissenschaftsfonds.

Some Personal Comments

- **1992**: Started to work on my PhD-thesis “quasi Monte Carlo Methods”
- **ParNum94**: Smolenice, Slovakia, 1994
  - First talk at a conference!
- **ParNum95:** Sorrento, Italy, 1995
  - Parallel Stochastic Simulation: Inversive Pseudorandom Number Generators
- **ParNum96**: Gozd Martuljek, Slovenia, 1996
  - On the Relevance of Splitting Properties and the Compound Method in Parallel Applications of Pseudorandom Number Generators
- **ParNum97:** Zakopane, Poland, 1997
  - Analyzing Streams of Pseudorandom Numbers for Parallel Monte Carlo Integration
- **ParNum00:** Bratislava, Slovakia, 2000
  - Further Remarks on Long-Range Correlations among LCGs
- **ParNum02:** Bled, Slovenia, 2002 (FHS)
  - A simple OMNeT++ queuing experiment using parallel streams.
- **ParNum05:** Portoroz, Slovenia, 2005 (FHS)
  - Selection of Good Lattice Points Utilizing a Cluster


Sorrento 95


ARALLEL
UMERIC


Zakopane 97

Bled 02

Some Personal Comments

- **1992 – 2001:** Research Assistant at the University of Salzburg
  - **FWF** - P9285 P11143 P12654 P8303 P12441 **ÖNB** - 7576
    Peter Hellekalek, Gerhard Larcher
  - **CEI - PACT** WP5, **FWF** P13732
    Peter Zinterhof, Marian Vajteršic

- **2001 → :** Position at the Salzburg University of Applied Sciences
  - Continued with FWF P8311-MAT "Quasi-Random Points: Theory and Software Development" together with Wolfgang Schmid
  - **ParNum02**: Bled, Slovenia and **ParNum05**: Portoroz, Slovenia
- **1995 → :** Lecturer at the School of Forest Products Technology & Timber Construction at the Salzburg University of Applied Sciences (FH-Salzburg)

2006 – New Topics – New Team

Cooperation of HTB and ITS at the FHS

Scientific
Computing

Alexander Petutschnigg
CT – Materialanalysis
Finite Elemente Method

Werner
Pomwenger
PhD - Student

Thomas
Forte
Researcher

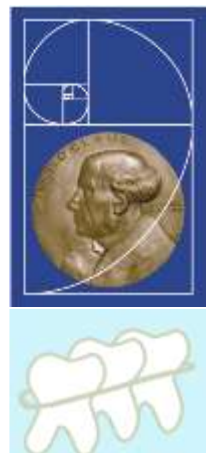
Michael
Eichriedler
Diploma Student

with *Paracelsus Medizinischen Privatuniversität PMU*

Peter Schuller-Götzburg
Biomechanics
Project Leader PMU

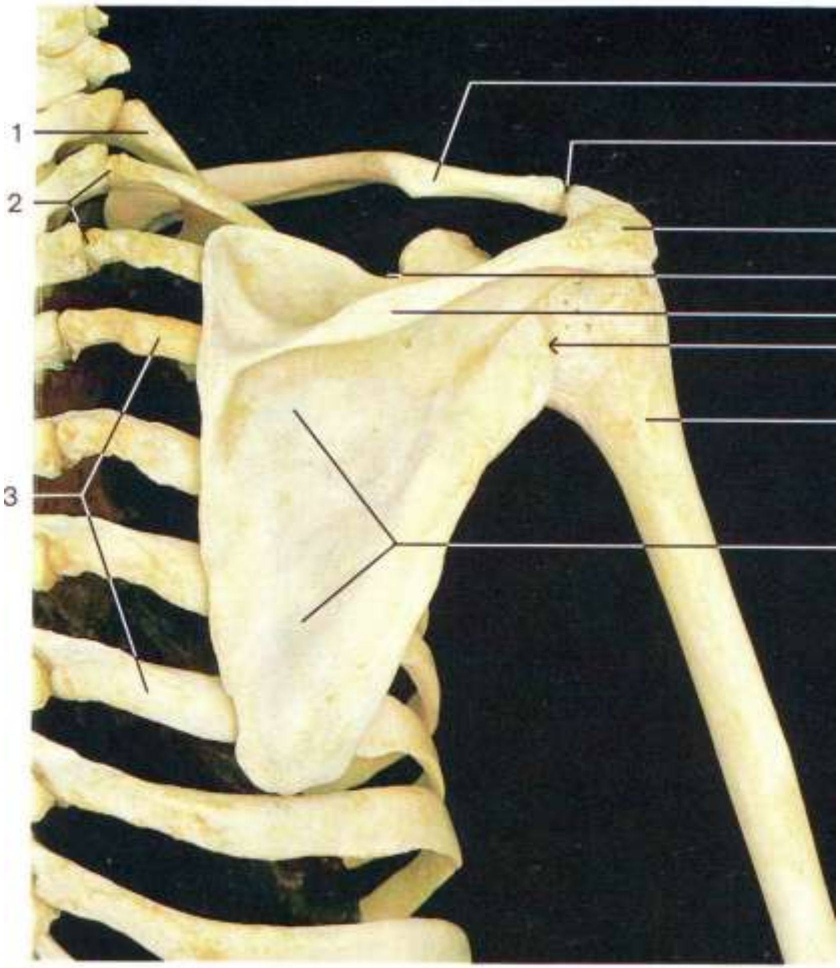
Prim. Herbert Resch
Shoulder- and
Ellbow Surgery

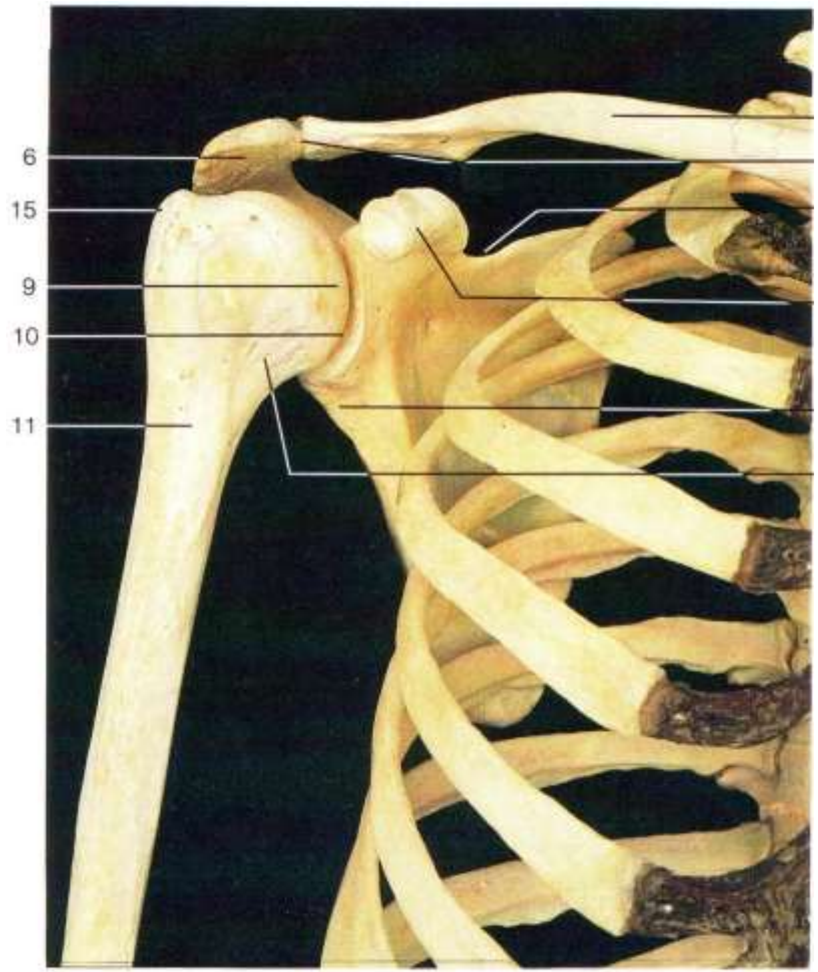
Rosemarie
Forstner
Radiology



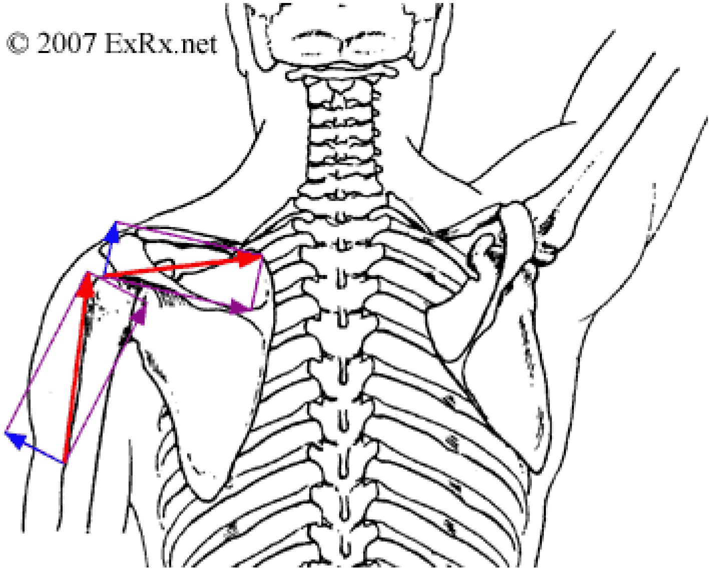
F. Watzinger
Landesklinikum
St. Pölten

Patient Specific Analysis of Shoulder Implants





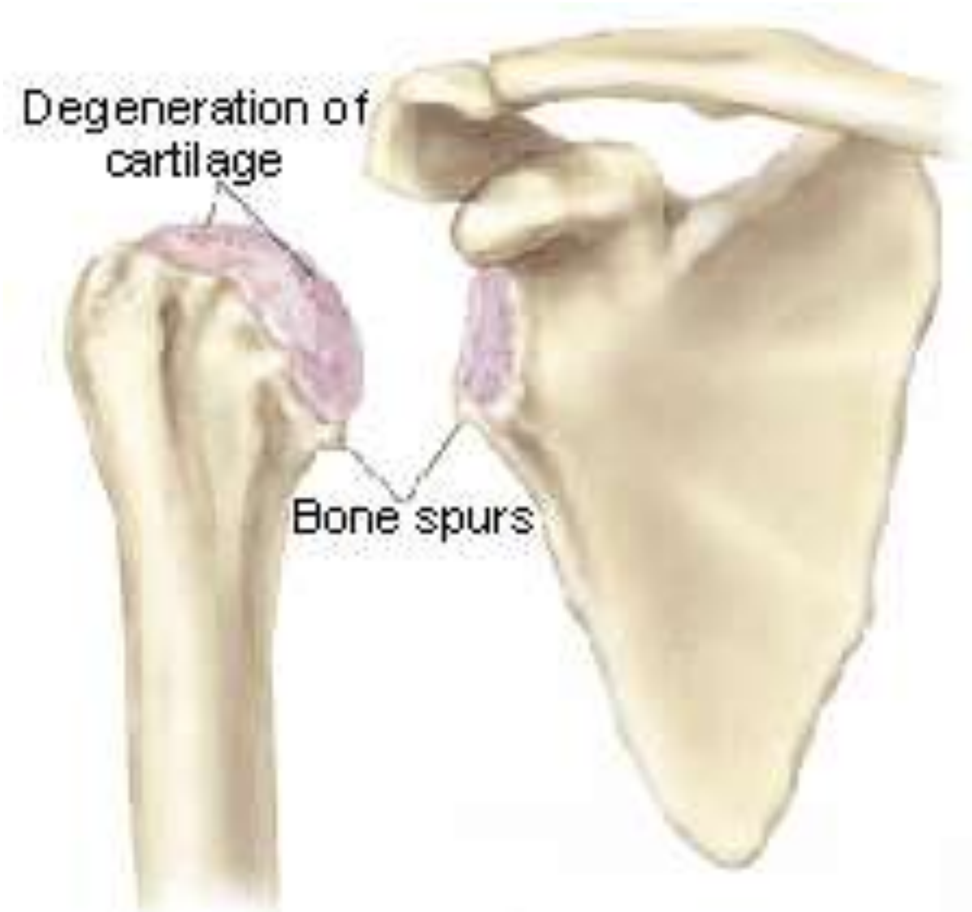
Anatomy and Simple Movements

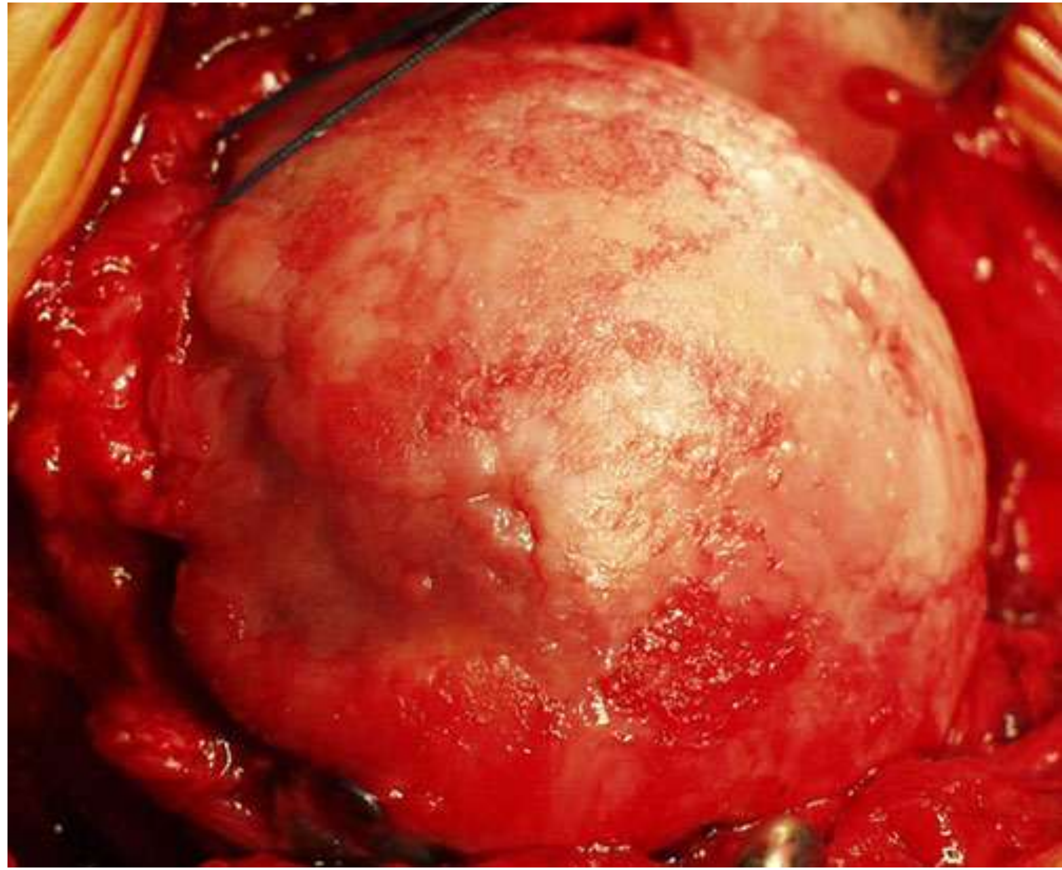


Abduction
Adduction

http://130.60.57.9/bewegungsapparat/index.swf (Mai 08)

Glenohumeral (shoulder) arthritis





Glenohumeral (shoulder) arthritis is a common source of pain and disability that affects up to 20% of the older population. Damage to the cartilage surfaces of the glenohumeral joint (the shoulder's "ball-and-socket" structure) is the primary cause of shoulder arthritis. http://www.leadingmd.com/ (May 2010)

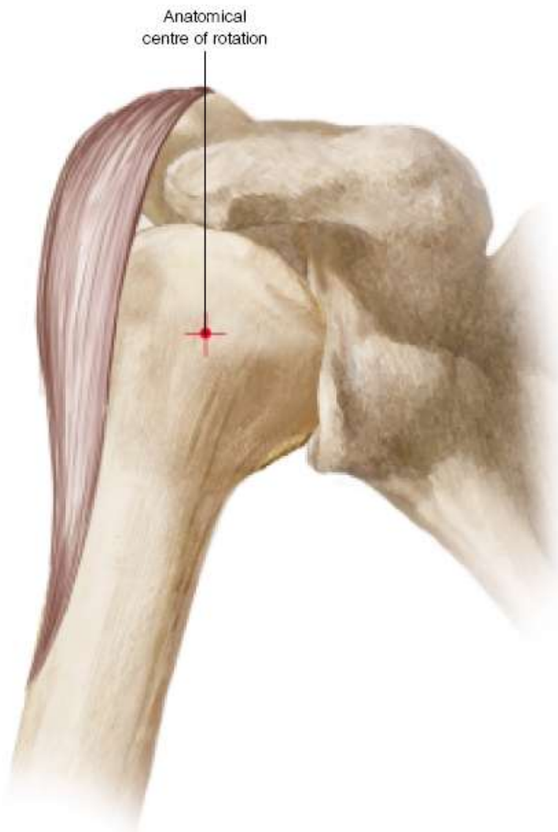
Total Shoulder Rep. - Anatomical Prosthesis

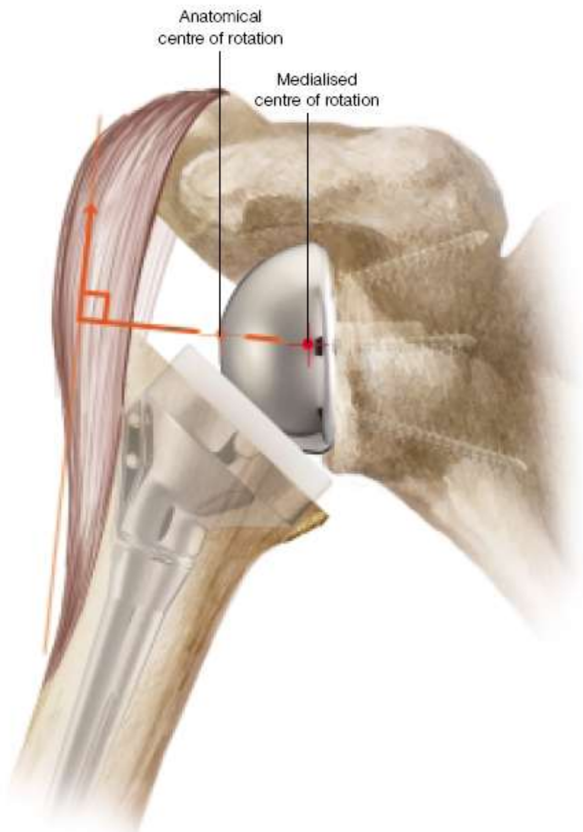
http://fly2india4healthblog.wordpress.com/
(May 08)

http://www.zimmer.co.uk/ http://www.joint-orthopedics.com/ http://www.stryker.com http://www.opnews.com/ (May 08)

Delta CTA™ Reverse Schulter Prothese

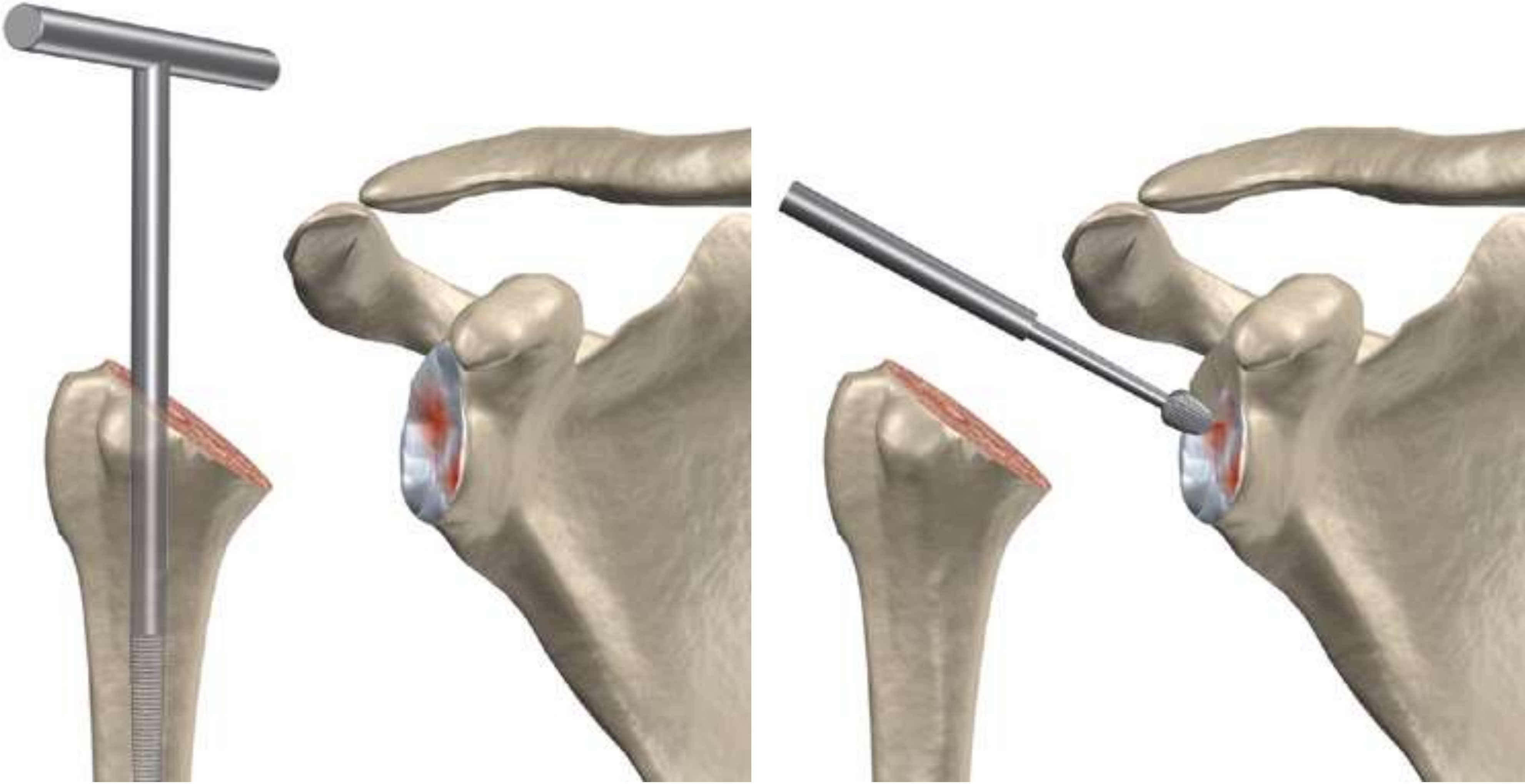
http://www.mybones.com/
http://www.shoulderdoc.co.uk





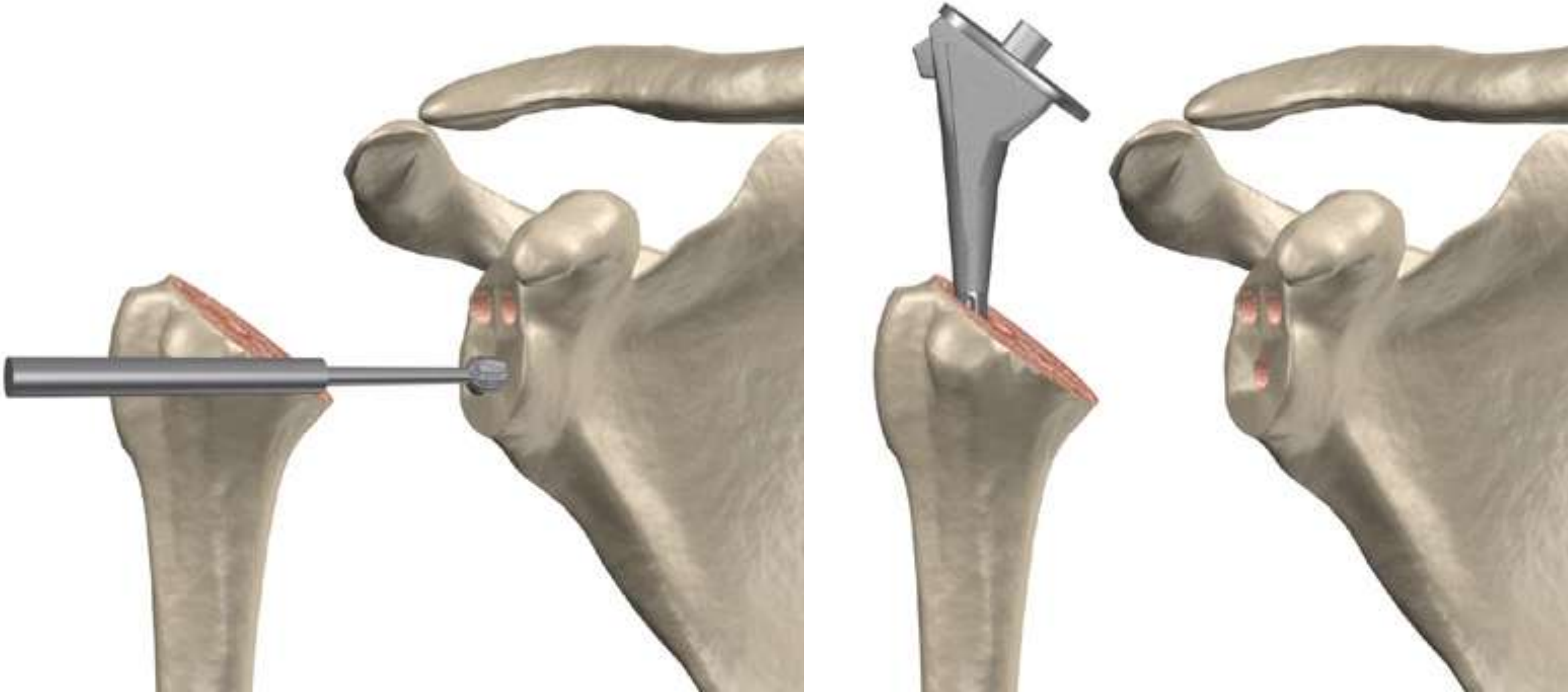
TSA - Total Shoulder Arthroplasty

TSA - Total Shoulder Arthroplasty



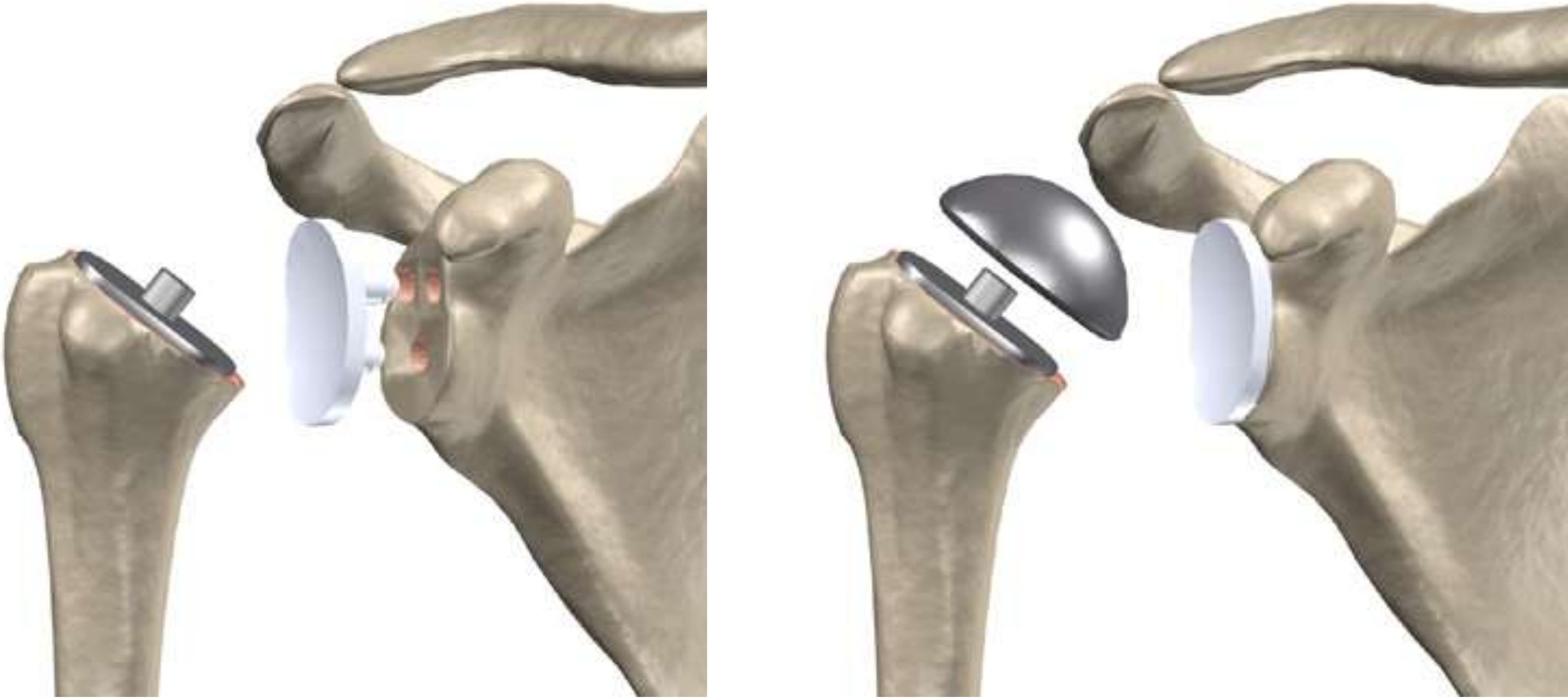
[8]

TSA - Total Shoulder Arthroplasty



[8]

TSA - Total Shoulder Arthroplasty



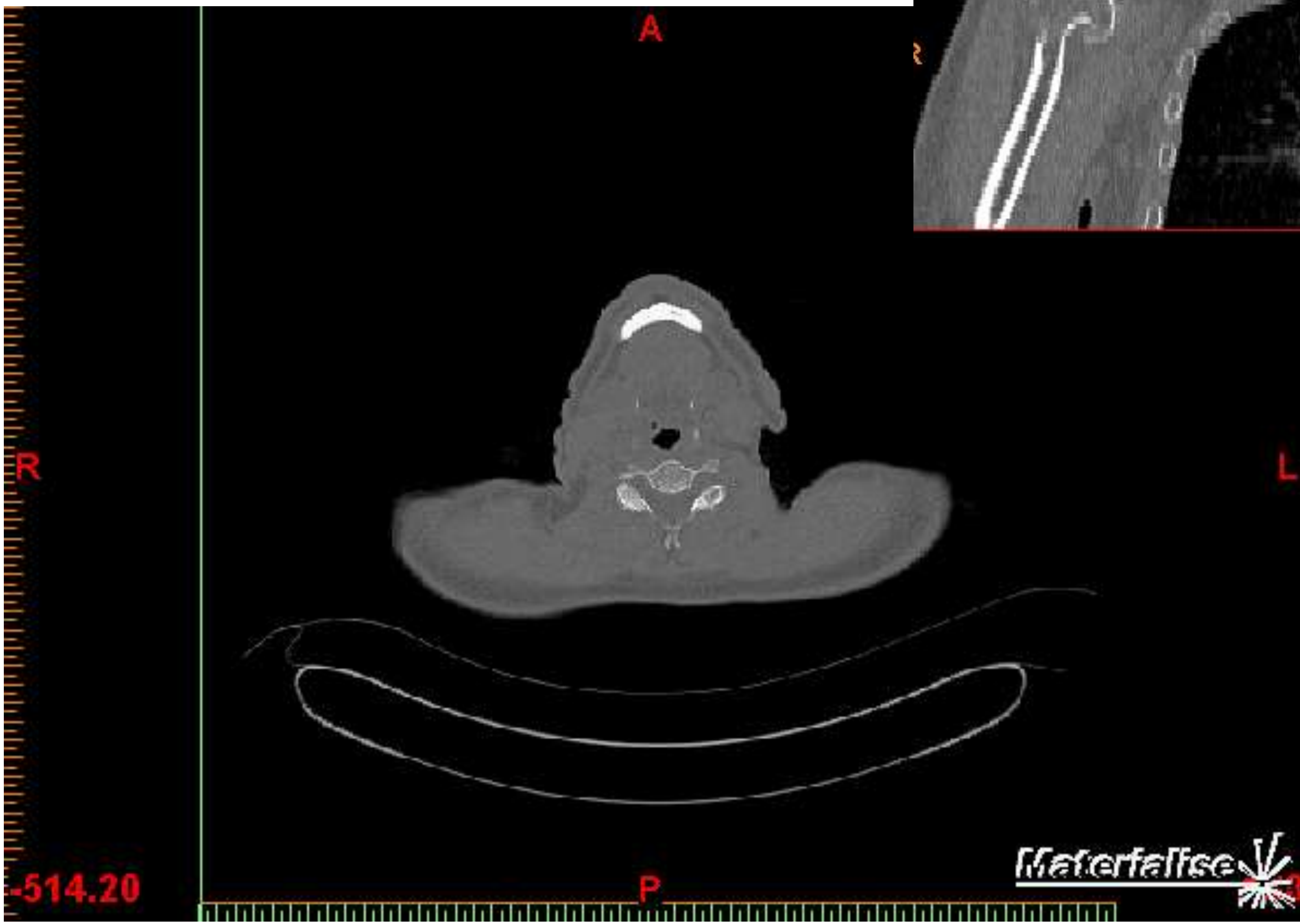
[8]

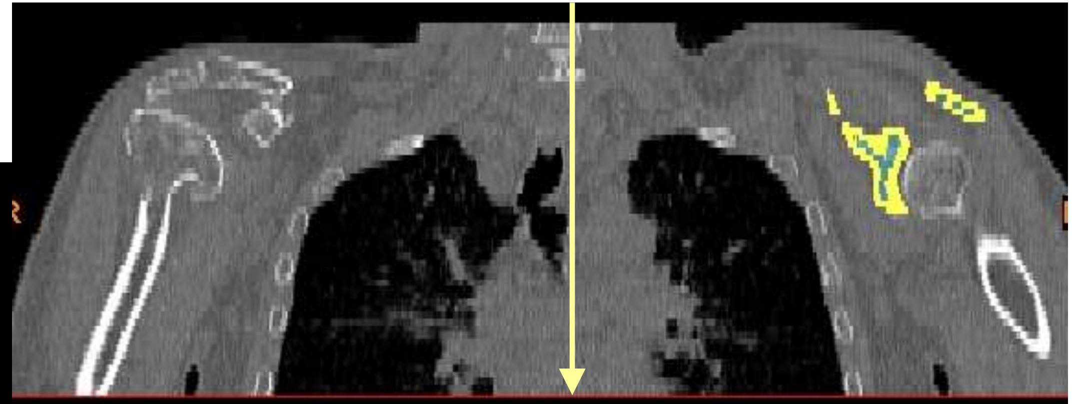
Patient Specific Analysis of Shoulder Implants

FWF – Project L526-B05

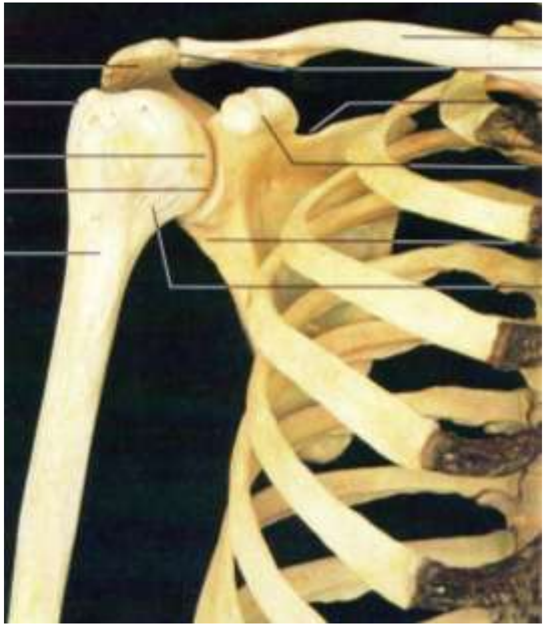
Image Set:	Barbara	Franziska	Erich	Rudolf	Klaus
Orig. Angle:	65	63	64	65	55
3D Model					

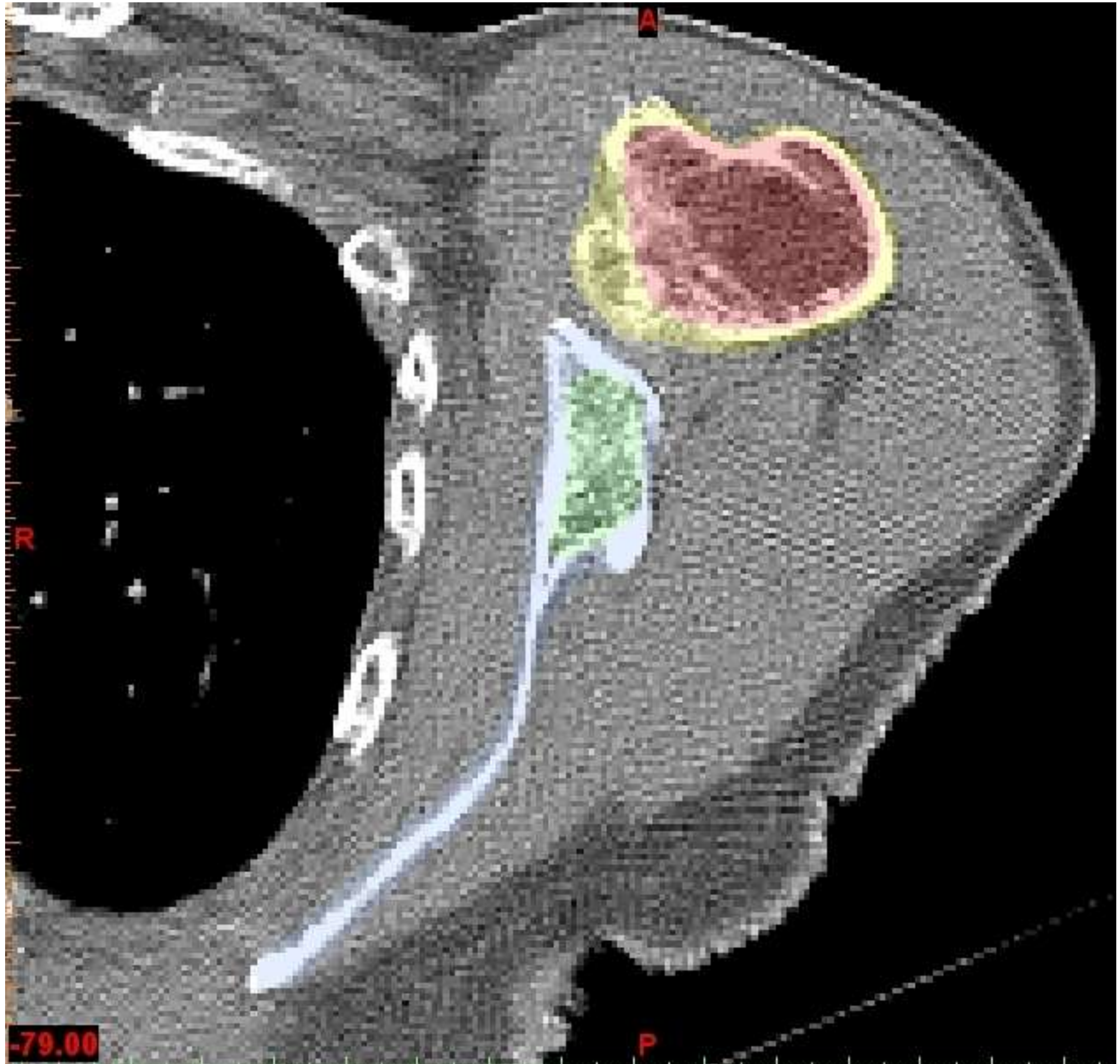
CT - Scans: Basis for 3D-Modelling



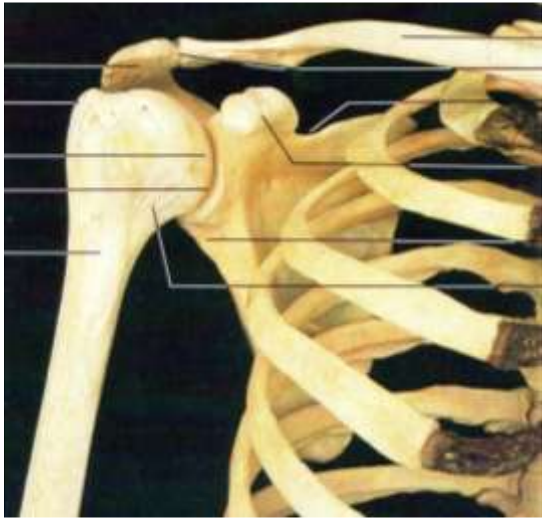


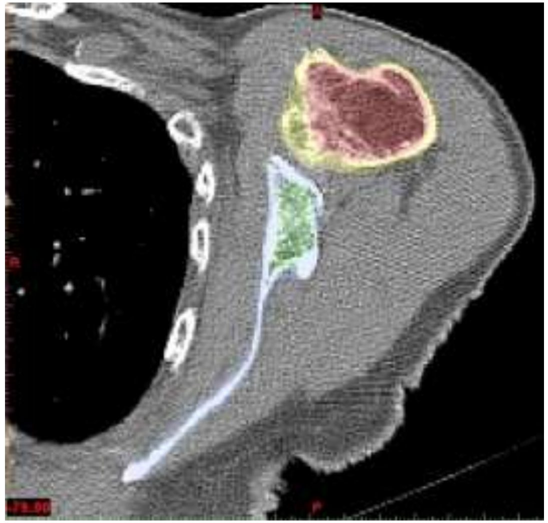
3D – Modelling - Segmentation

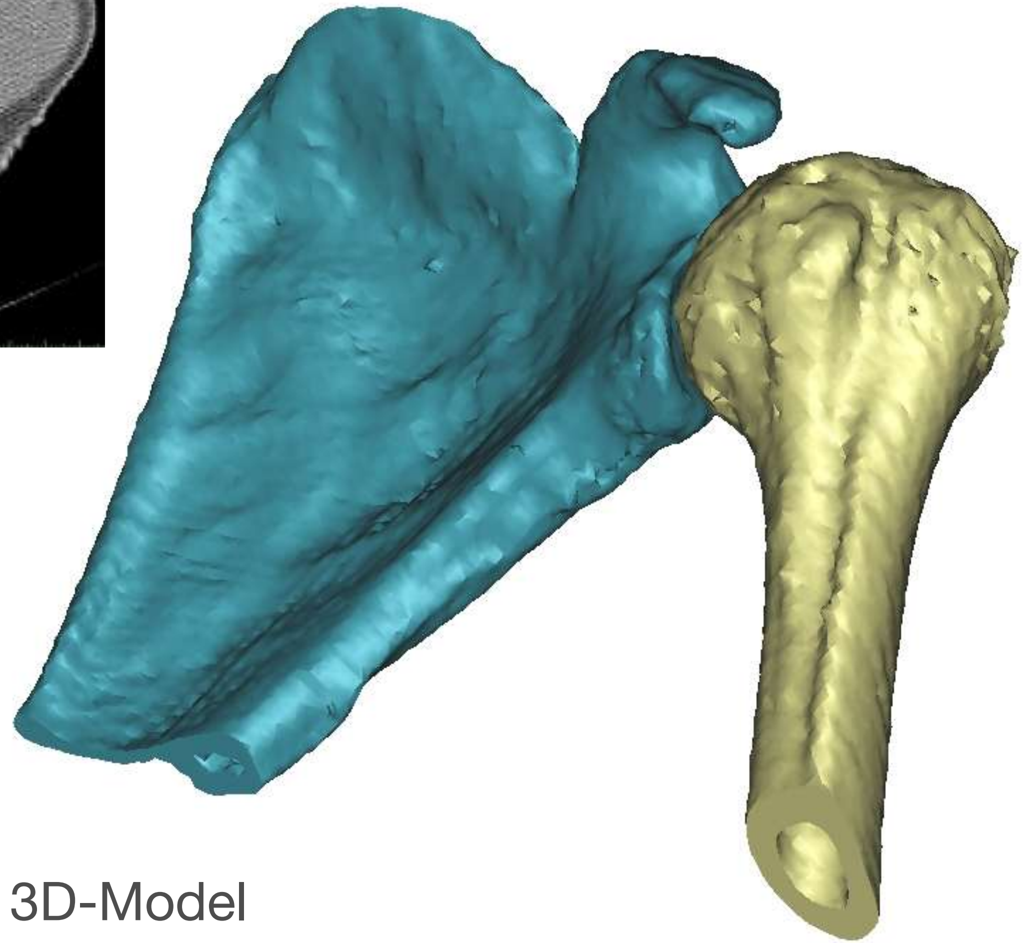




3D - Modelling - Surface Models

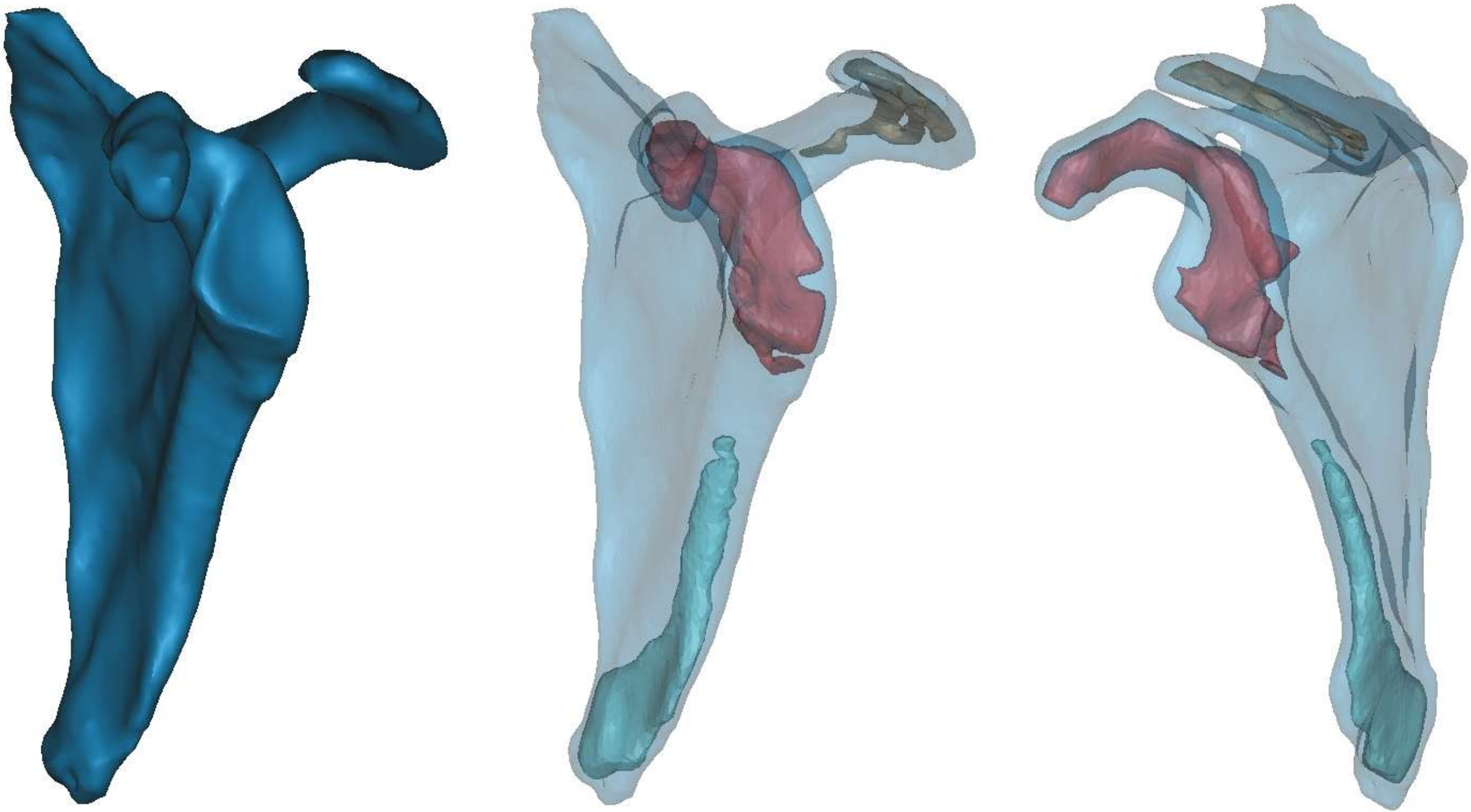






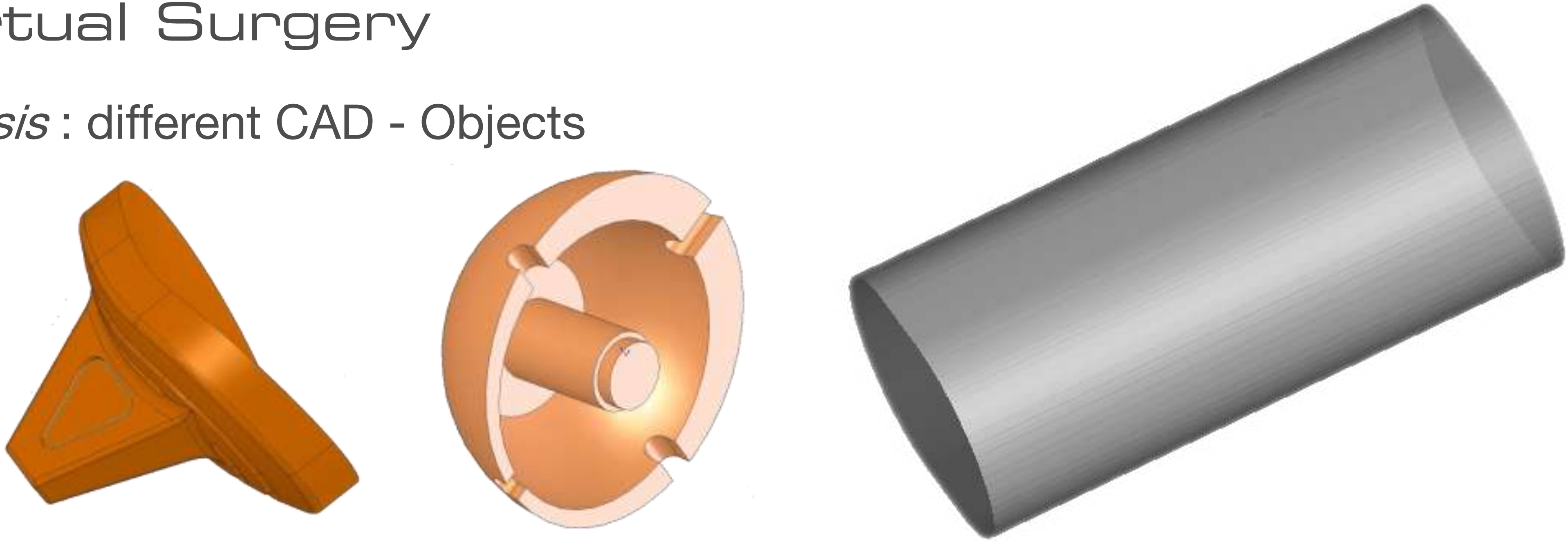
3D-Model

3D – Modelling - Smoothing

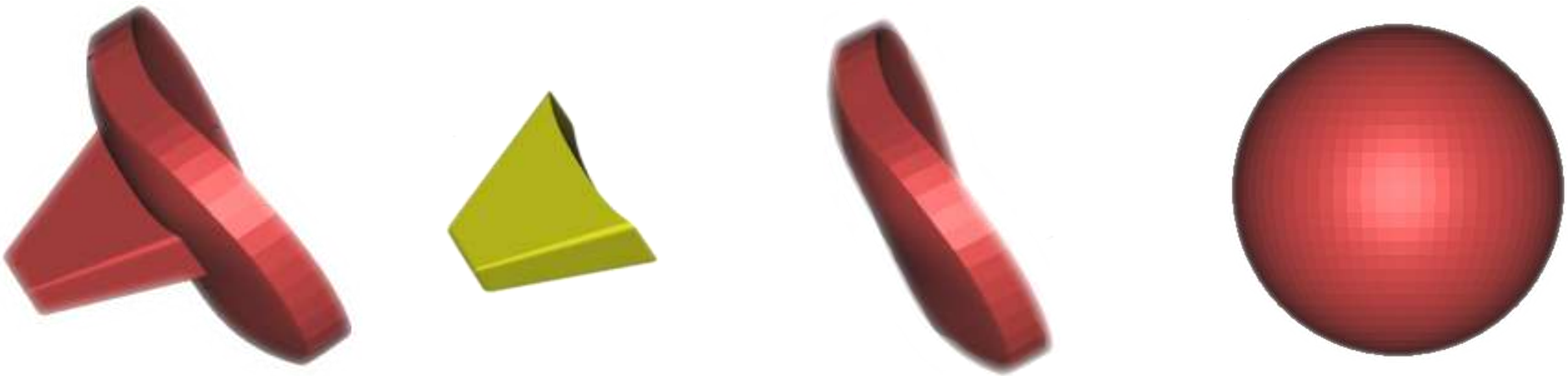


Virtual Surgery

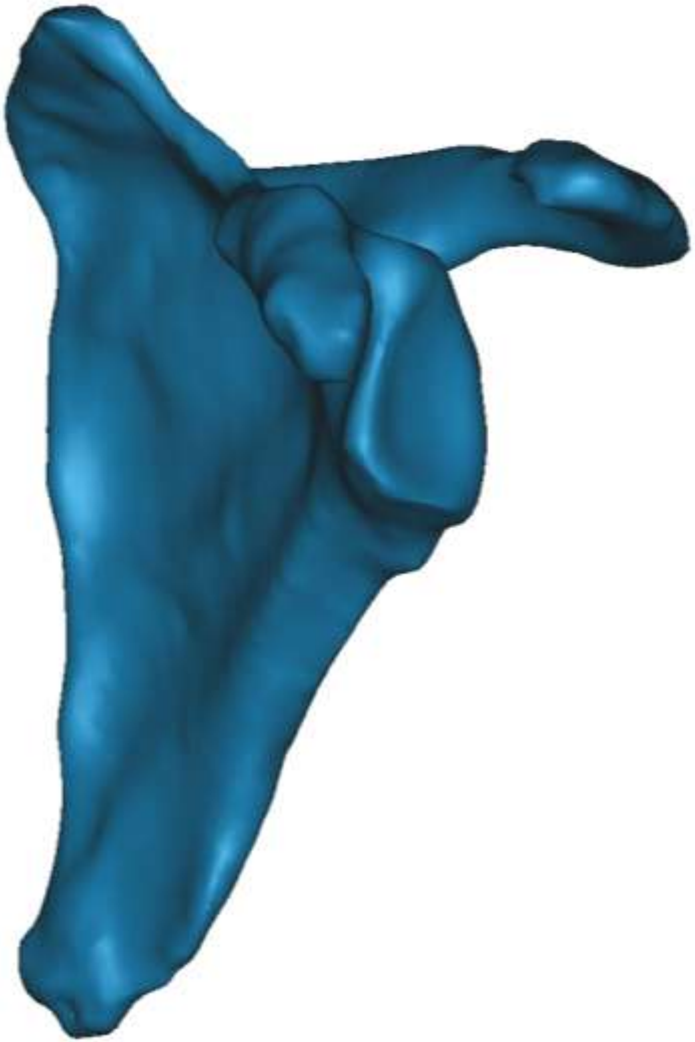
Basis : different CAD - Objects



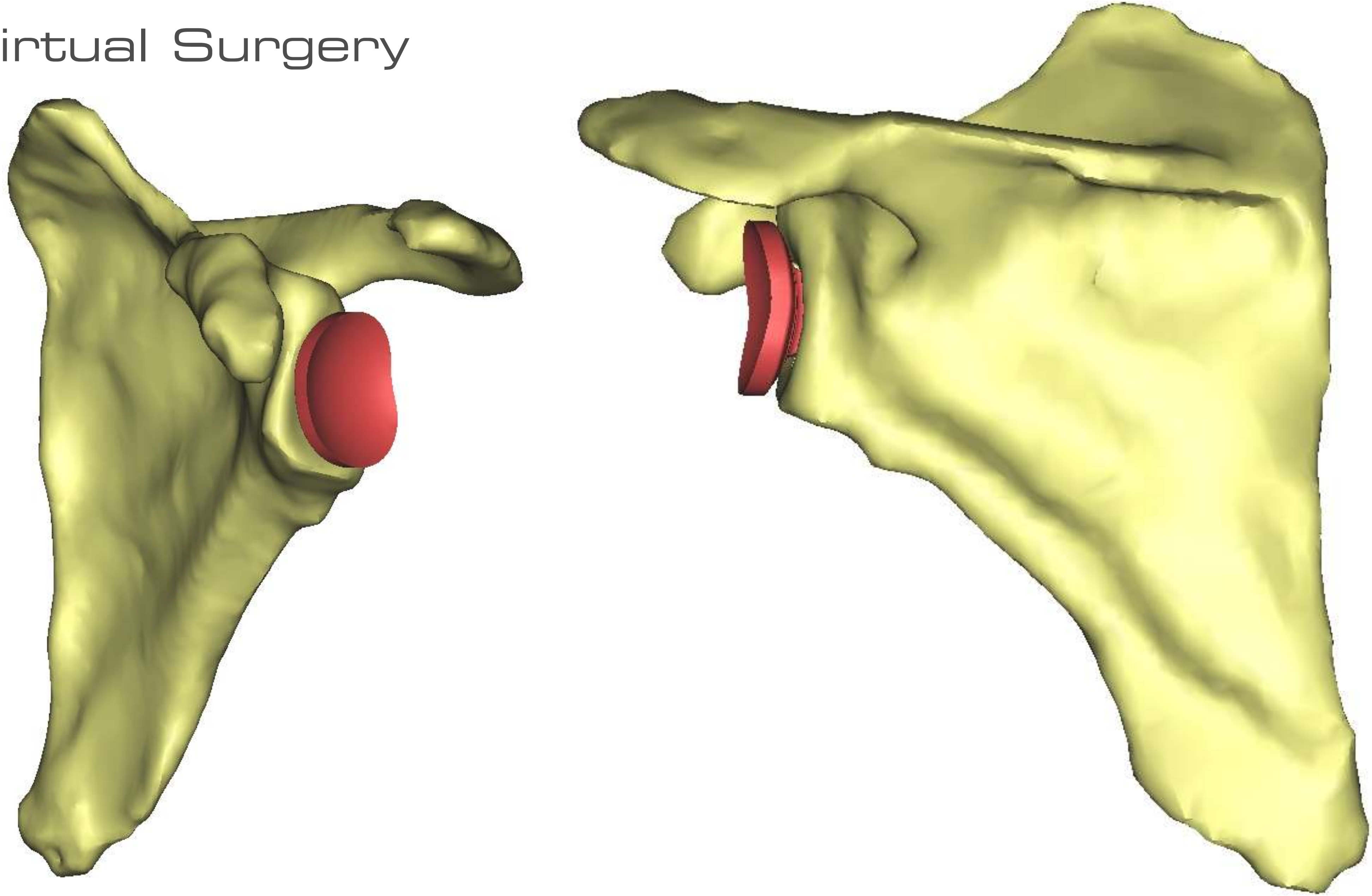
Method : Boolean Methods with different Templates



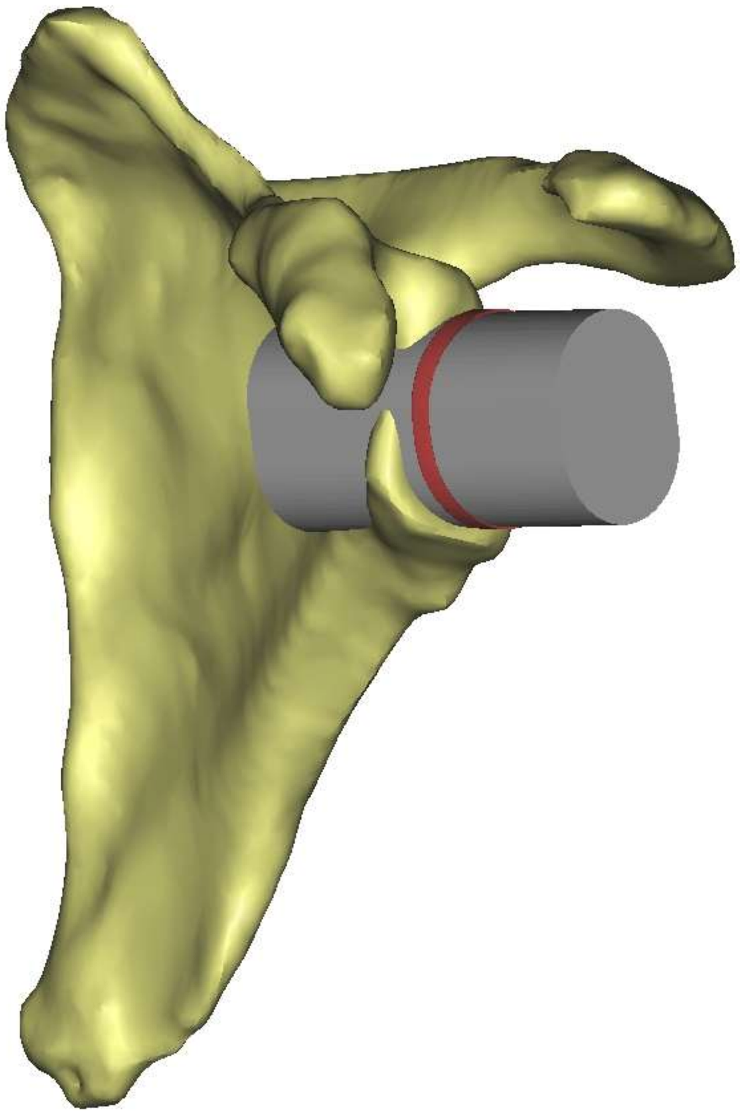
Virtual Surgery

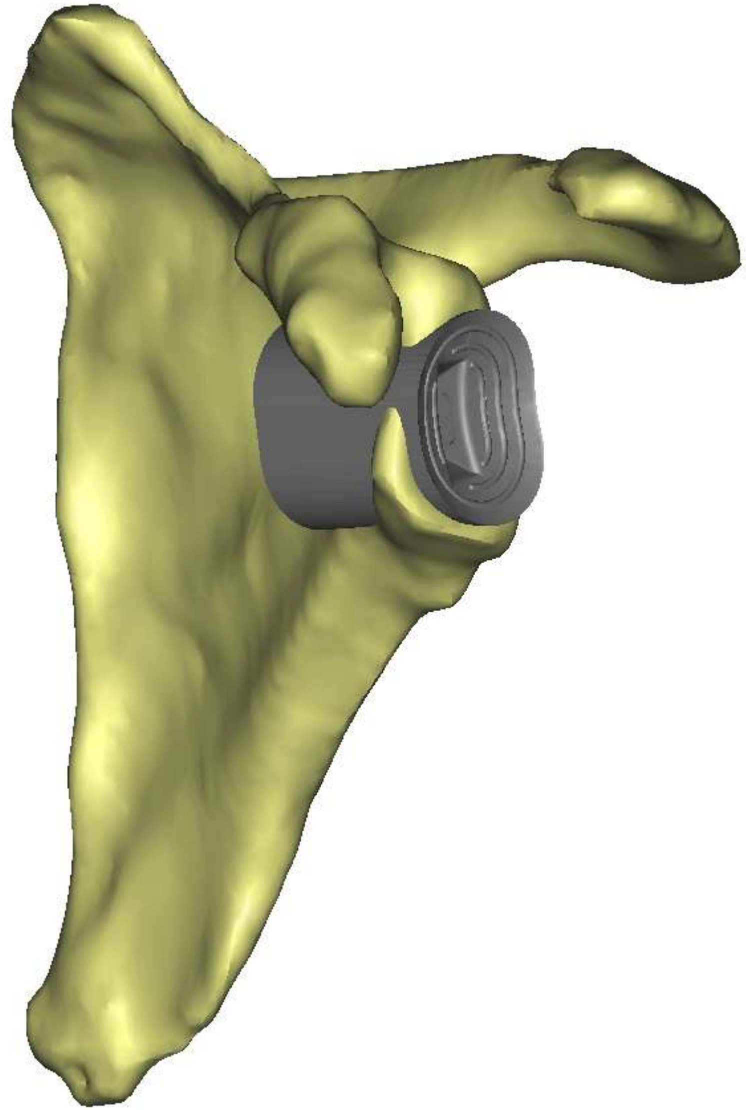


Virtual Surgery

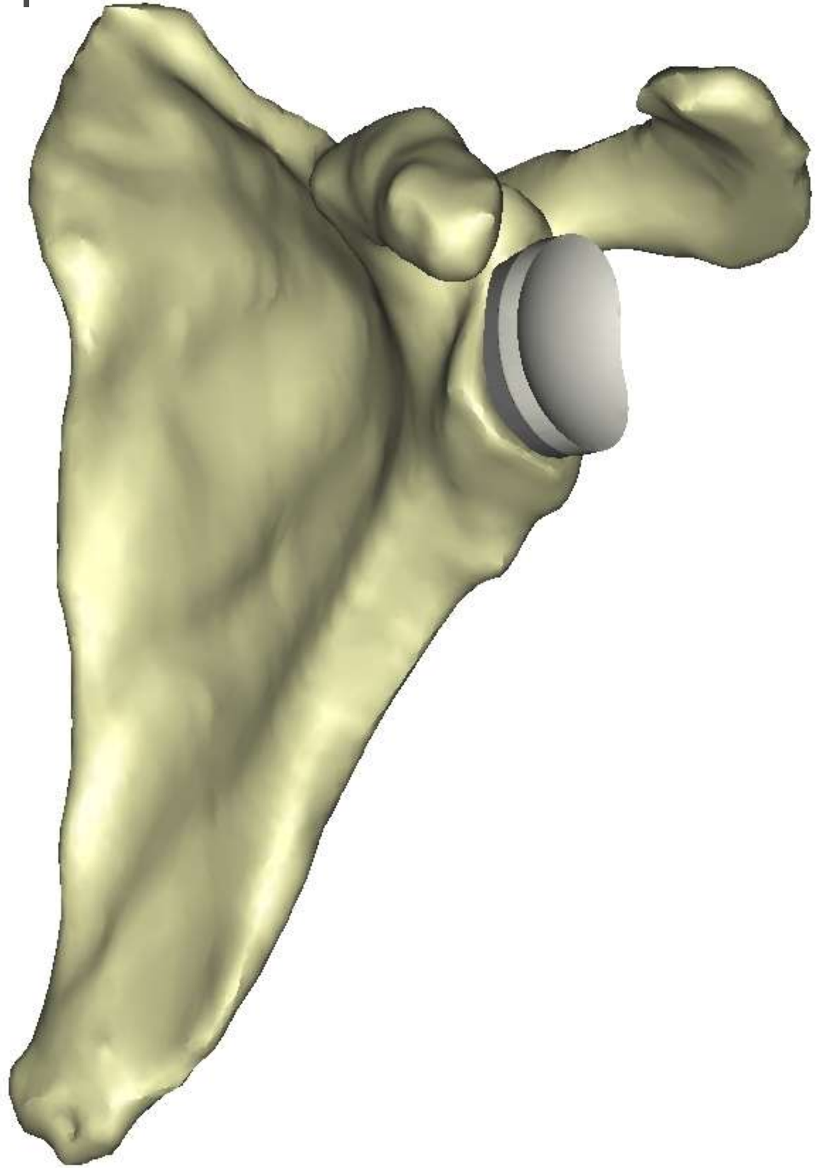


Model of Medical Cement

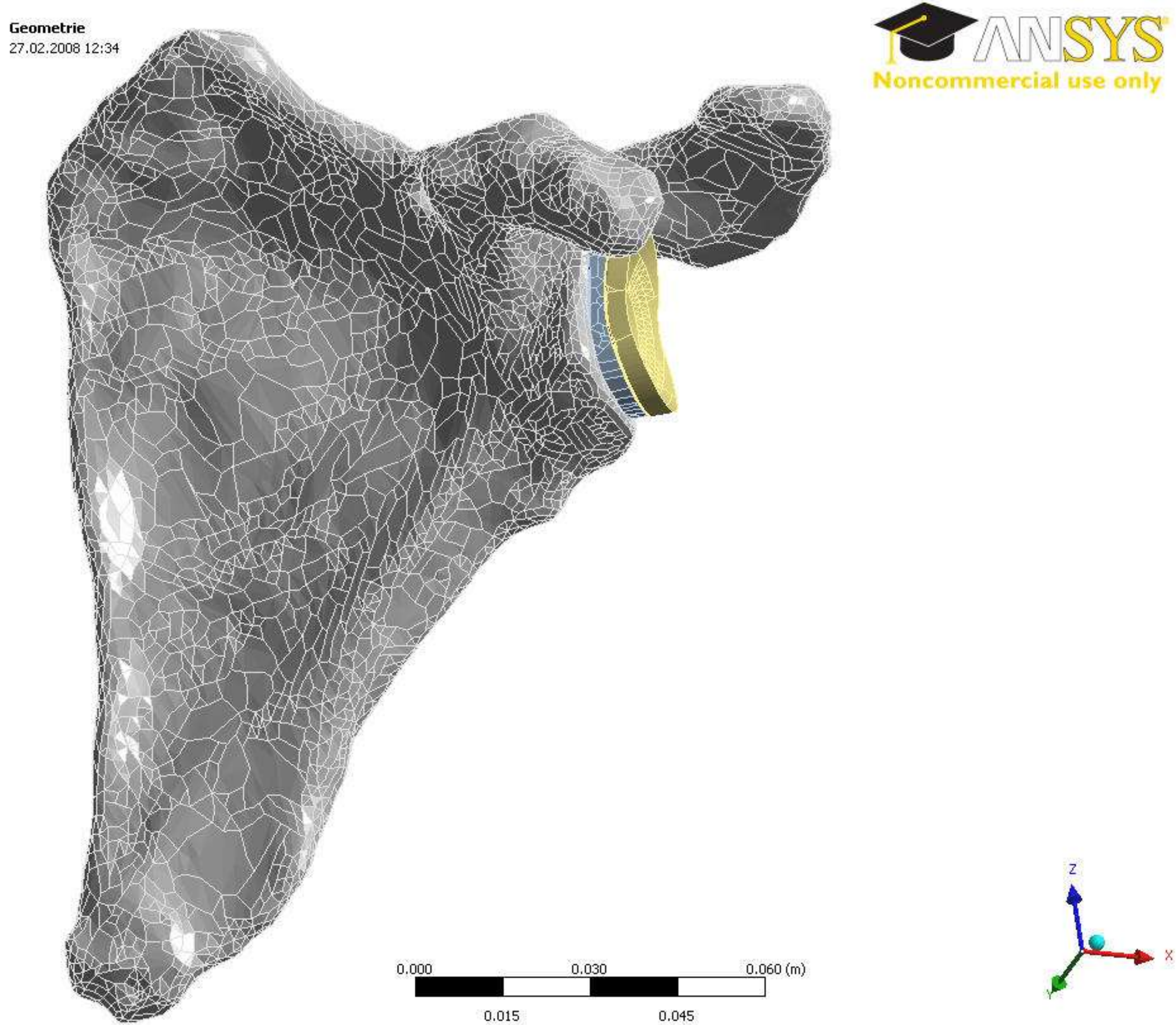




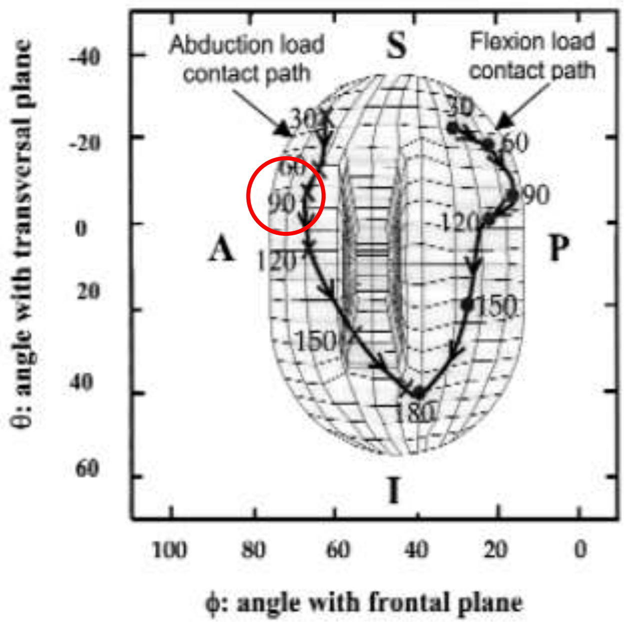
3D-Model of an implanted Shoulder

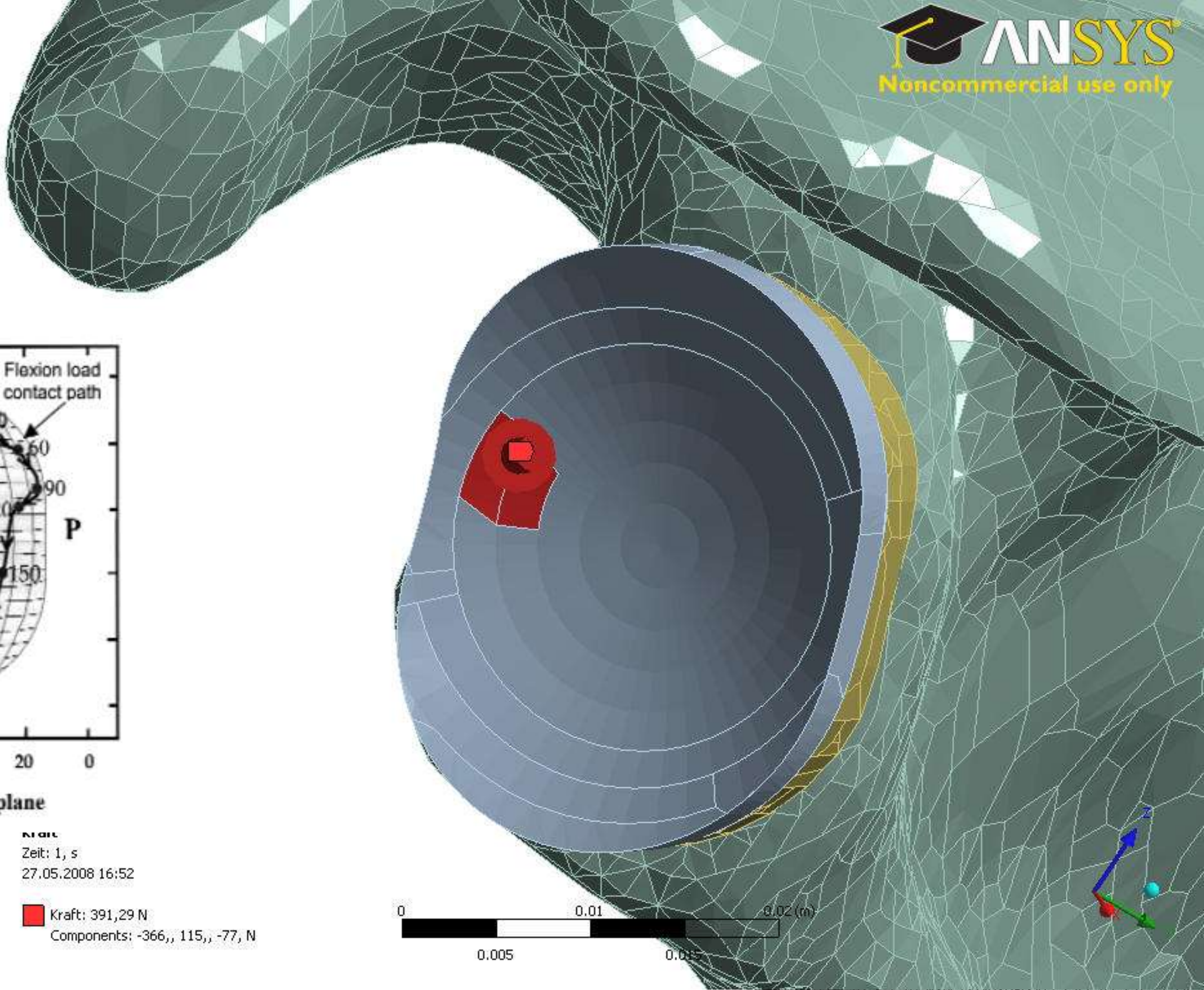


FE - Analysis


Geometrie
27.02.2008 12:34
Noncommercial use only
0.000
0.030
0.060 (m)
0.015
0.045
Z
X
Y

FEA – Case Study





Forces from Prof. F.C. van der Helm

% xyz-direction of passive forces:
% 0, 30, 60, **90**, 120, 150, 180 degrees abduction
% gh-joint

fx = [-5.873 -116.023 -295.891 **-355.755** -273.426 -97.190 -19.673];

fy = [-18.235 113.518   28.819   **-76.628** -175.082 -156.340 -76.685];

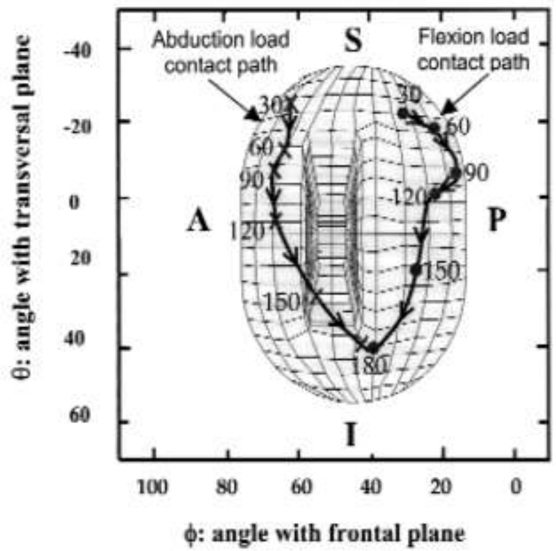
fz = [2.080   34.012   133.408 **148.241**   119.613   57.398 24.208];

% xyz-coordinates point of application passive forces

x = [17.273 15.992 14.724 13.709 12.869 12.411 13

y = [1.921   3.470   4.990   5.660   6.461   6.023   5

z = [6.023   9.109 10.698 11.767 12.326 13.026 12

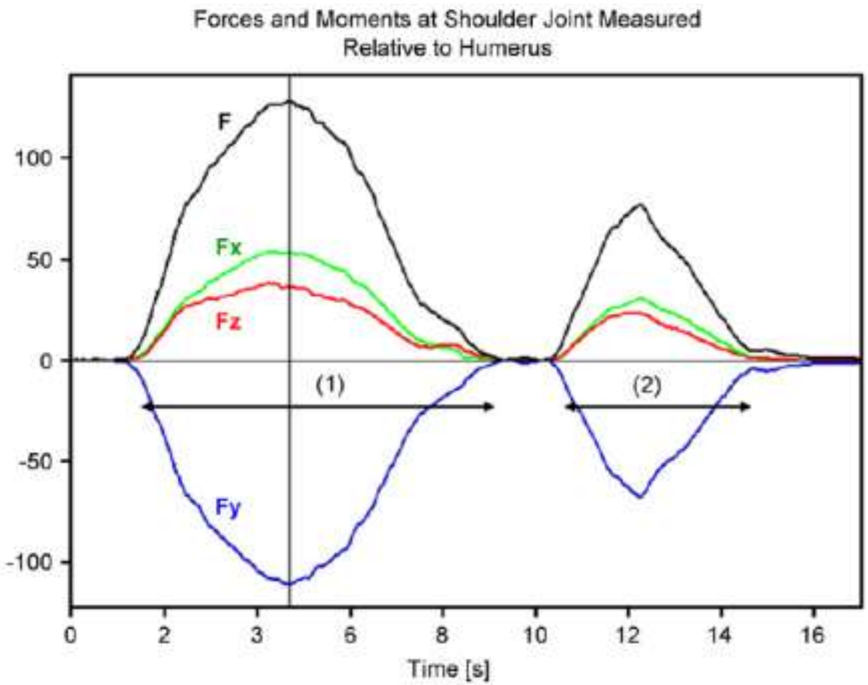


Comparison with real Forces

G. Bergmann et al., Charité - Universitätsmedizin Berlin www.biomechanik.de

In vivo glenohumeral contact forces –
Measurements in the first patient 7 months postoperatively.

J Biomech, 2006



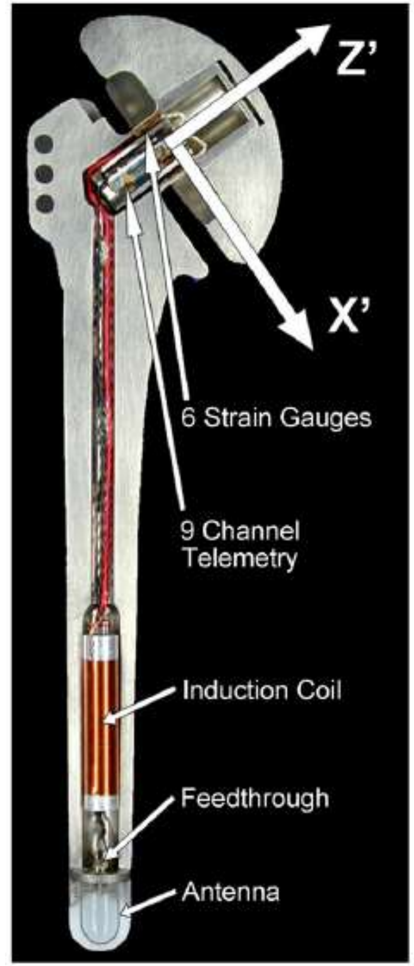
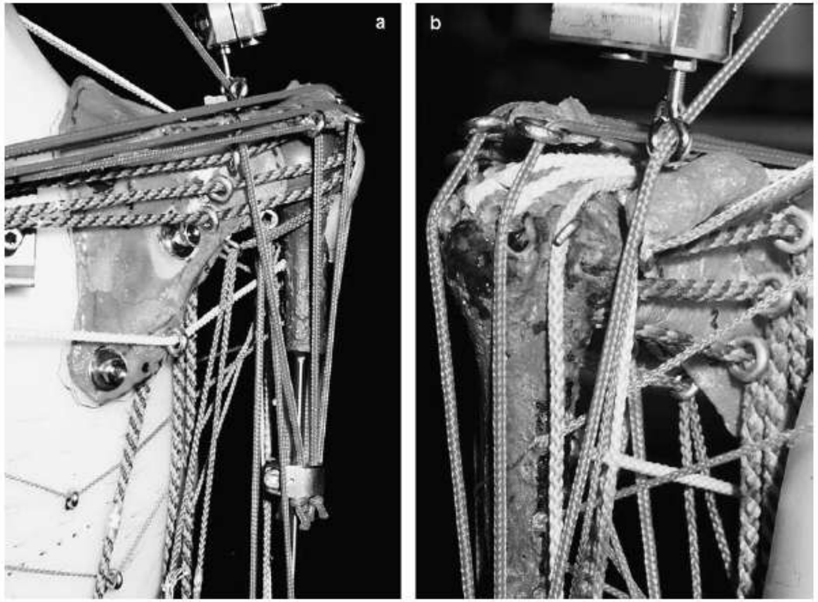


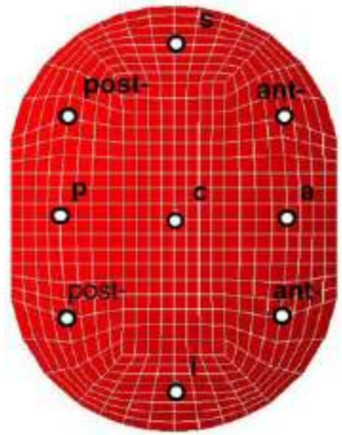
Fig. 5. Forces during flexion with and without 2 kg weight in hand. (1) 0–90° flexion with 2 kg in hand and back, (2) same activity without weight. I
physiotherapist marks the height of elevation. For more information see Fig. 4.

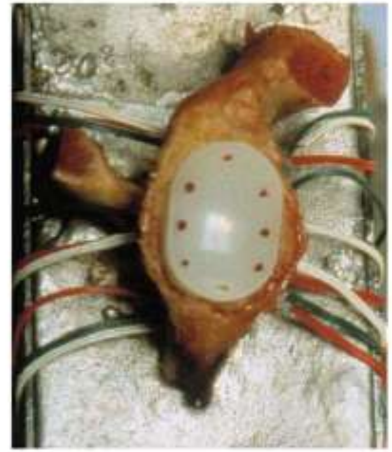
Large Research Community

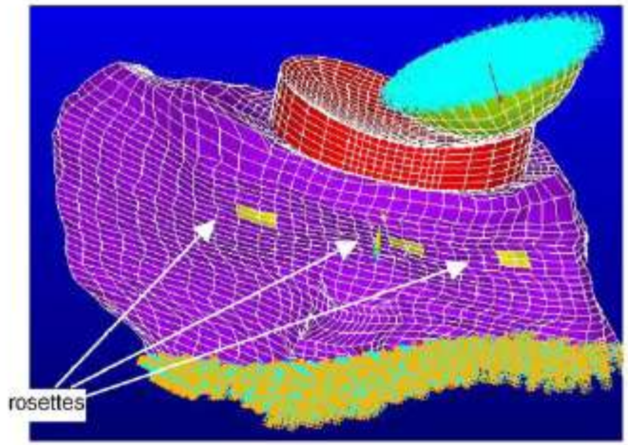


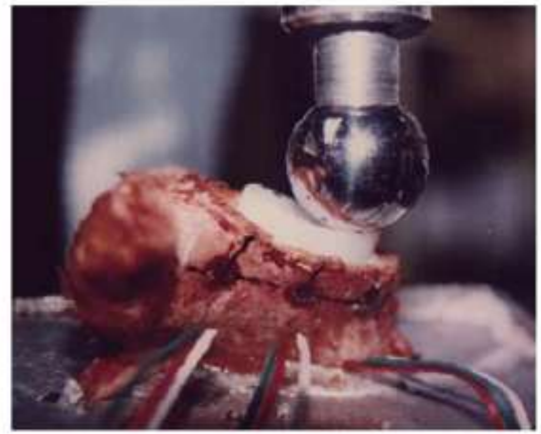
P. Favre, R. Sheikh, S.F Fucentese and H.A.C Jacob. An algorithm for estimation of shoulder muscle forces for clinical use. *Clin Biomech*, 20(8):822–833, Oct **2005**.

N. Maurel, **A. Diop** and **J. Grimberg.** A 3D finite element model of an implanted scapula: importance of a multiparametric validation using experimental data. J Biomech, 38(9):1865–1872, Sep 2005.





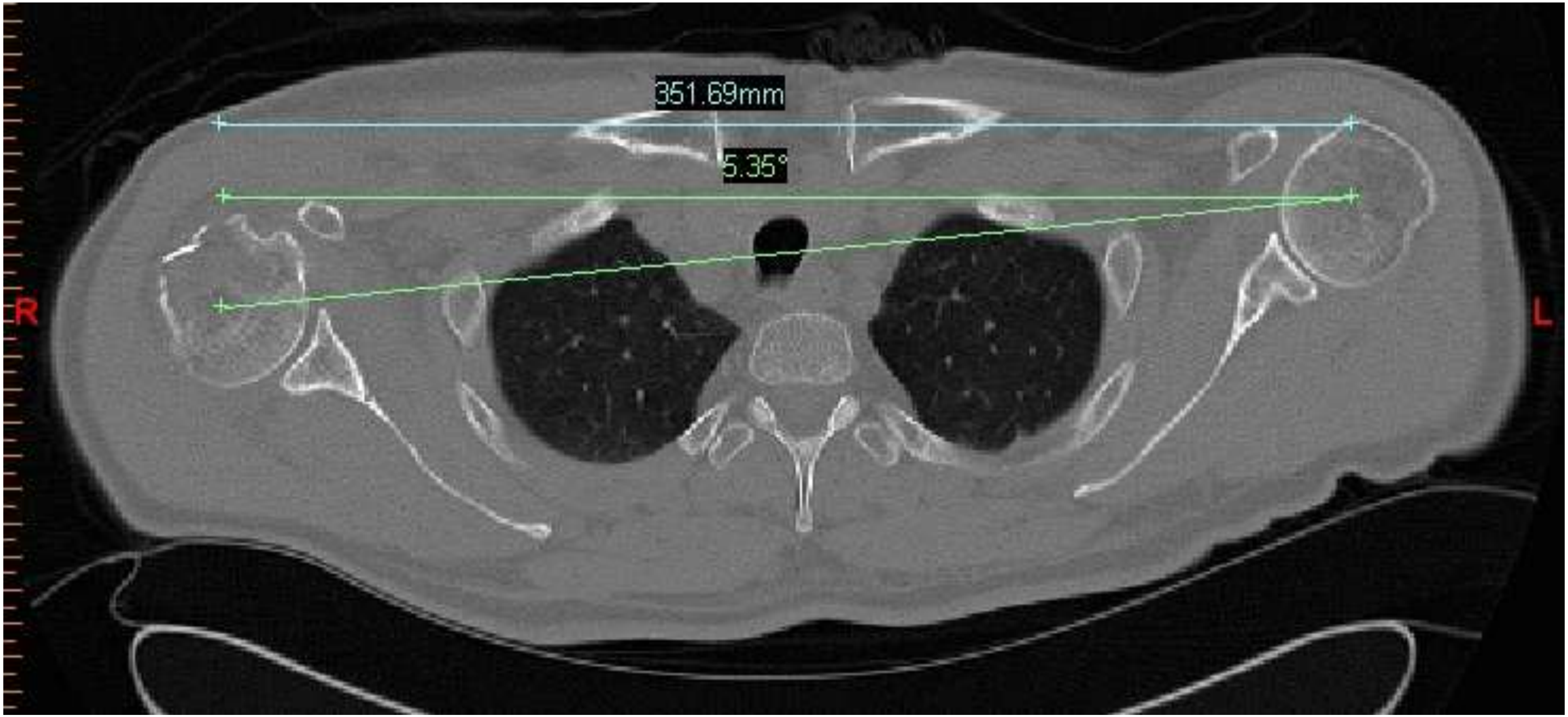




http://internationalshouldergroup.org/

Coordinate System Adaptions

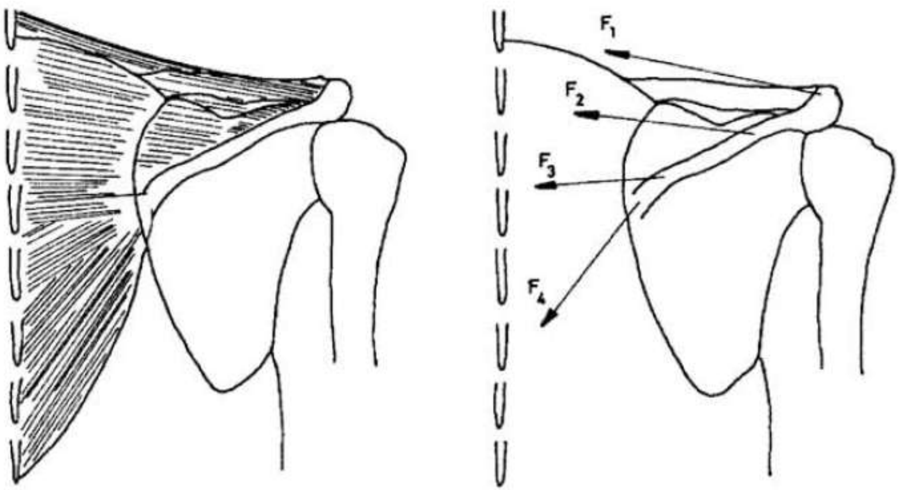
CT-Position



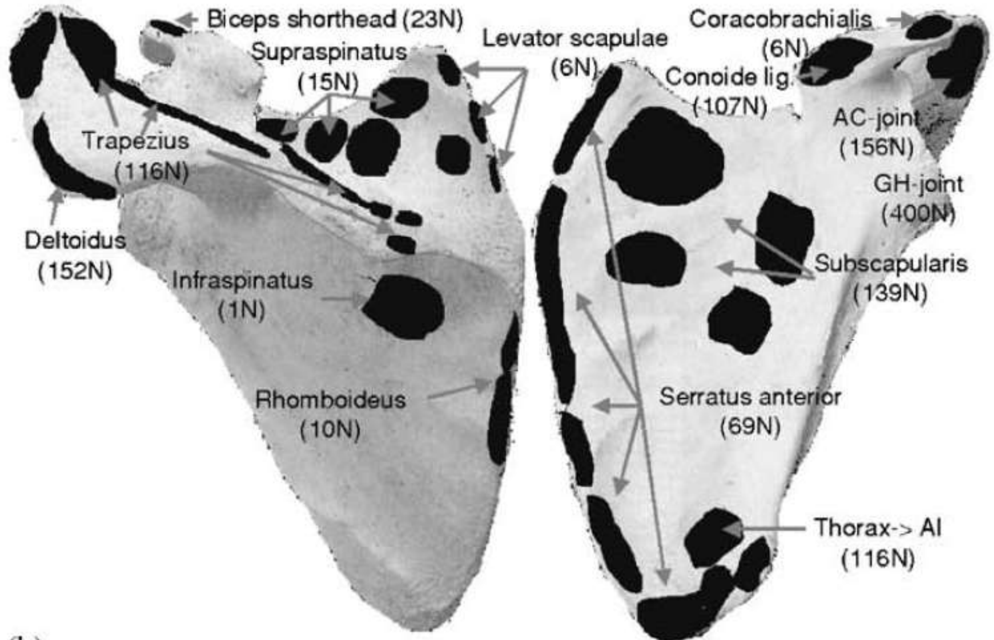
Boundary Conditions

Fixation of the Scapula, for example:

L.A. Murphy, P.J. Prendergast / Journal of Biomechanics 38 (2005) 1702–1711 1705



(a)



(b)

Material

Material Parameter

- Compacta

  Young`s Modulus: 2.2 GPa.
  Poisson`s ratio : 0.3

- Spongiosa

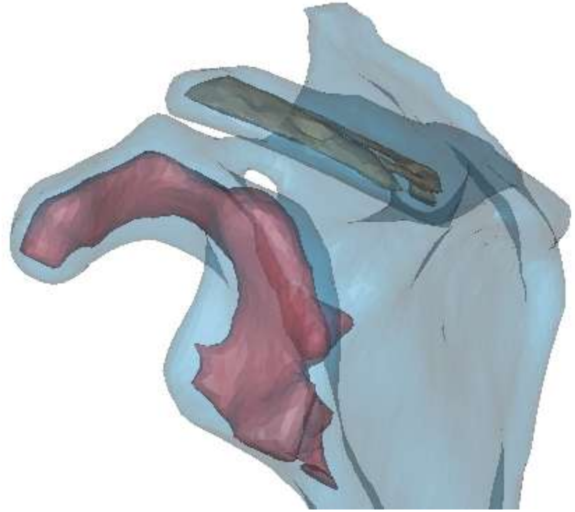
  Young‘s Modulus: 0.2 GPa
  Poisson‘s ration: 0.26

- Medical cement (Polymethylmethacrylat)

  Young`s Modulus: 2.2 GPa.
  Poisson`s ratio : 0.3

- Implant (Polyethylene)

  Young`s Modulus: 0.5 GPa.
  Poisson`s ratio : 0.4

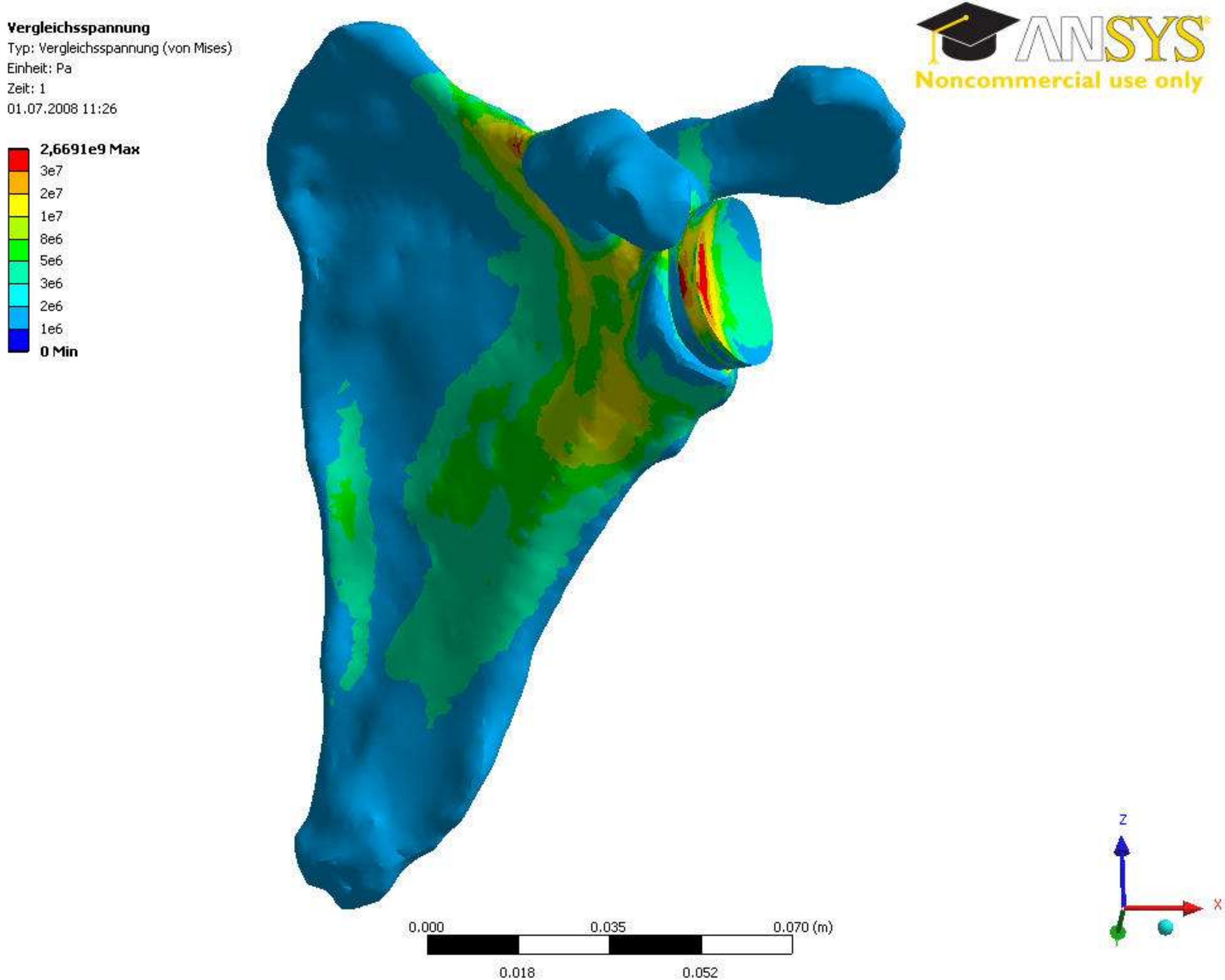


Scapula
Spongiosa

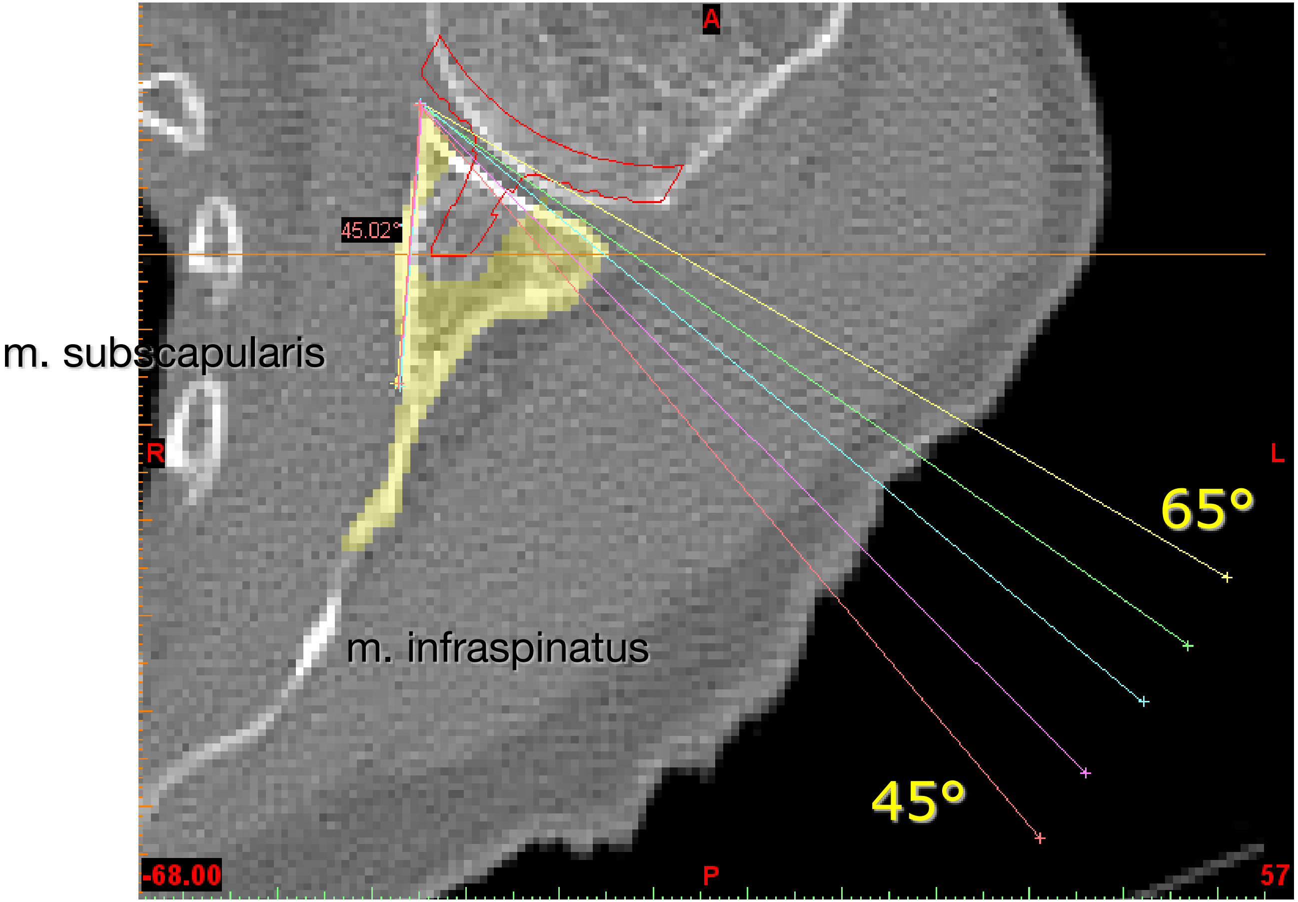
Zement

Implantat

Sample Results



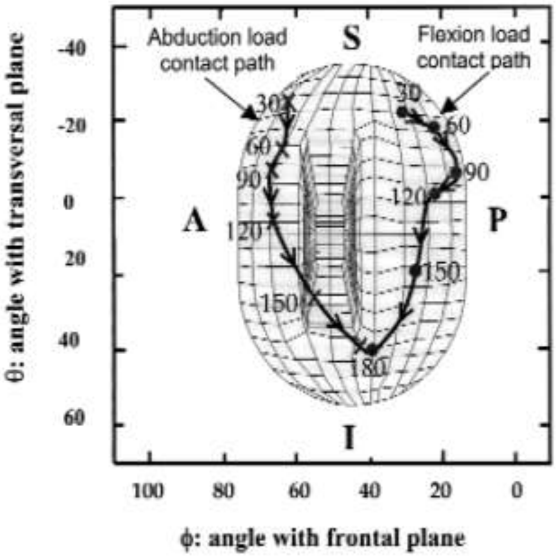
Recent Study 1: Simulation Arthrose

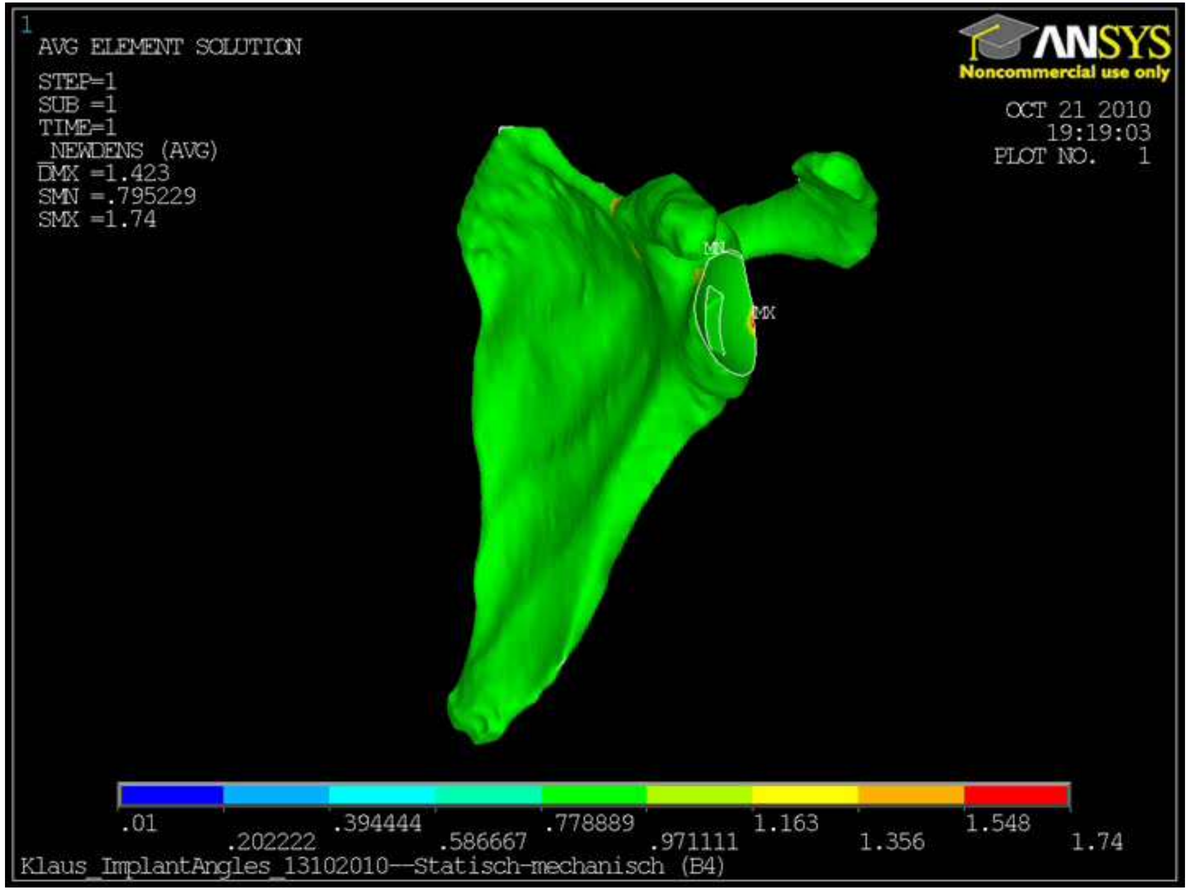


Angle from 65° to 45°

Need for HPC!

- Very complex models which need high computation time!
- Simulation of Standard Movements Simulation of Bone Remodelling



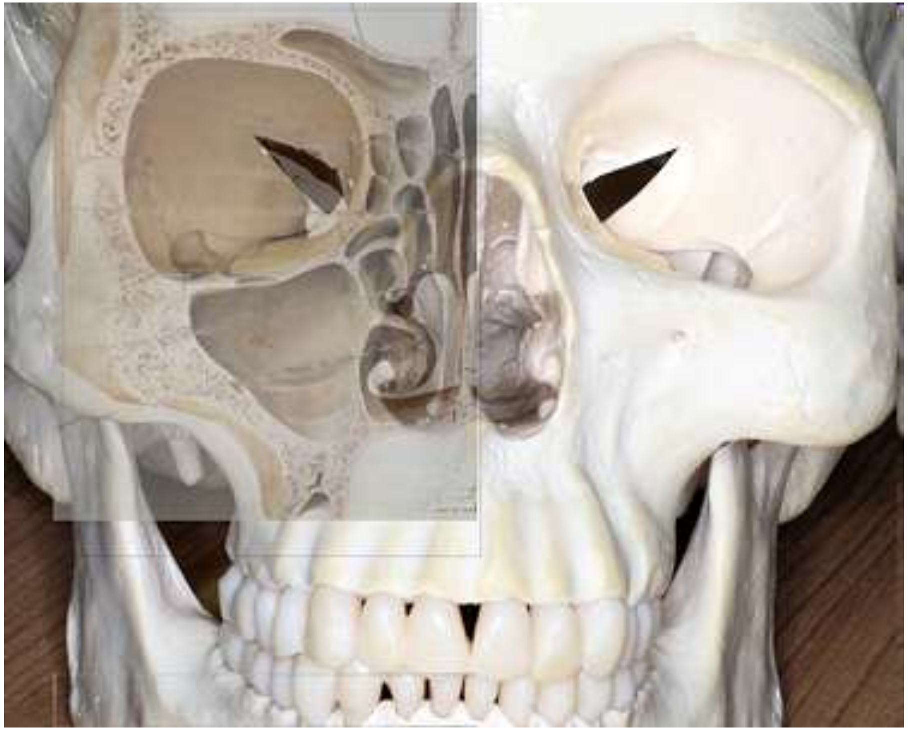


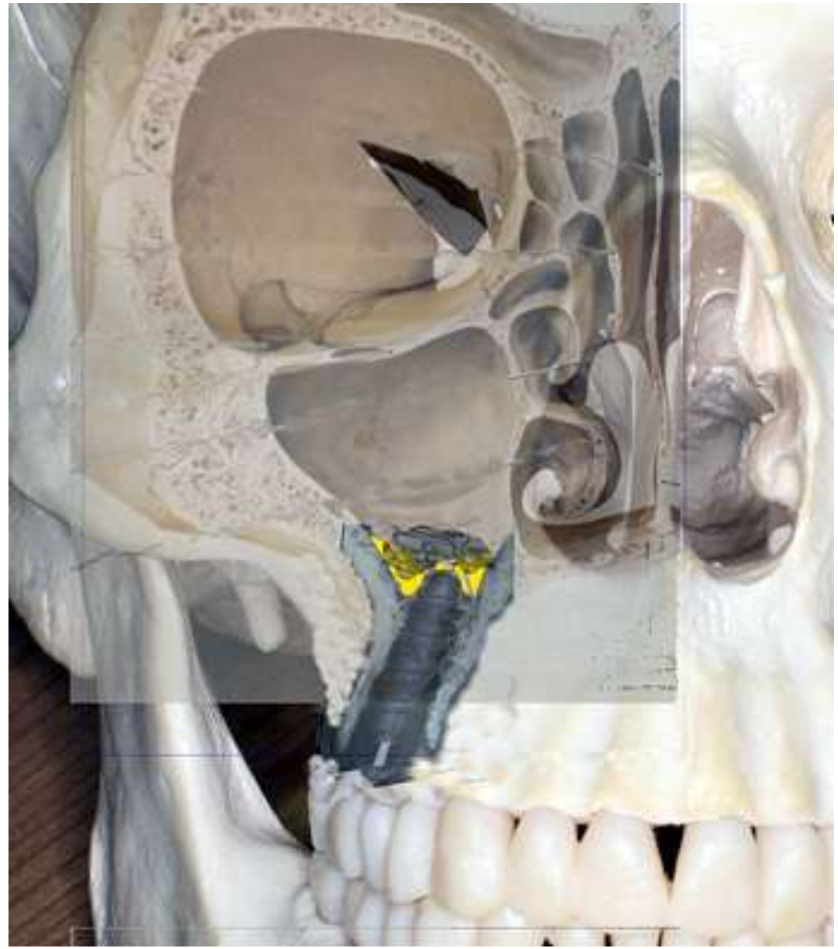
Results

1. K. Entacher, A. Petutschnigg, W. Pomwenger, H. Resch, P. Schuller-Götzburg. Patientenspezifische Optimierung von Schulterimplantaten. *CAME* 1(1):12-18, 2010.
2. P. Schuller-Götzburg, K. Entacher, A.Petutschnigg, R. Forstner and H. Resch. *Development of patient-optimized 3D-finite element models for an analysis of implanted shoulders*. Proc. of the 8th International Symposium on Computer Methods in Biomechanics and Biomedical Engineering CMBBE 2008 Porto, Portugal; J. Middleton, S.L. Evans, C. Holt, C. Jacobs, B. Walker (eds.) published by Arup 2009, ISBN: 978-0-9562121-0.8
3. P. Schuller-Götzburg, K. Entacher, A. Petutschnigg, M. Eichriedler, R. Forstner und H. Resch, Entwicklung von 3D-FE Modellen zur Simulation und Optimierung von Implantaten. *BIOmaterialien* 7(4) : 263-270, 2006.

Thanks: to ATOMIC GmbH for the possibility to calibrate the implants and the company Arthrex for CAD data of implants. For financial support we thank the Schoellerbank Austria and the Österr. Gesellschaft für Zahn-, Mund- und Kieferheilkunde ÖGZMK, Zweigverein Salzburg. The Project is supported by the FWF Translational Research Program L526-B05 and by the PMU -FFF Rise Project R-09/03/003-SCH.

Recent Study 2: Dental Implants





http://www.zahndoc-leugner.de/impla.html (Mai 09)

Recent Study 2: Dental Implants

- Again CT-Data as a Basis for Modeling
- Segmentation

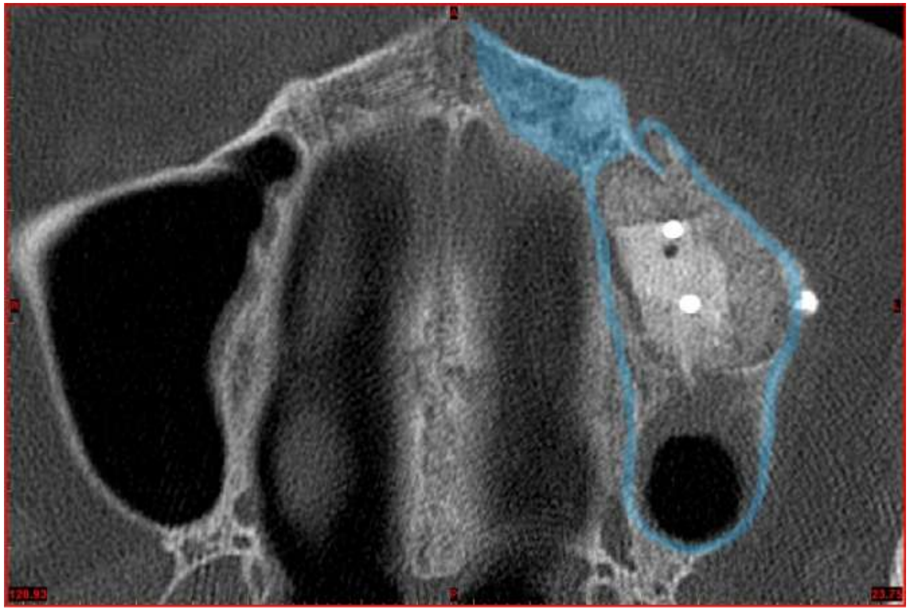


Fig. 7: Maxilla segmentation

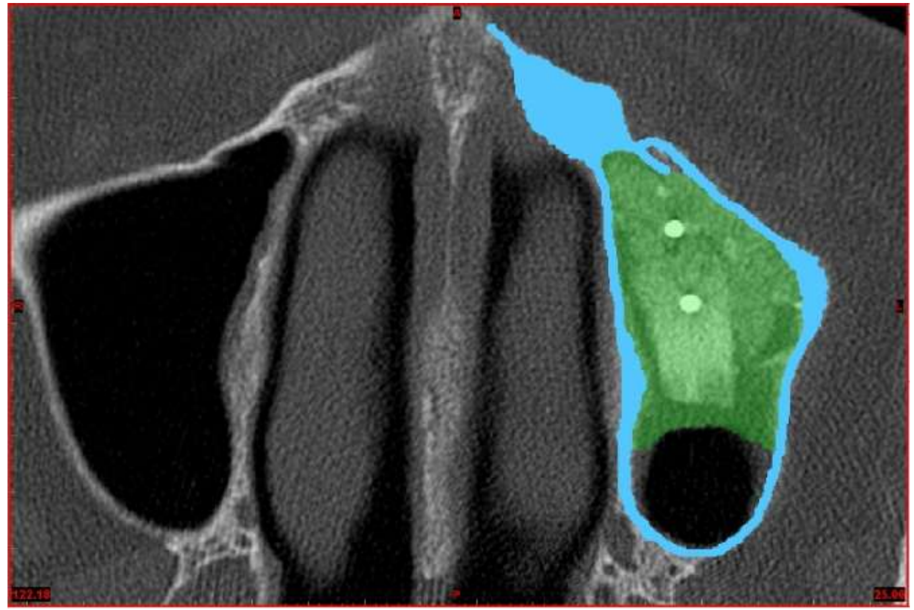


Fig. 8: Maxilla and bone augmentation mask

Materialise Software

Recent Study 2: Dental Implants

- 3D - Models
- Wrapping und Smoothing

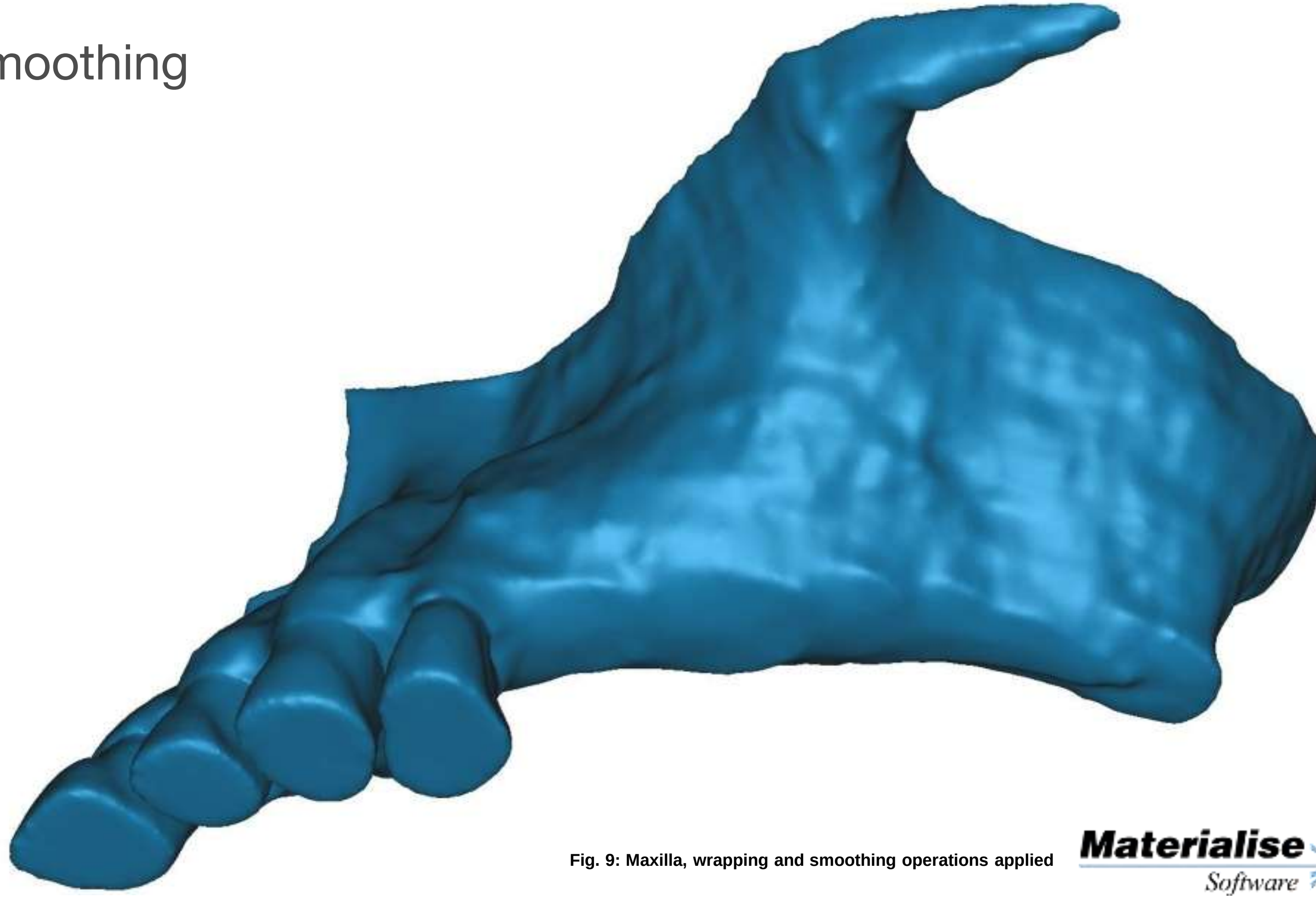
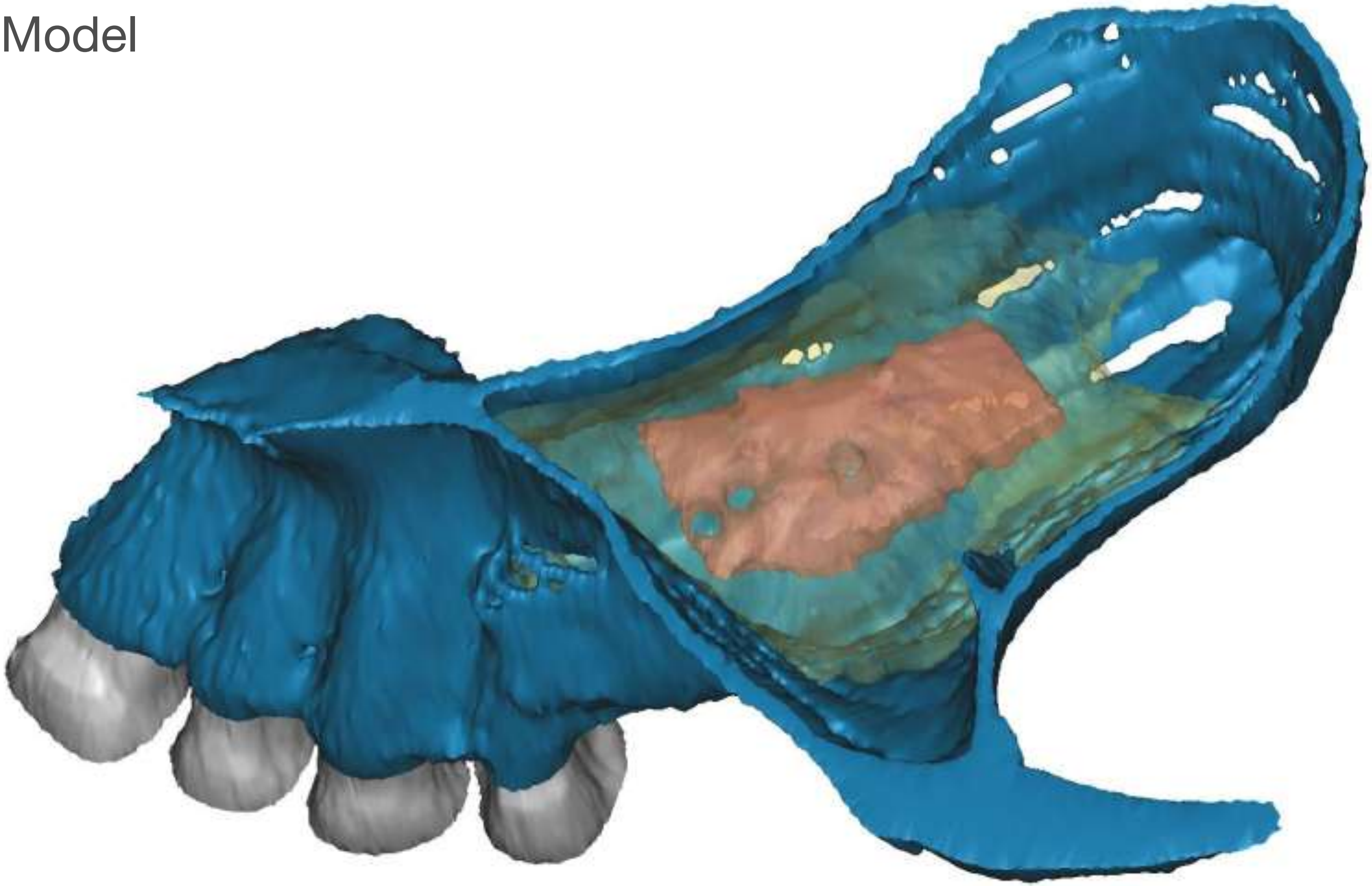


Fig. 9: Maxilla, wrapping and smoothing operations applied

Materialise Software

Recent Study 2: Dental Implants

- 3D – Model



Recent Study 2: Dental Implants

- Wrapping, Smoothing and Bone Block insertion

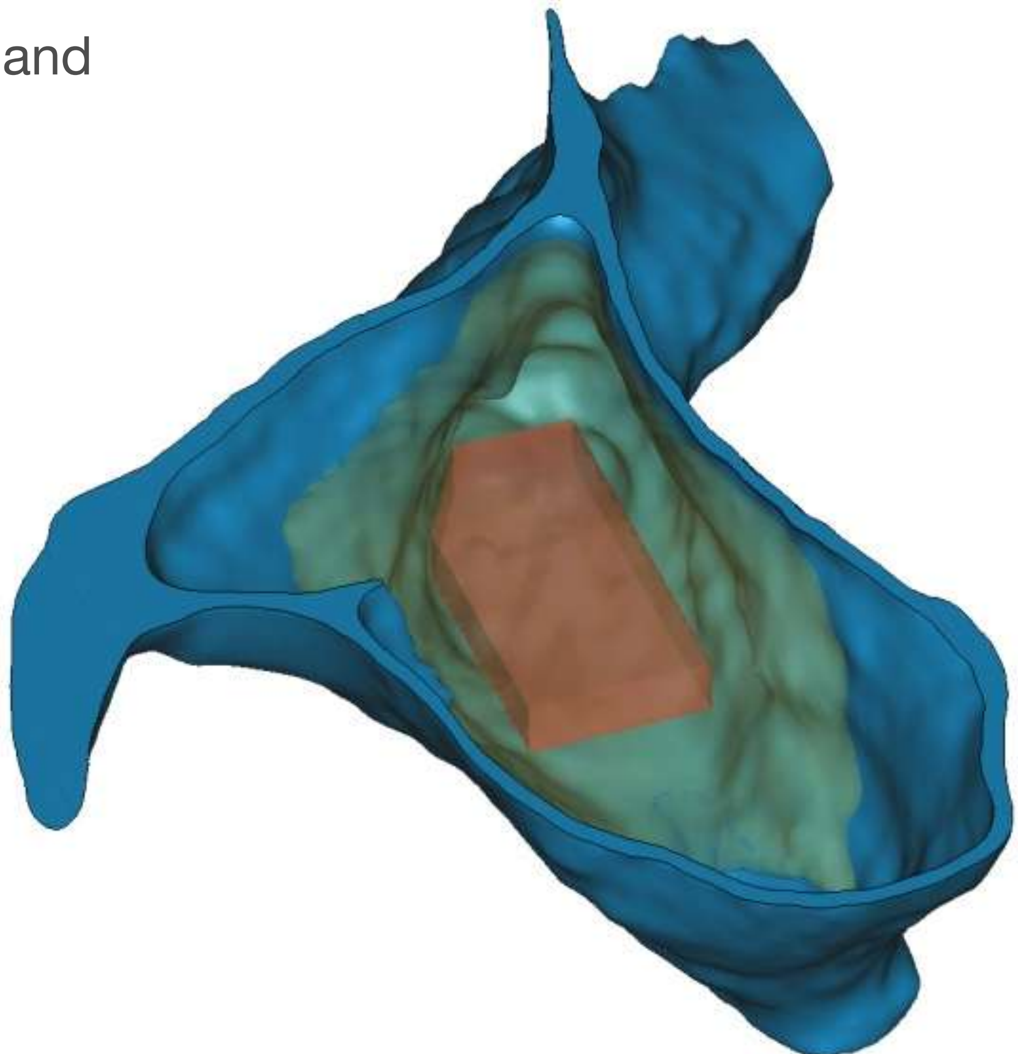


Fig. 10: Maxilla, wrapping and smoothing operations applied, and remodeling of augmented bone and bone block

Materialise Software

Recent Study 2: Dental Implants

- Virtual Surgery

Fig. 11: Bredent Medical Blue Sky Implant System

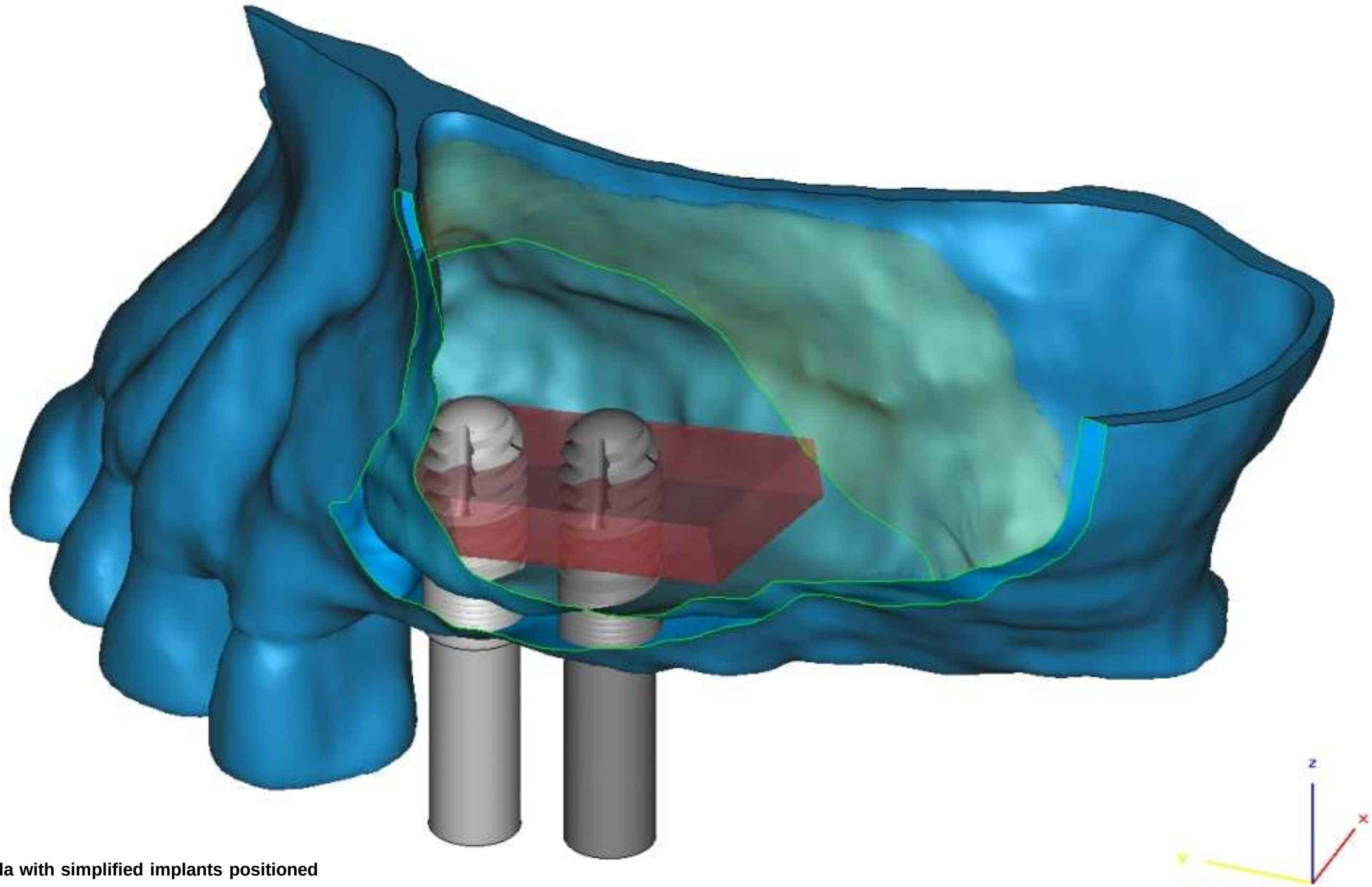


Fig. 12: Maxilla with simplified implants positioned

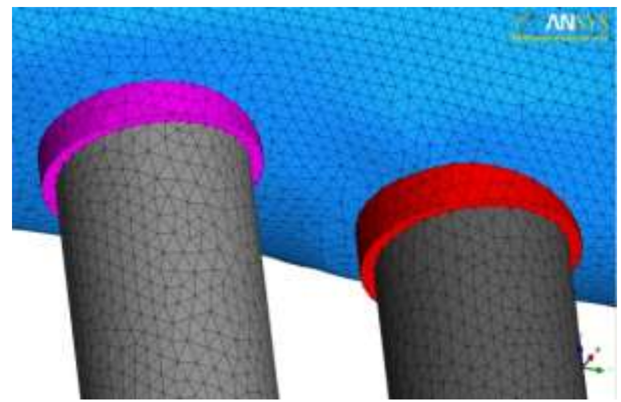
Recent Study 2: Dental Implants

- 3D – Volume Models (ANSYS ICEM CFD 12.0)

Fig. 13: Model meshed with volume elements

- Advanced CAD/geometry readers
- Built- in geometry creation and repair tools
- Geometry tolerant meshing algorithms
- Mesh diagnostics

Fig. 14: Nodes in common at material transitions (maxilla/implant/abutment)



Recent Study 2: Dental Implants

- 3D – Volume Models (ANSYS ICEM CFD 12.0)

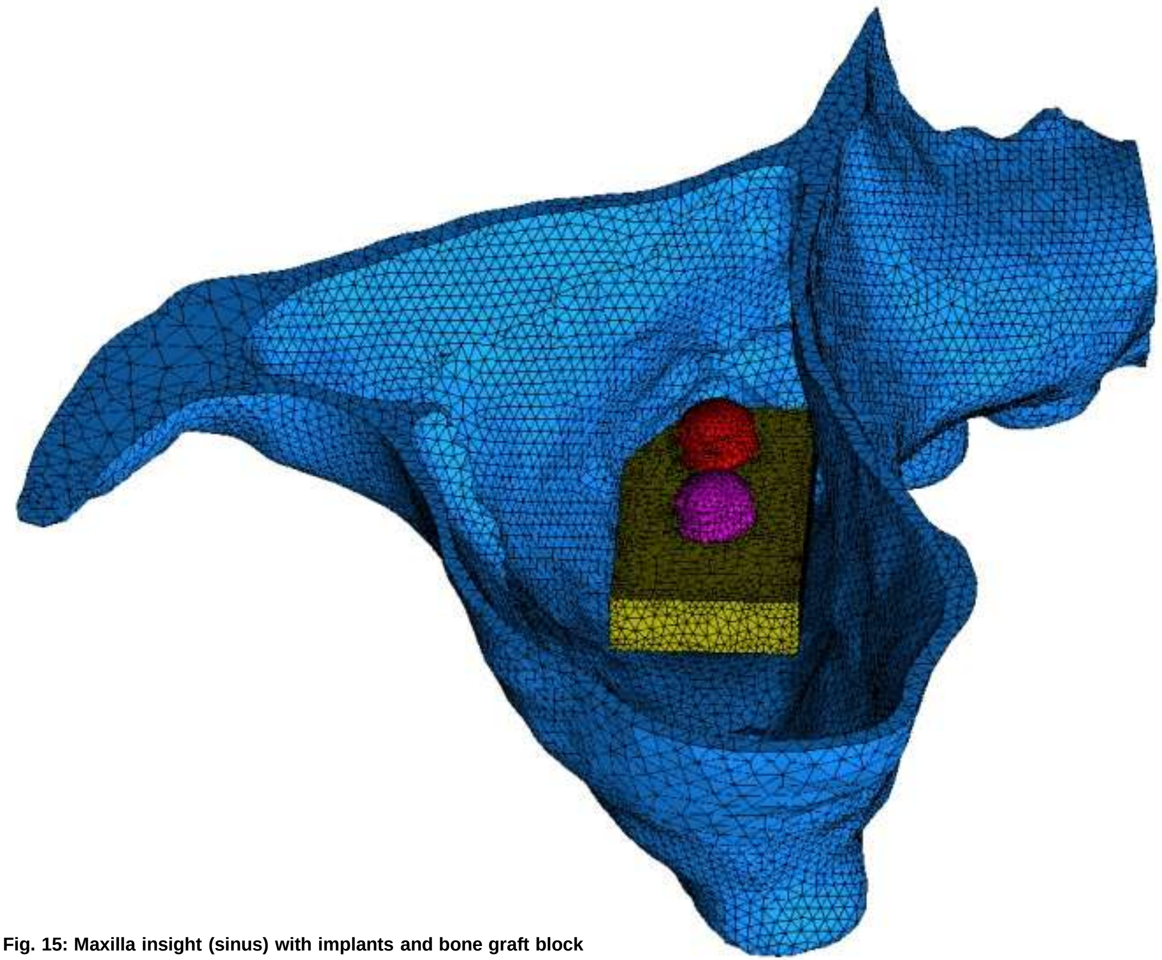
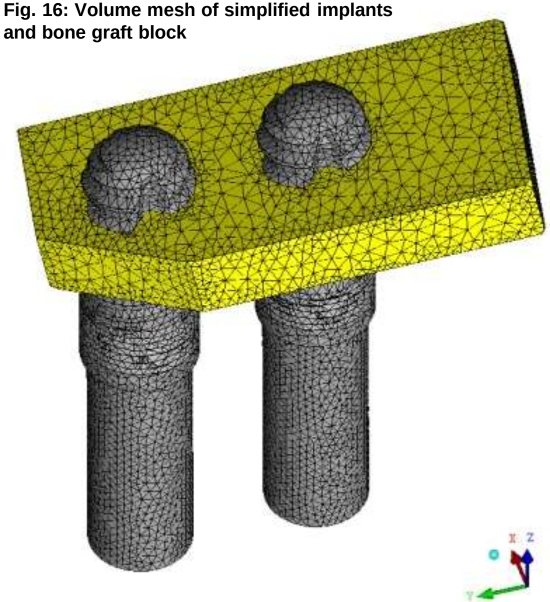


Fig. 15: Maxilla insight (sinus) with implants and bone graft block

- Advanced CAD/geometry readers
- Built- in geometry creation and repair tools
- Geometry tolerant meshing algorithms
- Mesh diagnostics

Fig. 16: Volume mesh of simplified implants and bone graft block



ANSYS

Recent Study 2: Dental Implants

- ## Boundary Conditions
  - Masticatory forces: Corresponding to the mean maximal forces given in table 3, Mericske-Stern et.al. *J Prosth Dent*, 84 (5), 535-547, 2000.
  - Z-axis: 96N (*masticatory force)*
  - Y-axis: 36N (*protrusion)*
  - X-axis: 13N (*laterotrusion)*

Material	Young's M. (MPa)	Poisson's R.
Cancellous bone	1.370	0.30
Cortical bone	13.700	0.30
Titanium	103.400	0.35

Table 1: Material properties

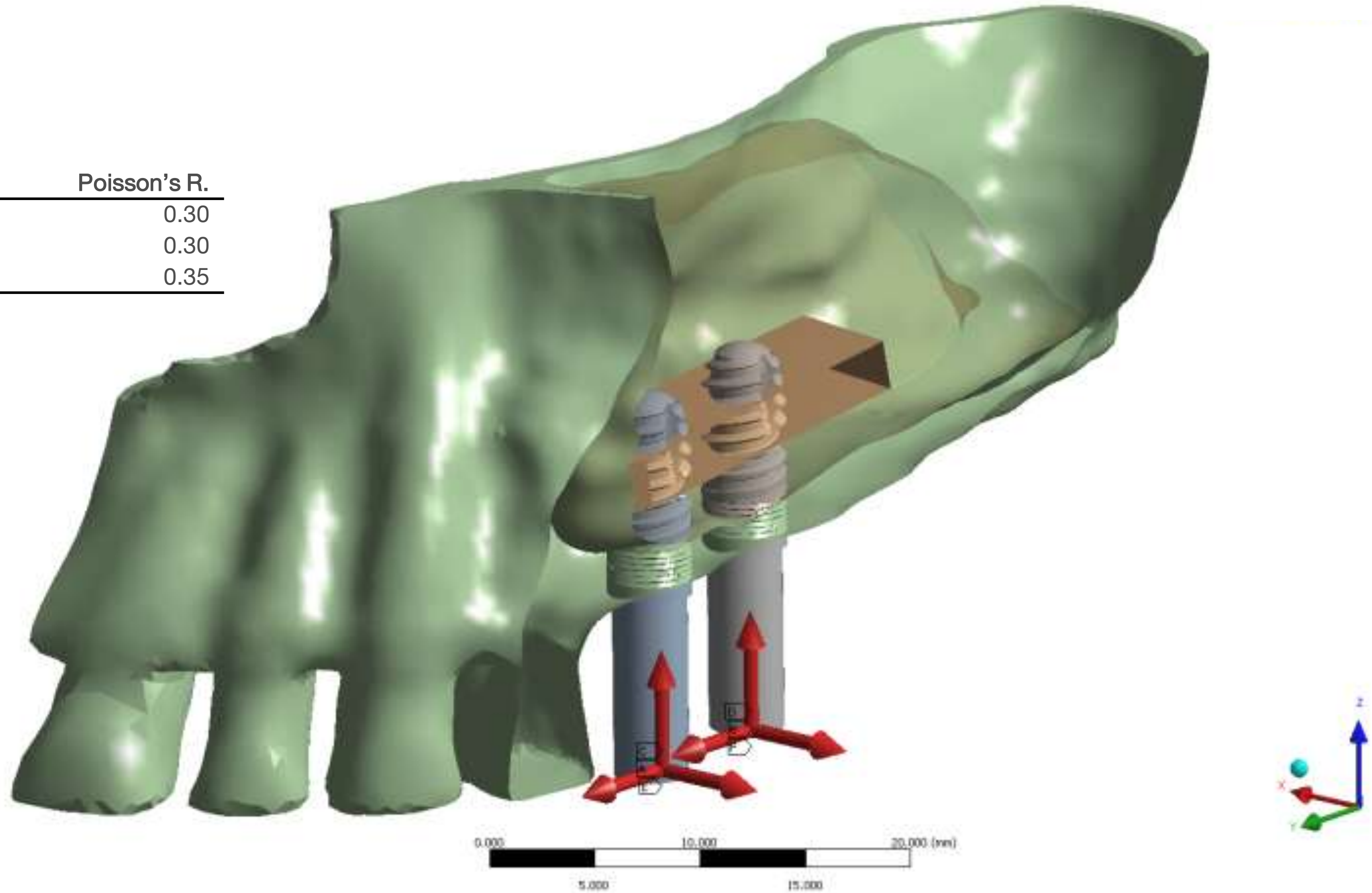


Fig. 17: Ansys FE model with applied forces

Recent Study 2: Dental Implants

- Results

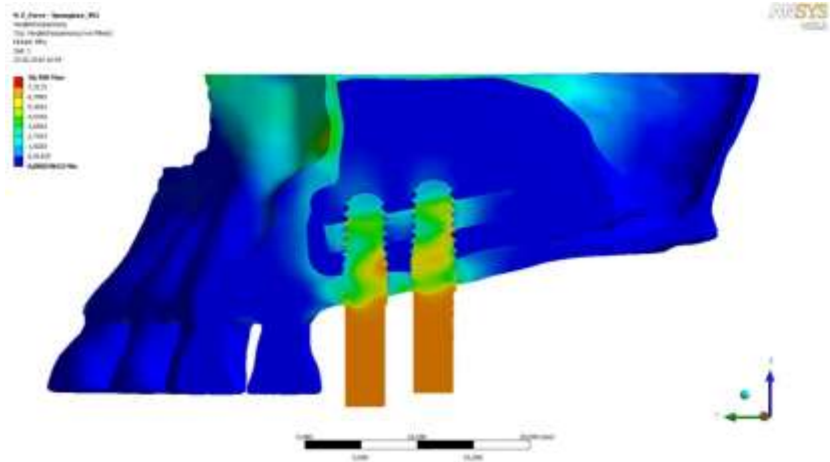


Fig. 18: Stress distribution - cut through full model

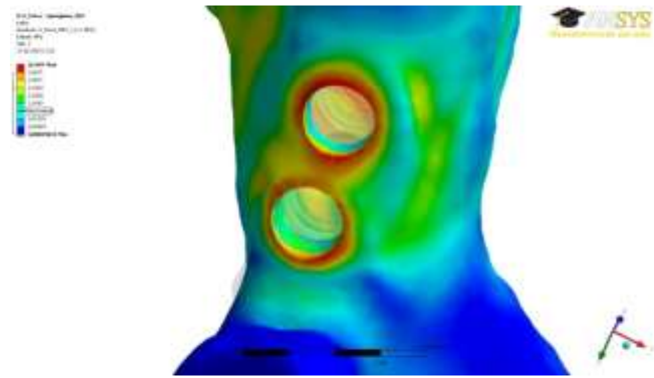


Fig. 19: Stress distribution on maxilla (cranial view)

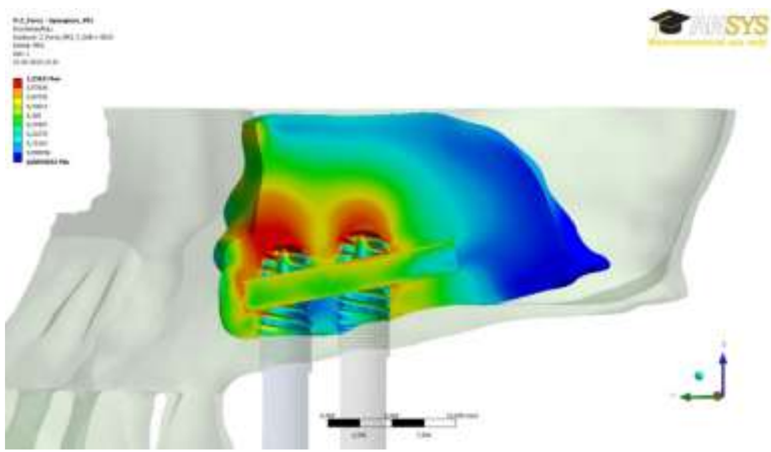


Fig. 20: Stress distribution - cut through bone augmentation

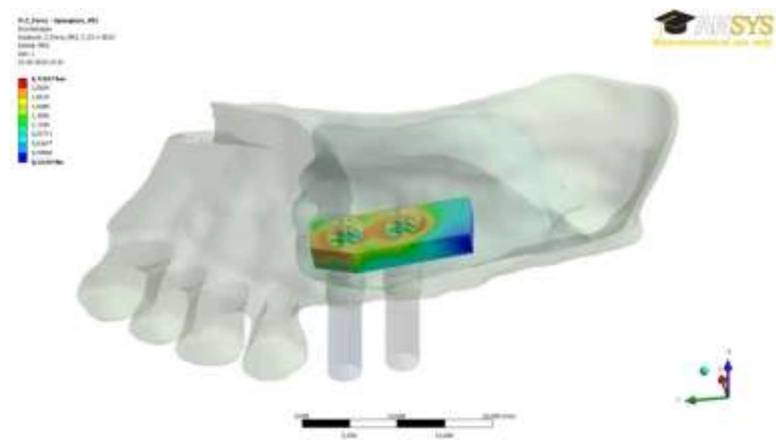


Fig. 21: Stress distribution on cortical bone graft block

Results

1. P. Schuller-Götzburg, K. Entacher, A. Petutschnigg, W. Pomwenger, and F. Watzinger. Sinus lift with cortical bone graft block: a patient-specic 3D-finite element study. *The International Journal of Oral & Maxillofacial Implants*, 2011, to appear.
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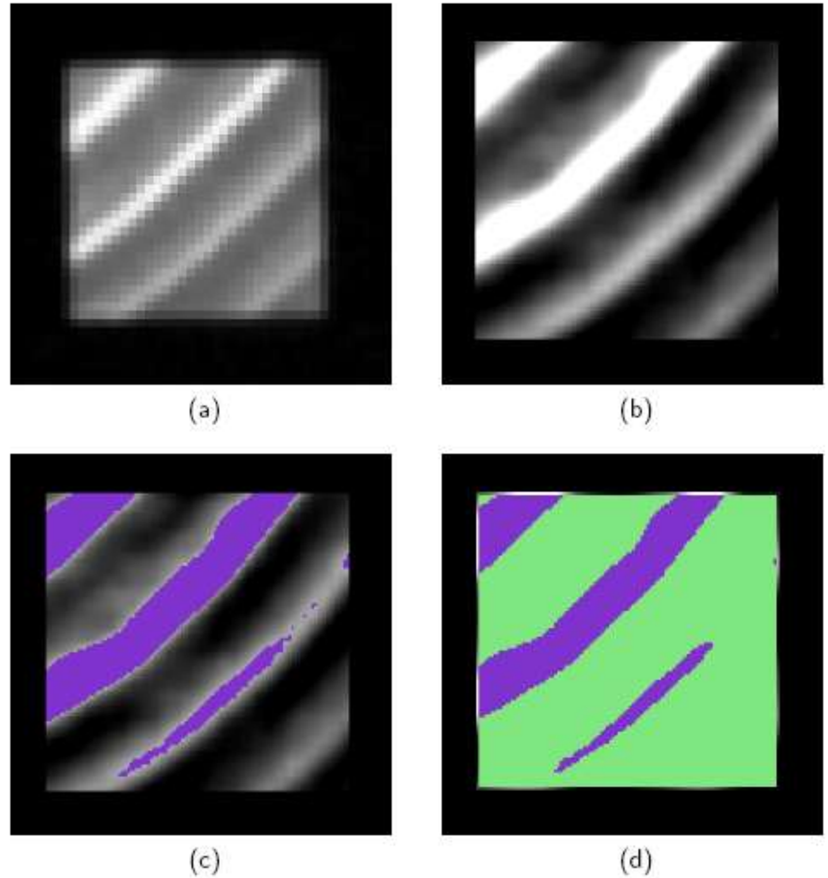
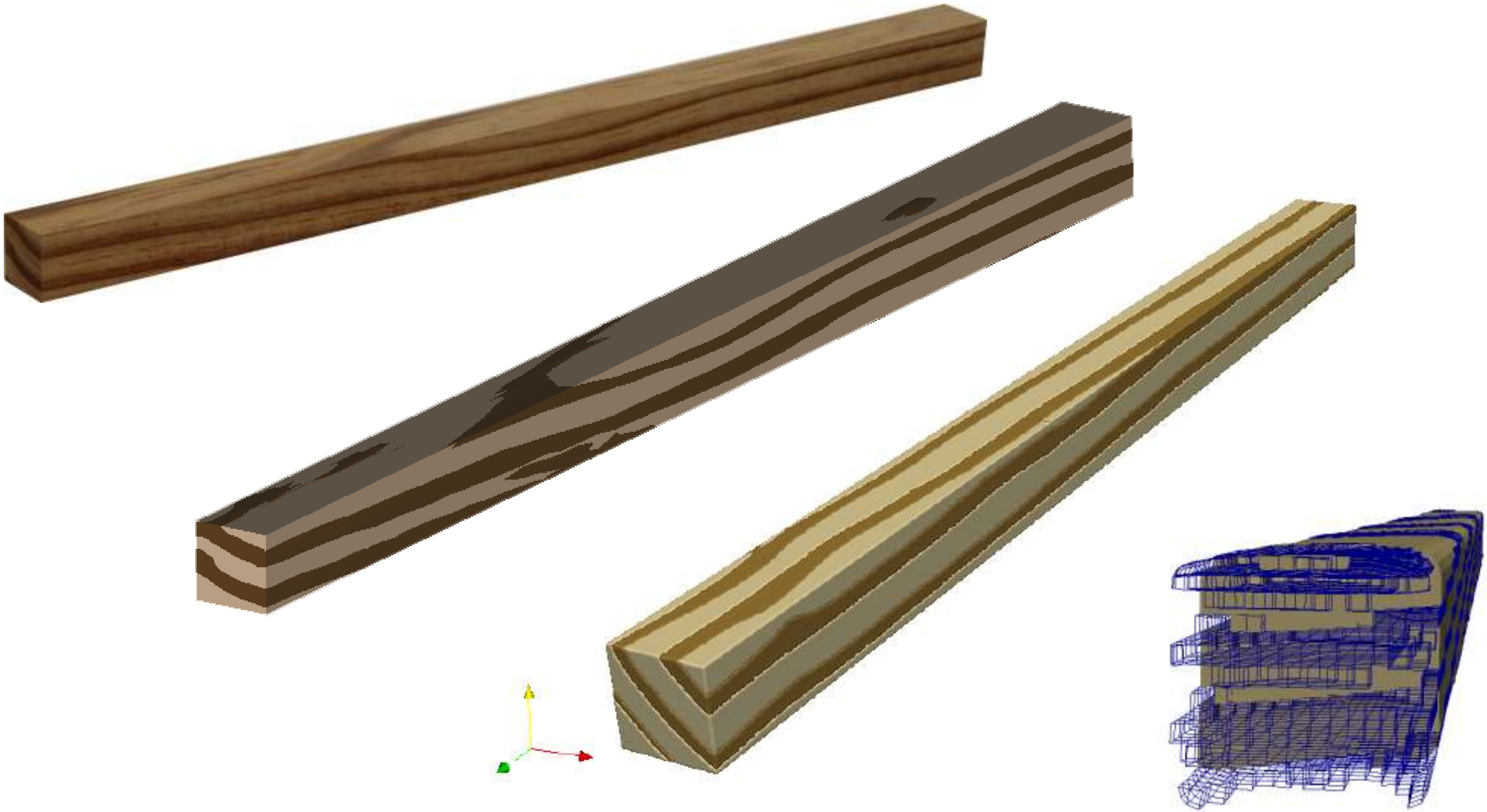
4. P. Schuller-Götzburg, K. Entacher, A. Petutschnigg, W. Pomwenger and F. Watzinger. *Finite Element Analysis of Sinus Lift with Cancelous Bone Graft Block*. Proceedings of the 2nd South East European Conference on Computational Mechanics SEECCM 2009. M. Papadrakakis, M. Kojic, V. Papadopoulos (eds.) Rhodes, Greece, 22–24 June 2009.

Thanks: to the company Bredent for CAD data of implants. For financial support we thank the Österr. Gesellschaft für Zahn-, Mund- und Kieferheilkunde ÖGZMK, Zweigverein Salzburg. The Project is supported by the FWF Translational Research Program L526-B05.

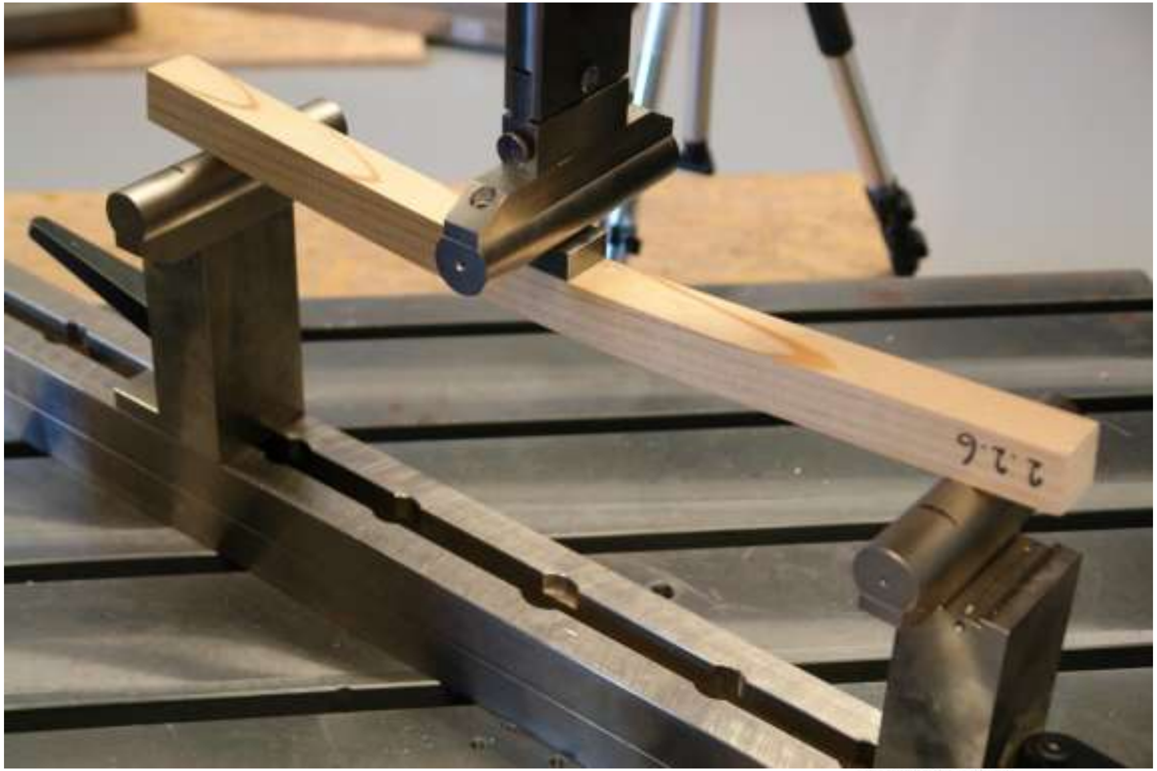
Recent Study 3: FEA of Wood

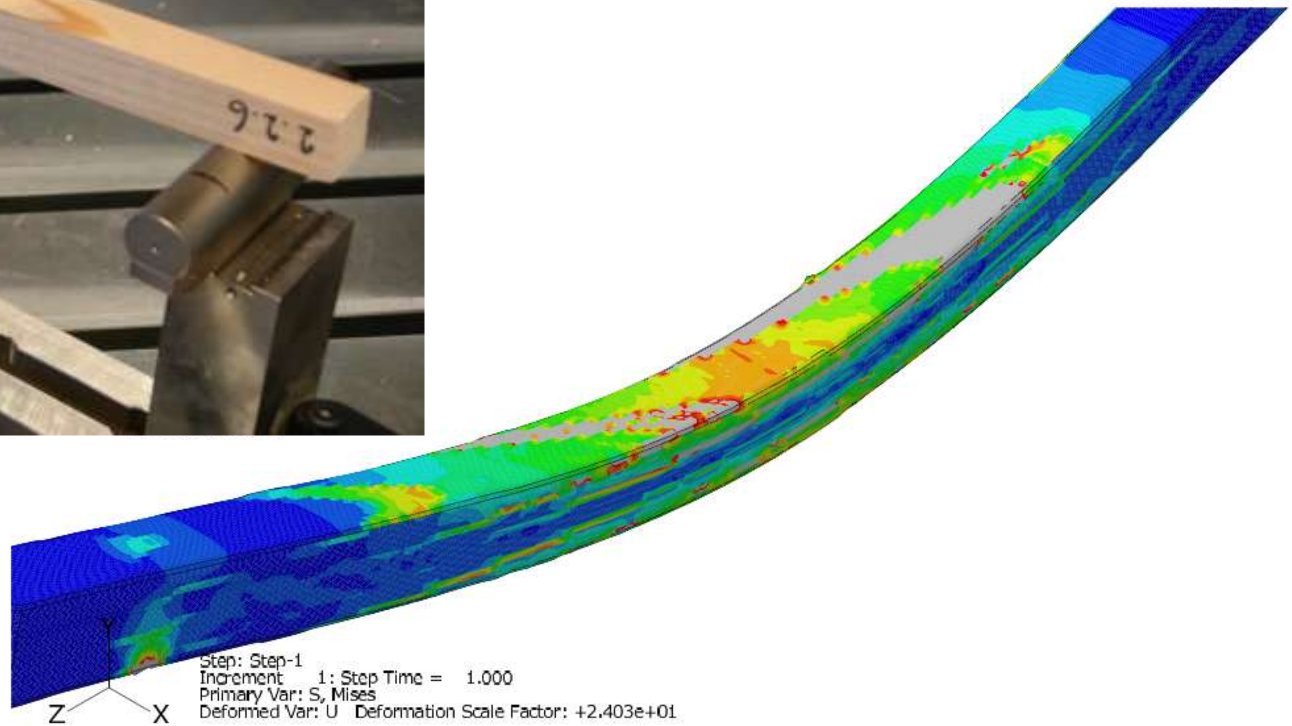


Recent Study 3: FEA of Wood



Recent Study 3: FEA of Wood





Wood Technology Results in General

1. K. Entacher , M. Öttl, A. Petutschnigg und R. Bauer. Finite Elemente Analyse von Holz auf Basis von CT Daten. Holztechnologie, to appear 2011 (hopefully).
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Thanks: FWF P17434 "Generalised linear models for wood characterisation“ and L526-B05

Recent Study 4: Wood Based Prod. Analysis

Wood Panels: MDF, Particle (Chip) Board, OSB

Master Thesis at Dept. of Computerscience and a Cooperation of ITS and HTB

Simon Kranzer

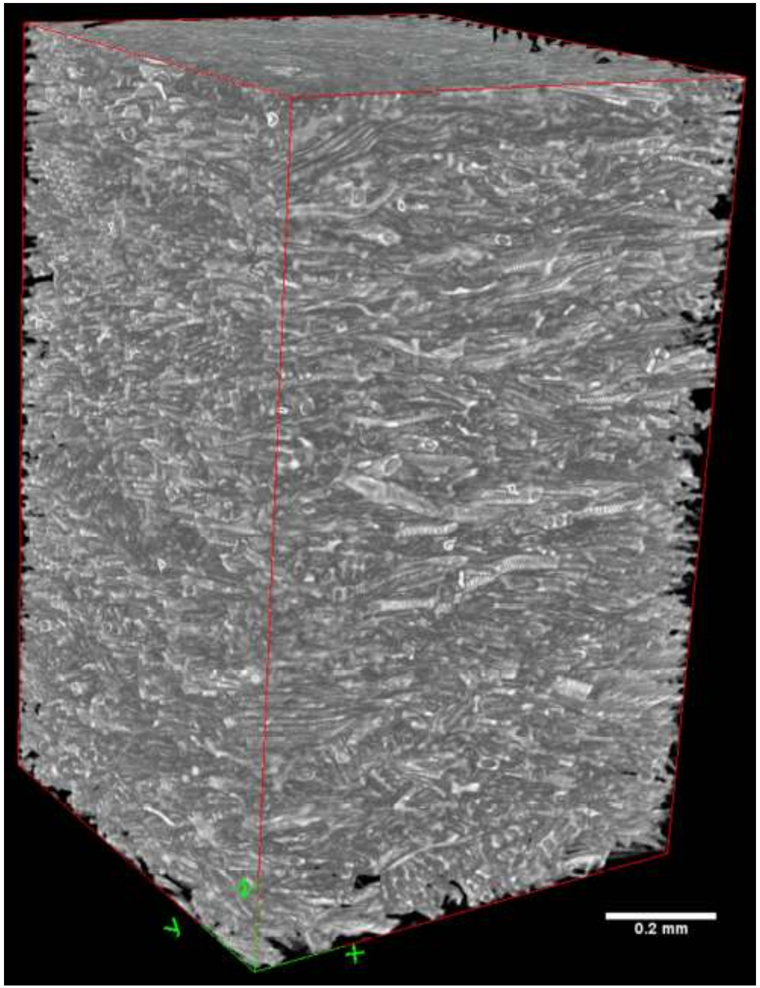
Karl Entacher

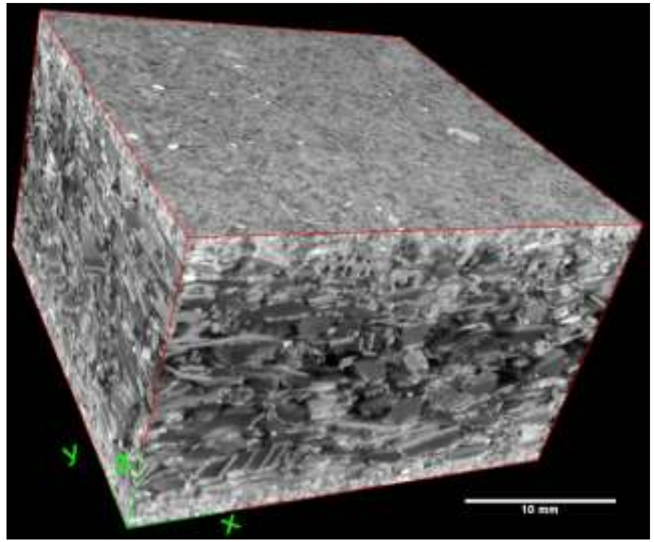
Gernot Standfest

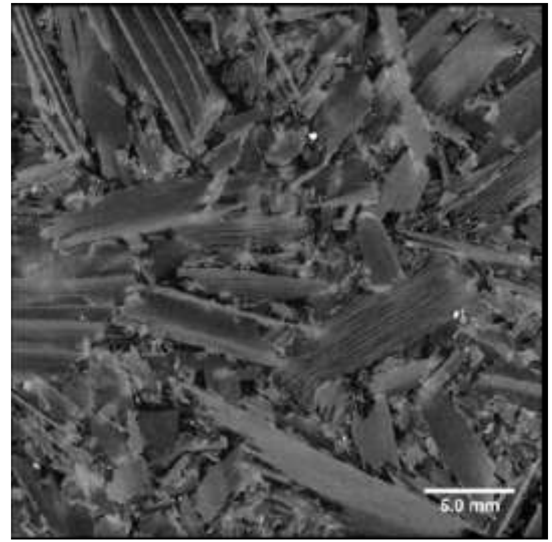
Alexander Petutschnigg

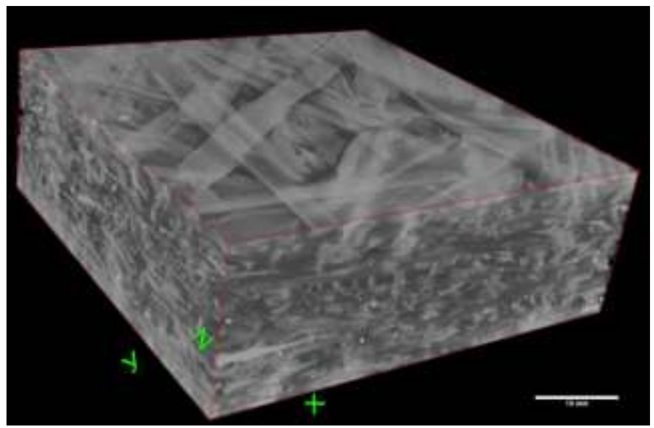
Recent Study 4: Wood Based Prod. Analysis

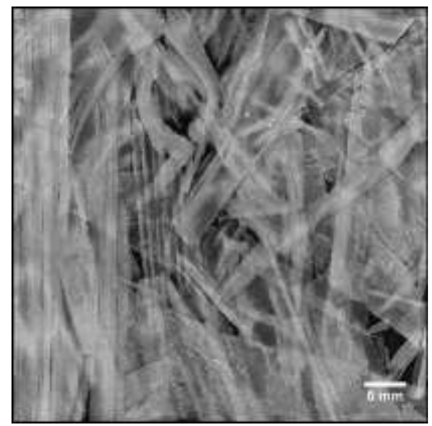
Sub μ–CT imaging: MDF, Particle Board, OSB





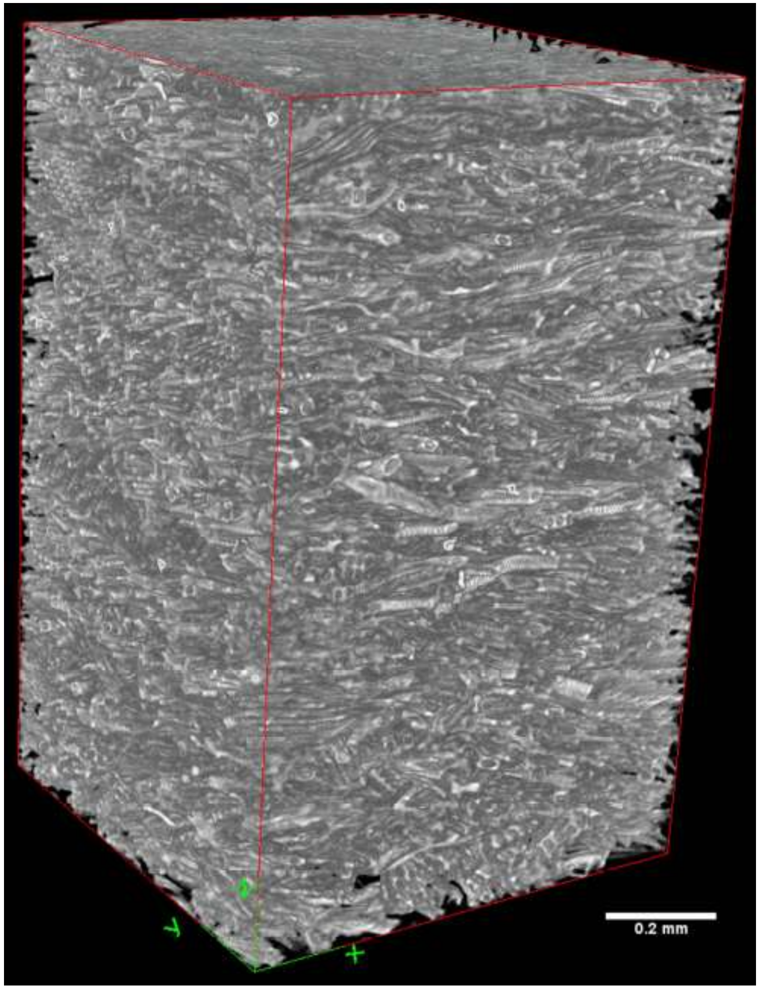


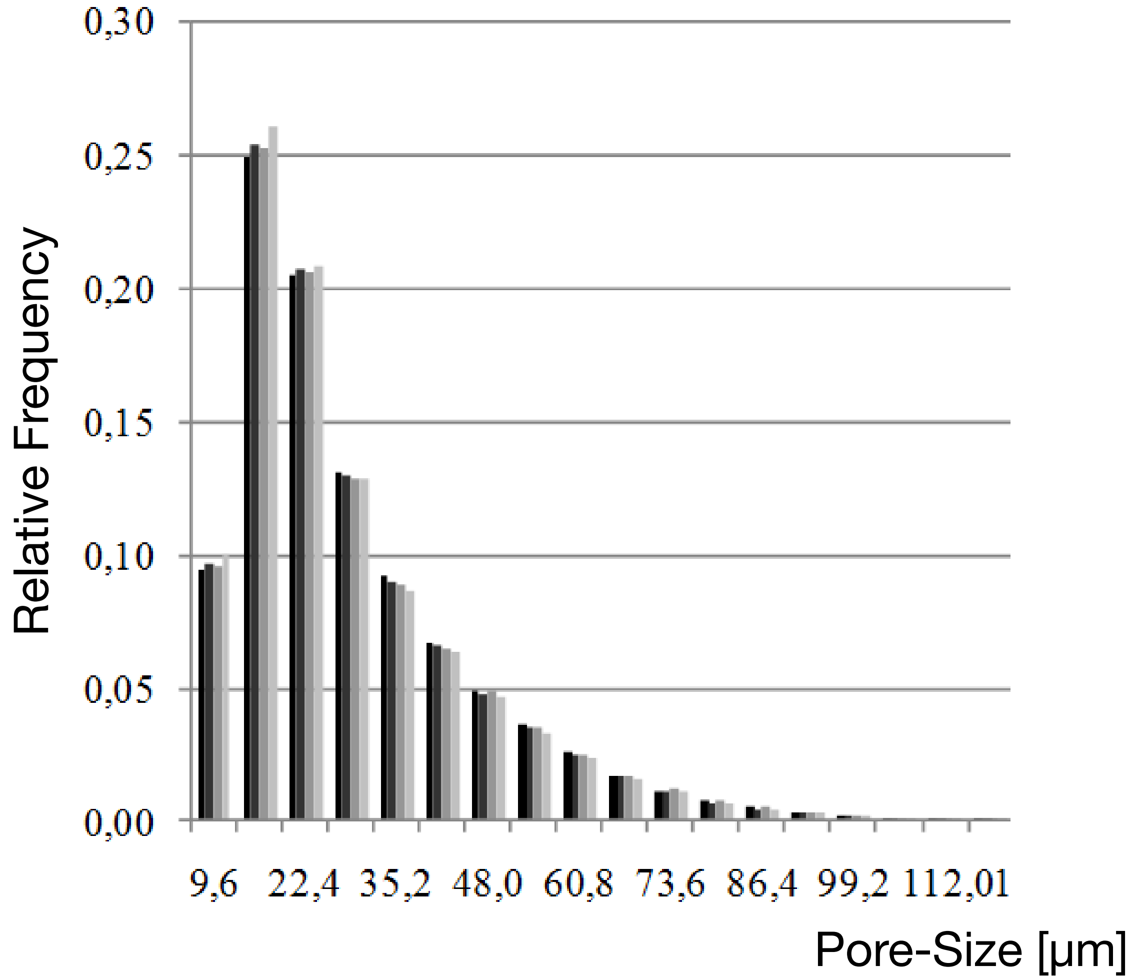




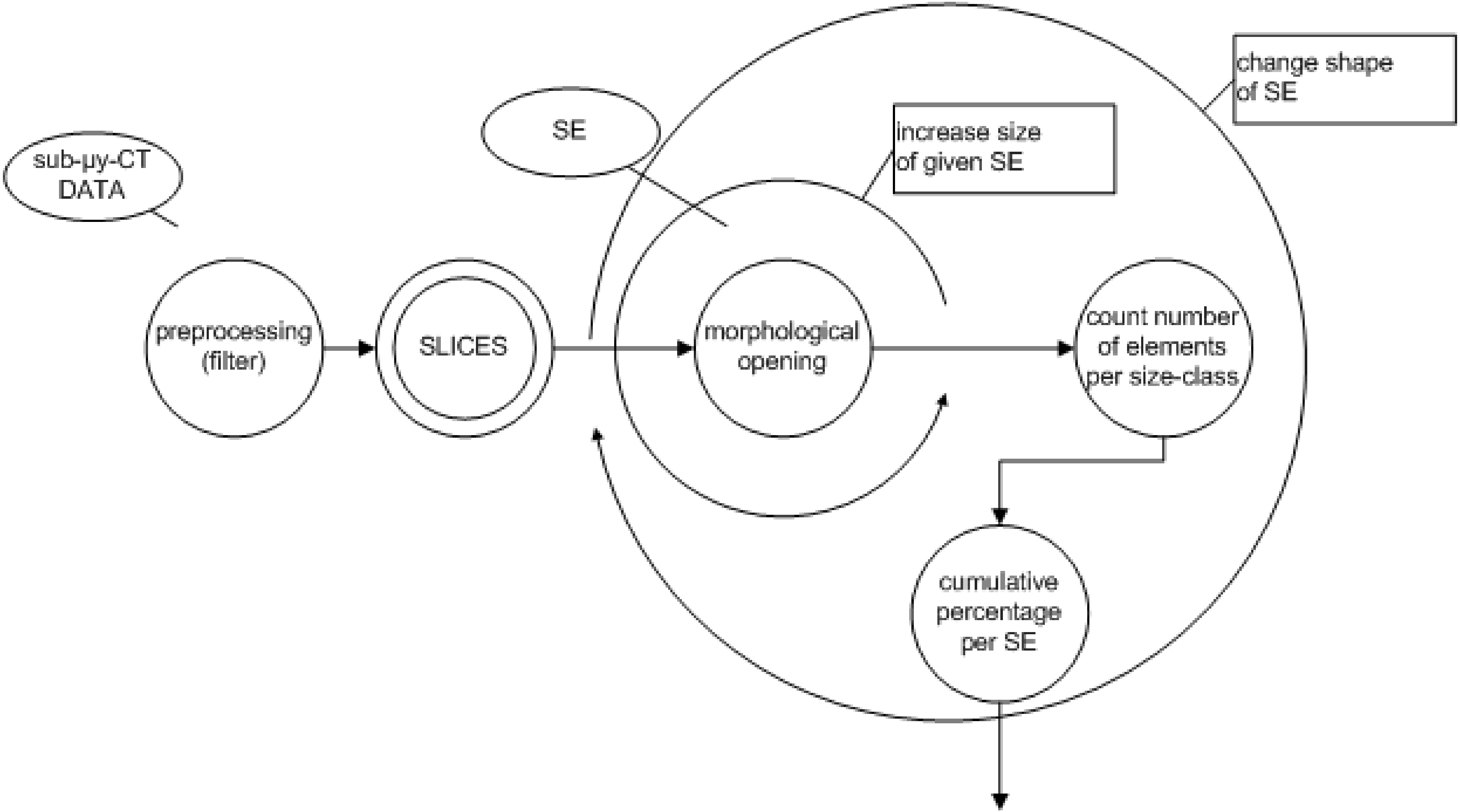
Recent Study 4: Wood Based Prod. Analysis

Goal: Analysis of the Pore-Size Distribution





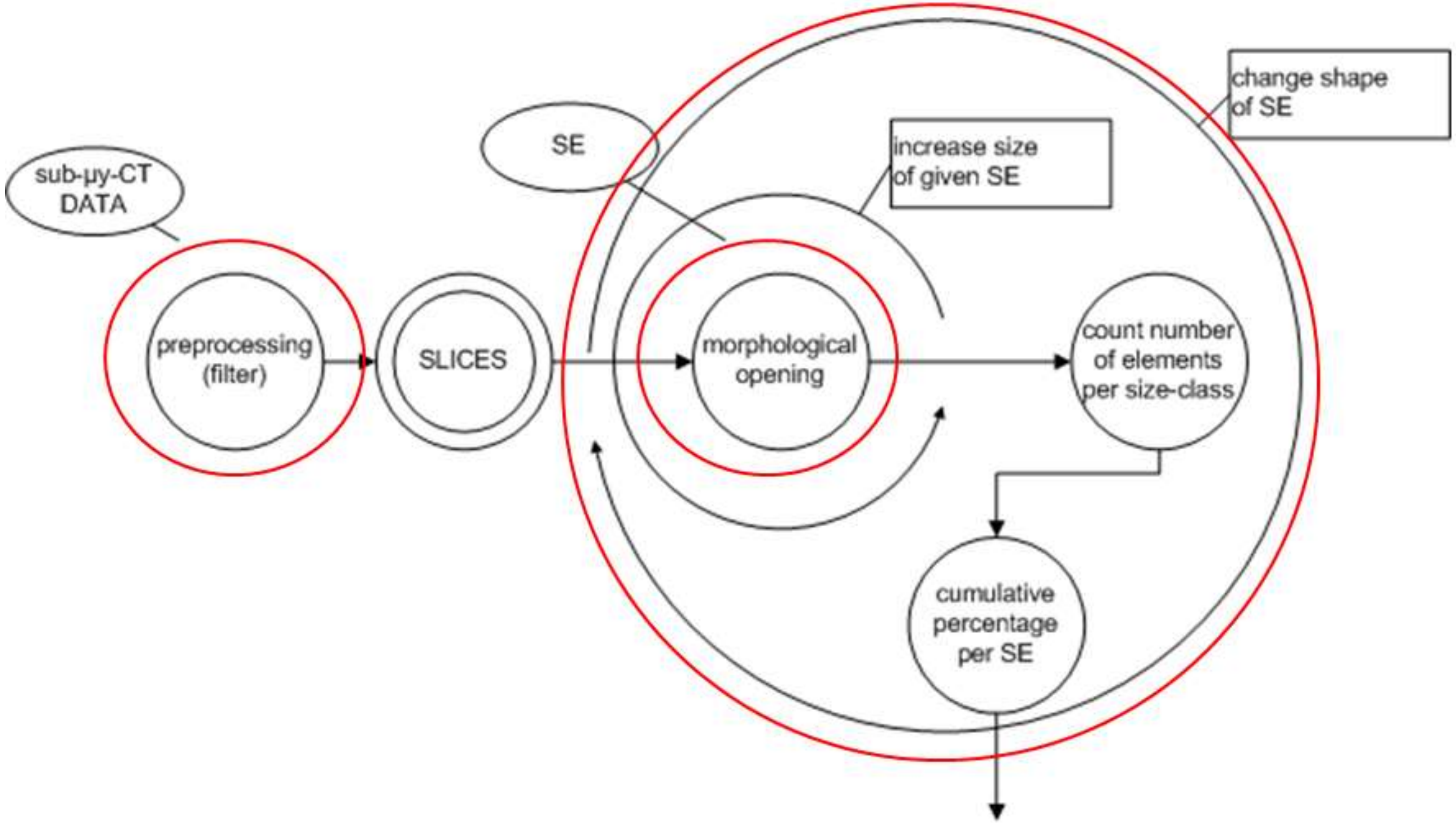
Method



sub-µy-CT DATA
preprocessing (filter)
SLICES
SE
morphological opening
increase size of given SE
change shape of SE
count number of elements per size-class
cumulative percentage per SE

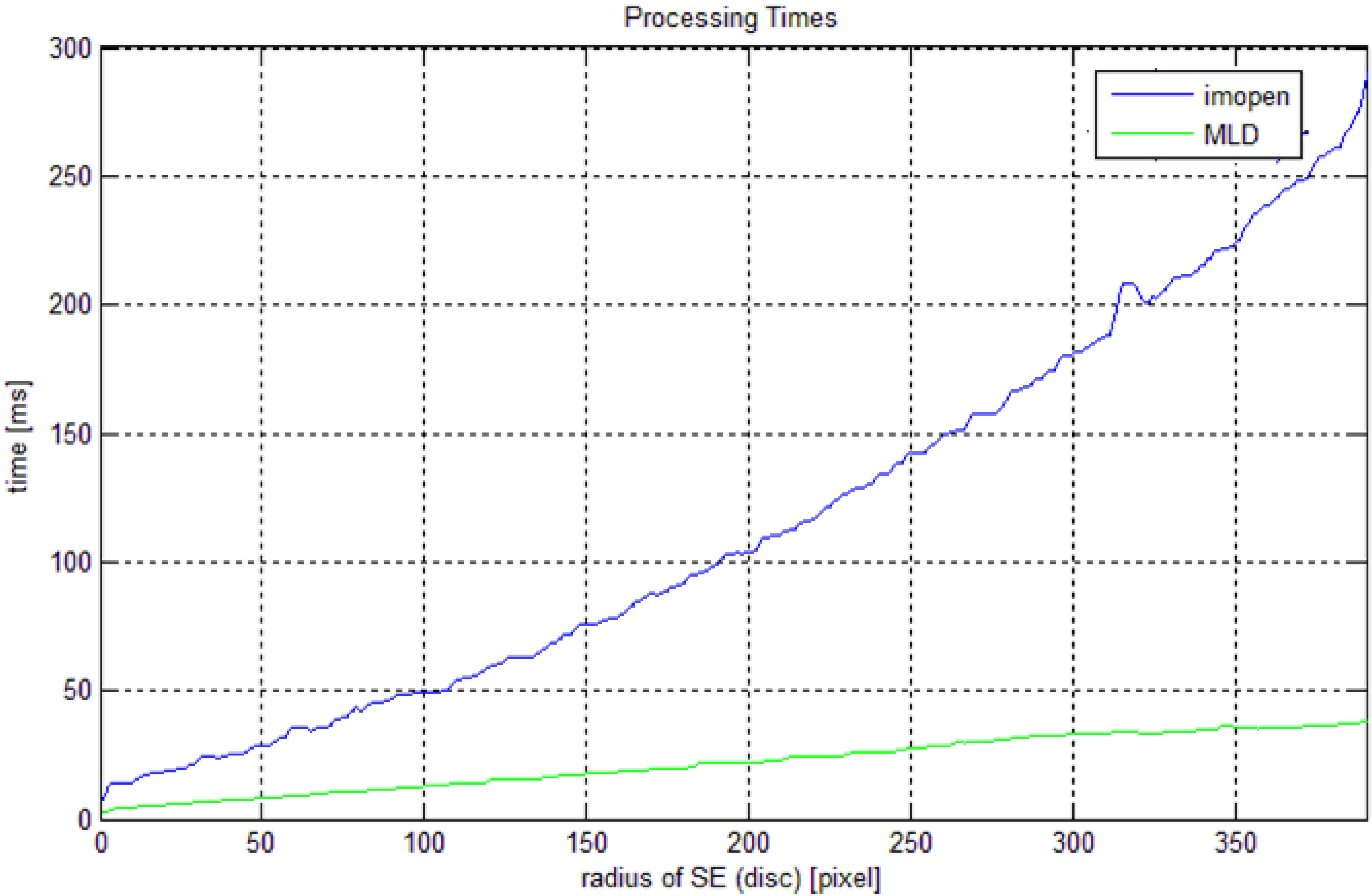
Analysis

Prototype implementations of the method showed that processing time increased dramatically with the size of the used structuring elements.



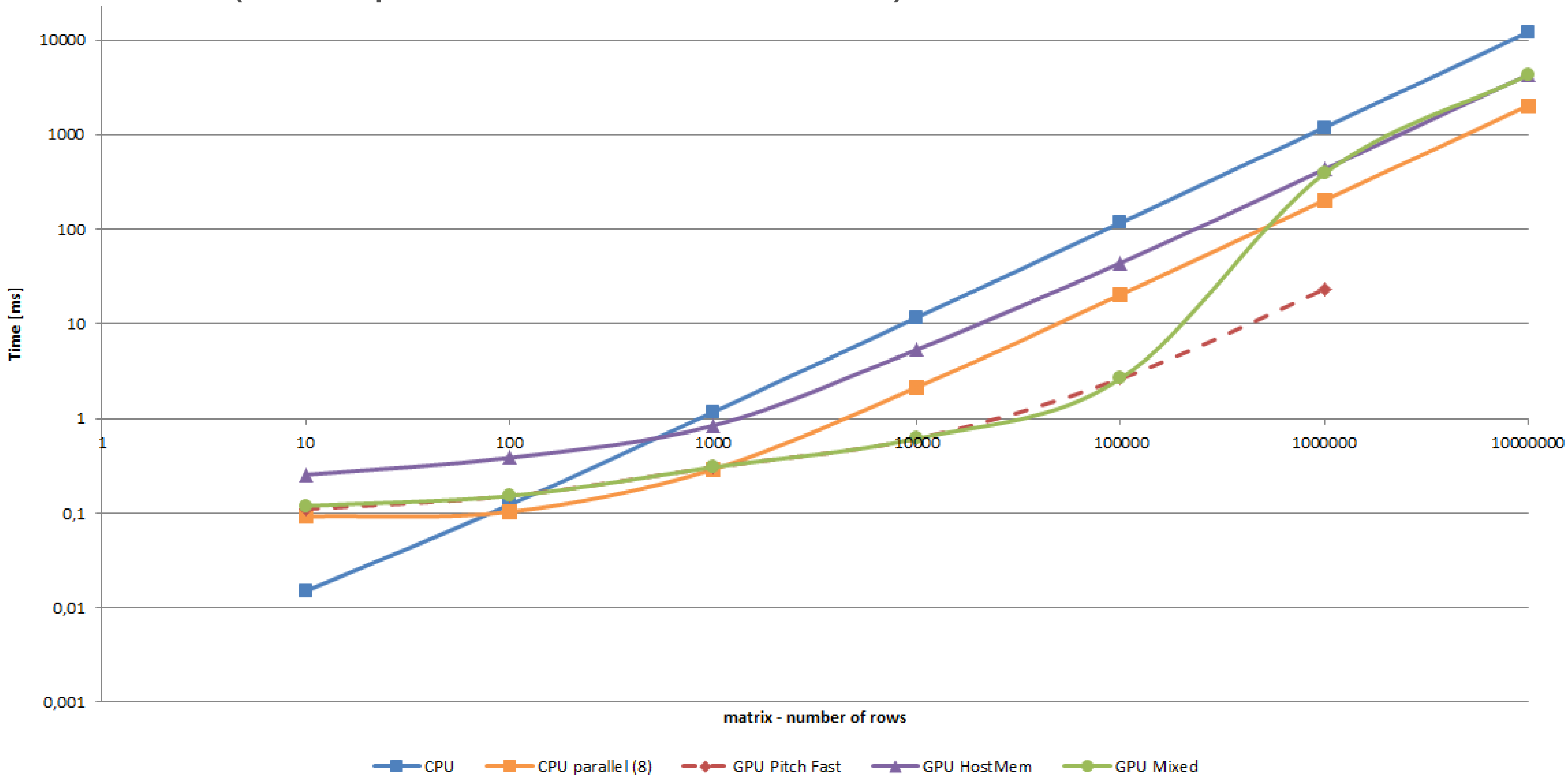
Parallel Investigations

Speedup using “Multi-level decomposition of Euclidean spheres” MLD



Parallel Investigations

Relative speedup when porting the matrix manipulation to a multicore CPU or GPU (Example: Cartesian Product)



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Thanks for your Attention and Happy Birthday

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K. Entacher, A. Petutschnigg, W. Pomwenger
T. Forte, S. Kranzer, G. Standfest

Paracelsus Medizinische Privatuniversität
P. Schuller-Götzburg, R. Forstner, H. Resch



FWF Der Wissenschaftsfonds.

L526-B05

Materialise Software

ANSYS

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