



From Multidisciplinary Research to Medical Application: FEA as Part of an Integrative Project for Dental Implants

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R. Sader (c,f), H.-F. Zeilhofer (e,f)**

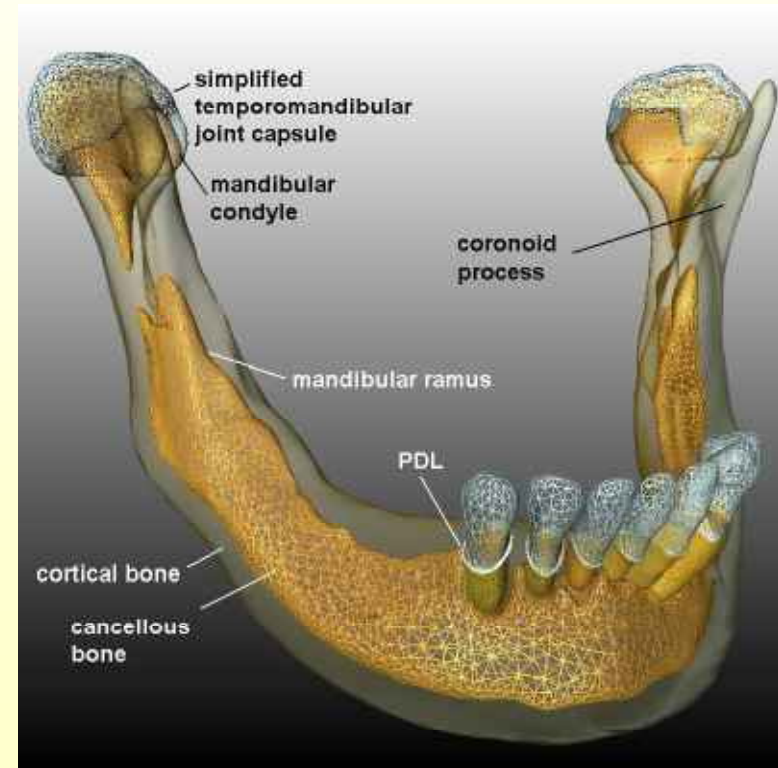
**(a) Hamburg Univ. of Appl. Sc., (b) CADFEM GmbH, (c) Univ. of
Frankfurt, (d) Vienna Univ. of Techn. (e) Univ. Hosp. Basle,
(f) Center of Adv. Cranio-Max.-Fac. Surgery, TU Munich**

Germany – Austria – Switzerland



Overview

- A) Introduction and motivation
- B) Development of the project
- C) Summary and conclusion

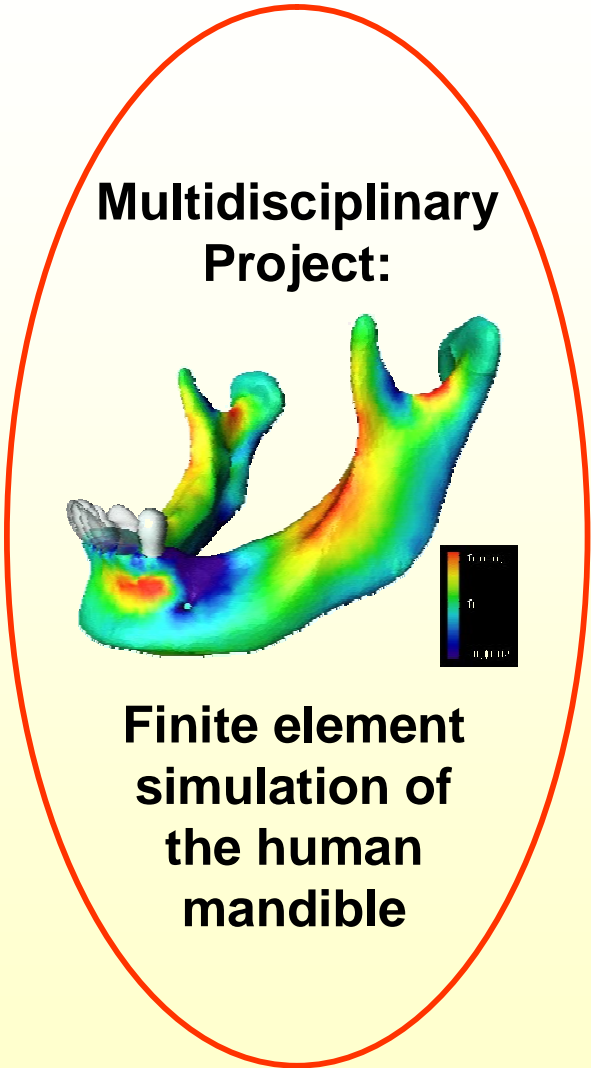
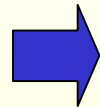


A) Introduction and Motivation



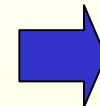
Medicine

Open questions:
improved implant
planning, implant
loss, ...



**Multidisciplinary
Project:**

**Finite element
simulation of
the human
mandible**



Medicine

Solution

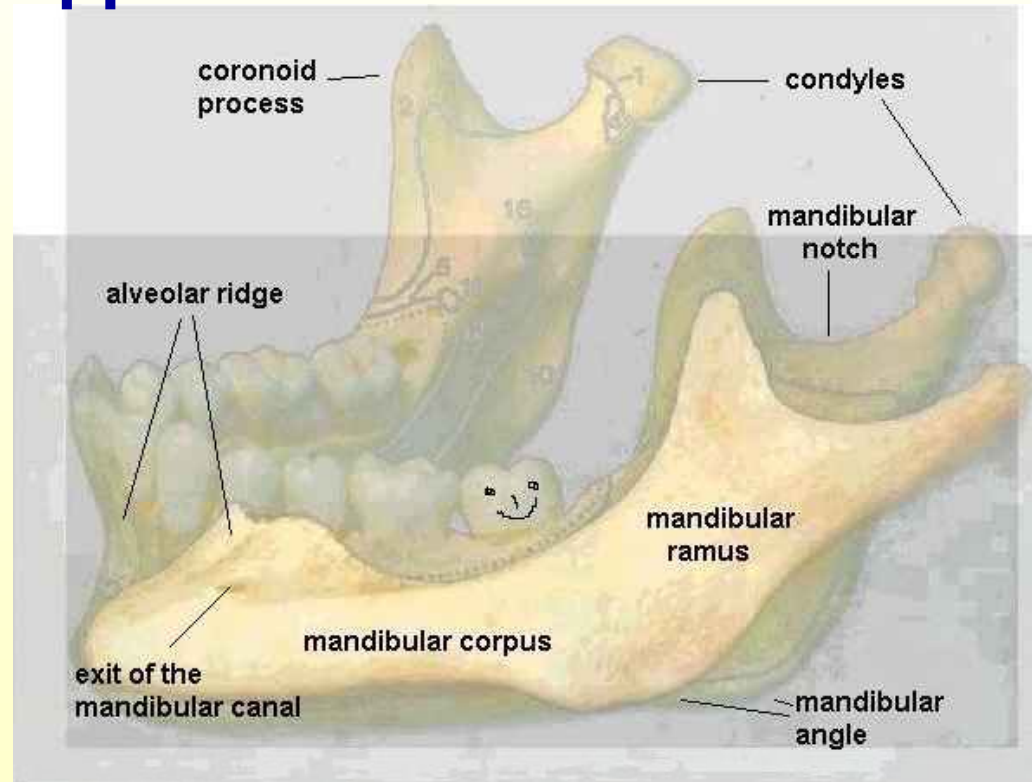
at the beginning

at the end

Philosophy of the project

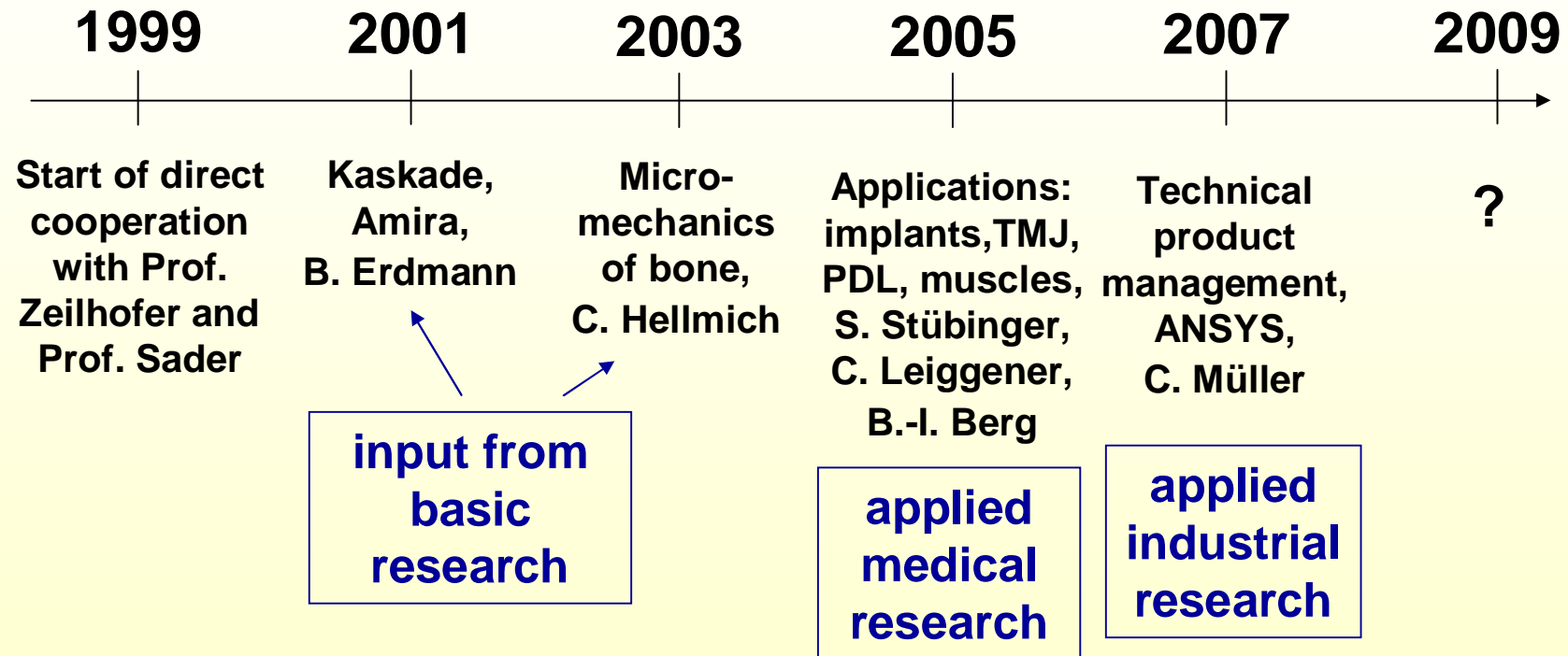


- The mandible is in the center of the project
- Stepwise approximation of the real anatomy



B) Development of the project

Simulation of the human mandible with the finite element method



Observation: two years steps of innovation

Step 1

1999

Simulation of the human mandible with the finite element method

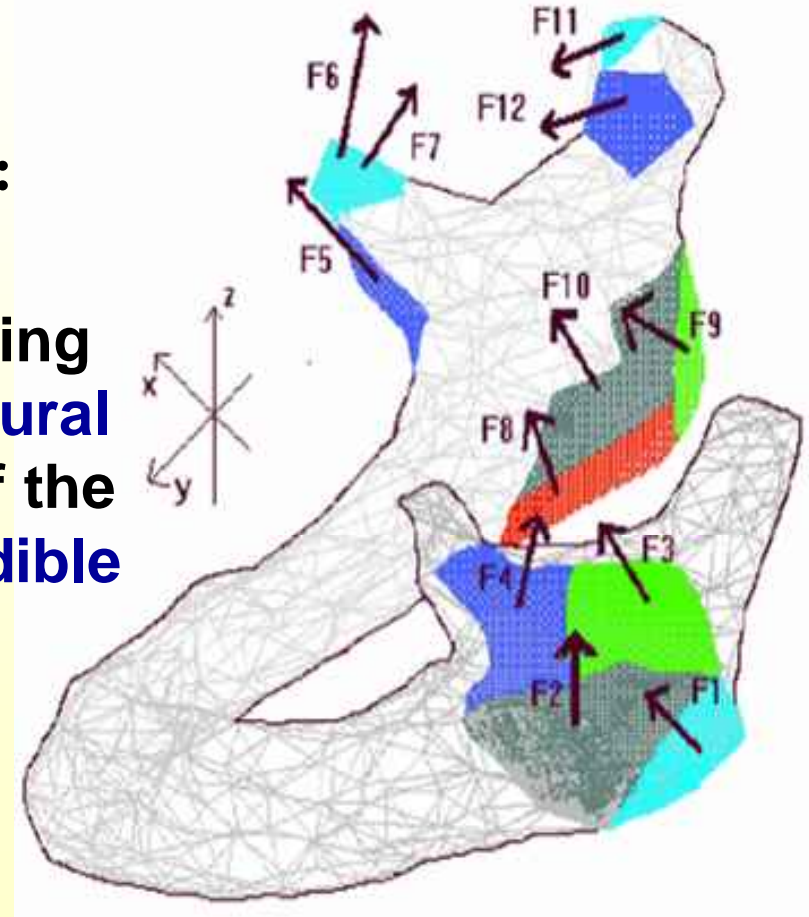


H.-F. Zeilhofer, R. Sader
HFZ, TU Munich



“numerical testing for functional anatomy”

Objective:
A better understanding of the **structural behaviour** of the human mandible



Step 2

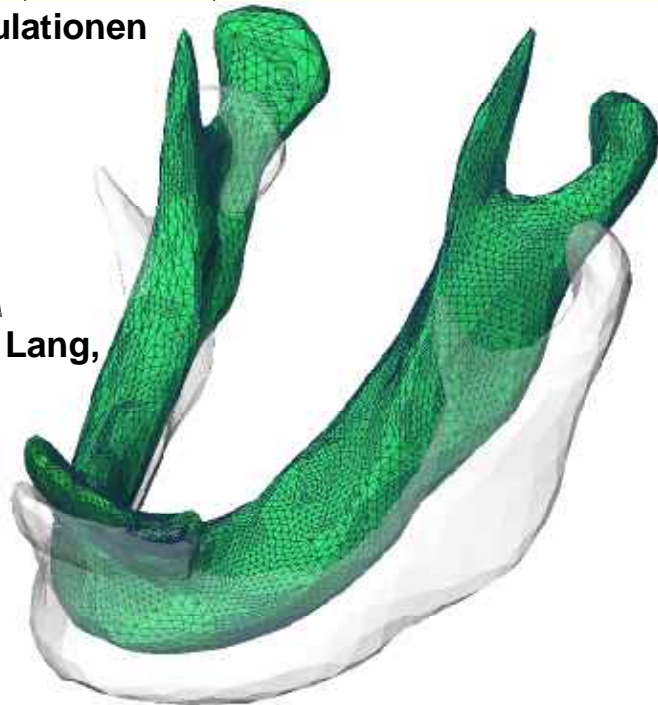
2001



Bodo Erdmann, ZIB Berlin,
FEM Simulationen



Beratend: Jens Lang,
TU Darmstadt,
Numerik

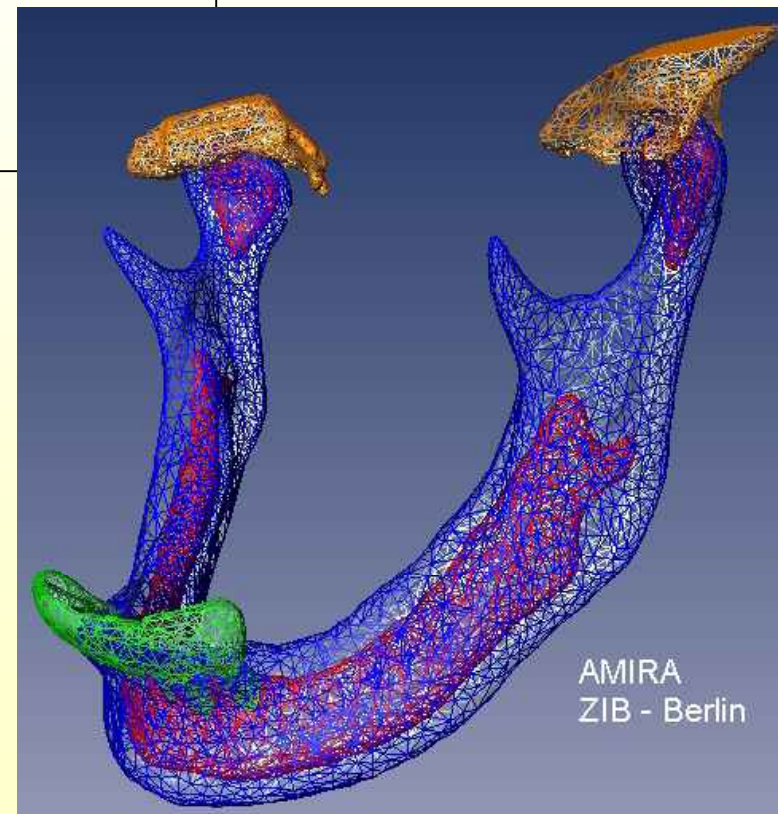


New Input:

2 strong research tools
from **Mathematics** and
from **Visualization**:

Kaskade

Amira



Step 3

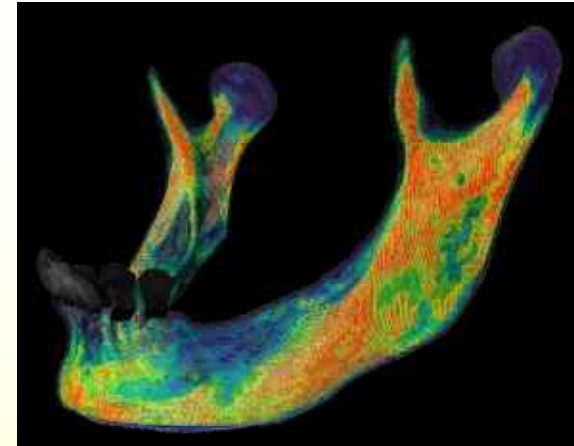
2003



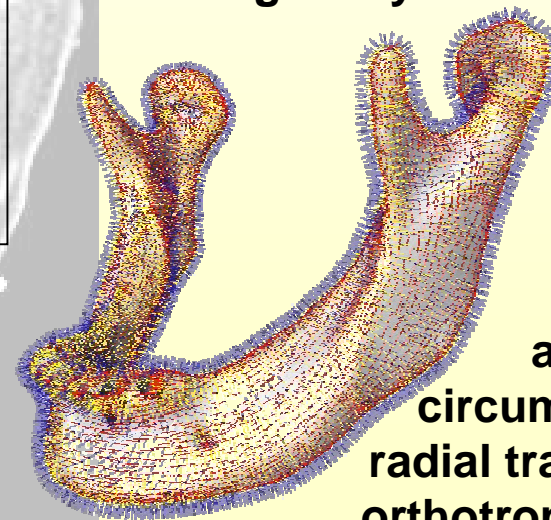
Christian Hellmich,
TU Wien

New Input:
fundamental research
from **nano-** and
micromechanics:

inhomogeneity
and
anisotropy
of the mandible
could be accessed.

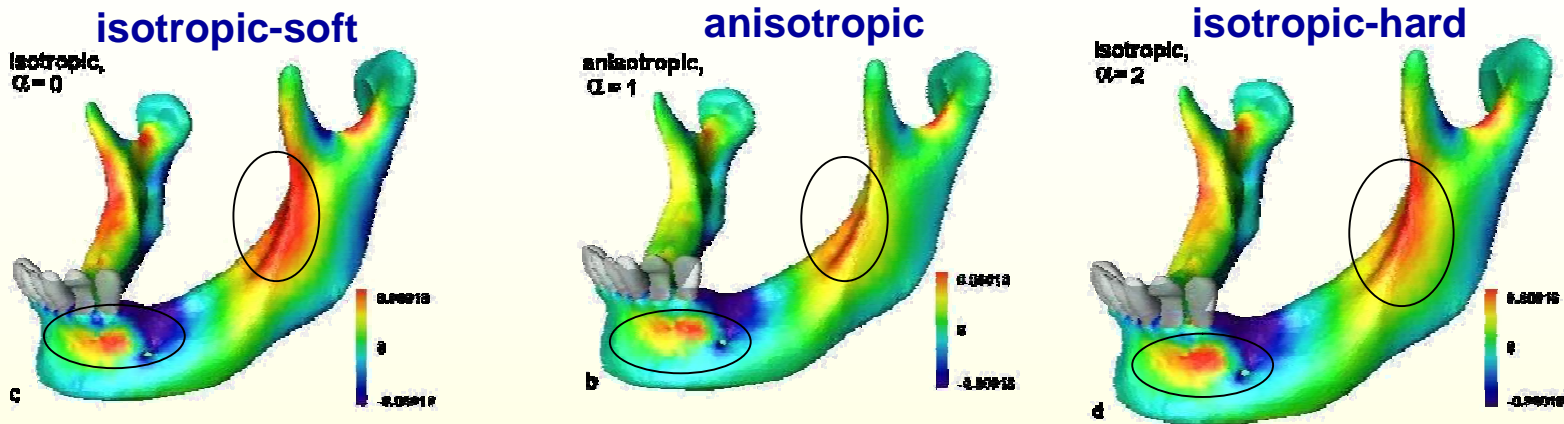


Volumetric profile of the
inhomogeneity of the mandible

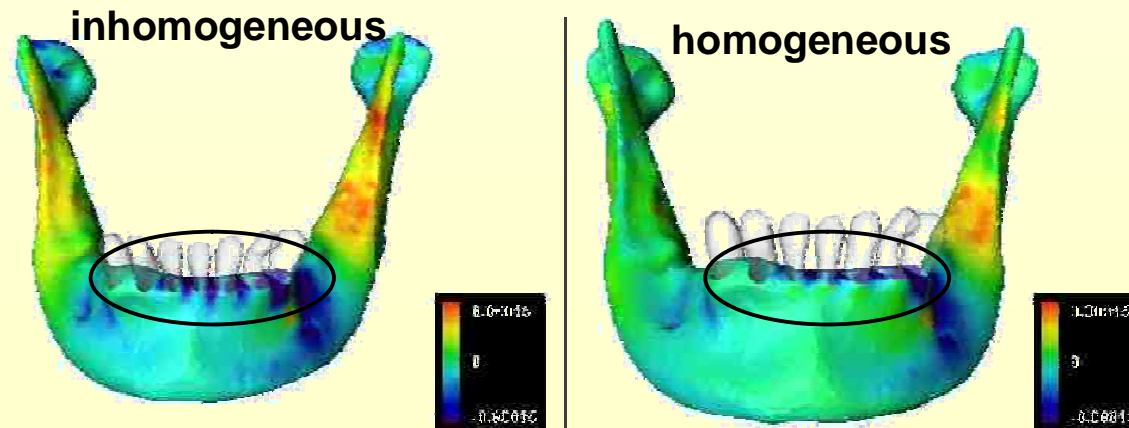


axial,
circumferential,
radial trajectories of
orthotropic elasticity

Impact of tissue anisotropy and inhomogeneity



Anisotropy seems to “spare” the mandible from loading.
But the opposite seems to be true for the inhomogeneity.



Step 4 2005



**New Input from the
University Hospital
Basel, Switzerland:**

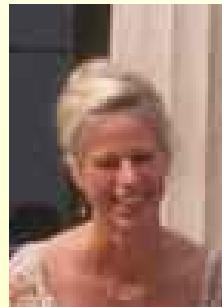
bundle of applications:

- implantology
- periodontology
- TMJ disorders
- muscular tissue
and movements

Application !



**S. Stübinger,
oral surgery,
implantology**



**B.-I. Berg,
cranio-
maxillofacial
surgery**



**C. Leiggenger,
cranio-
maxillofacial-
surgery**



**Prof. Zeilhofer,
cranio-
maxillofacial-
surgery**

Introduction of the Periodontal Ligament to the finite element model:

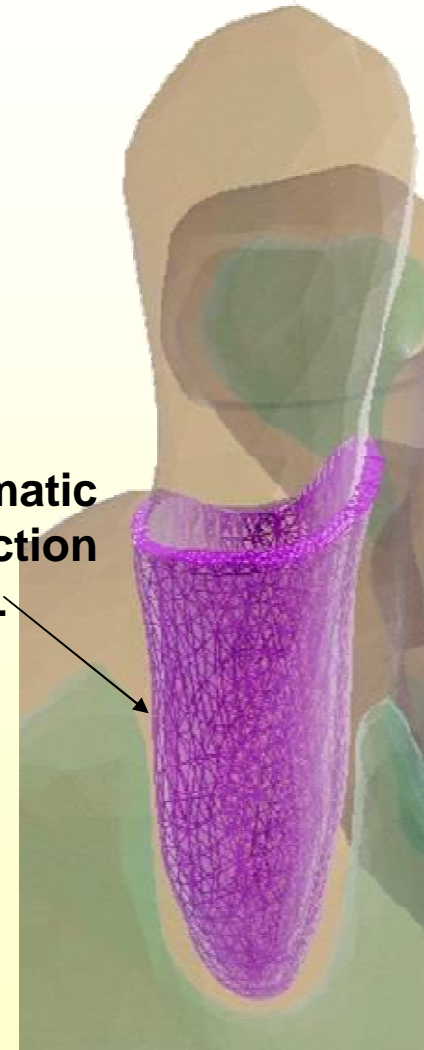


dental anatomy
as part of the
mandible

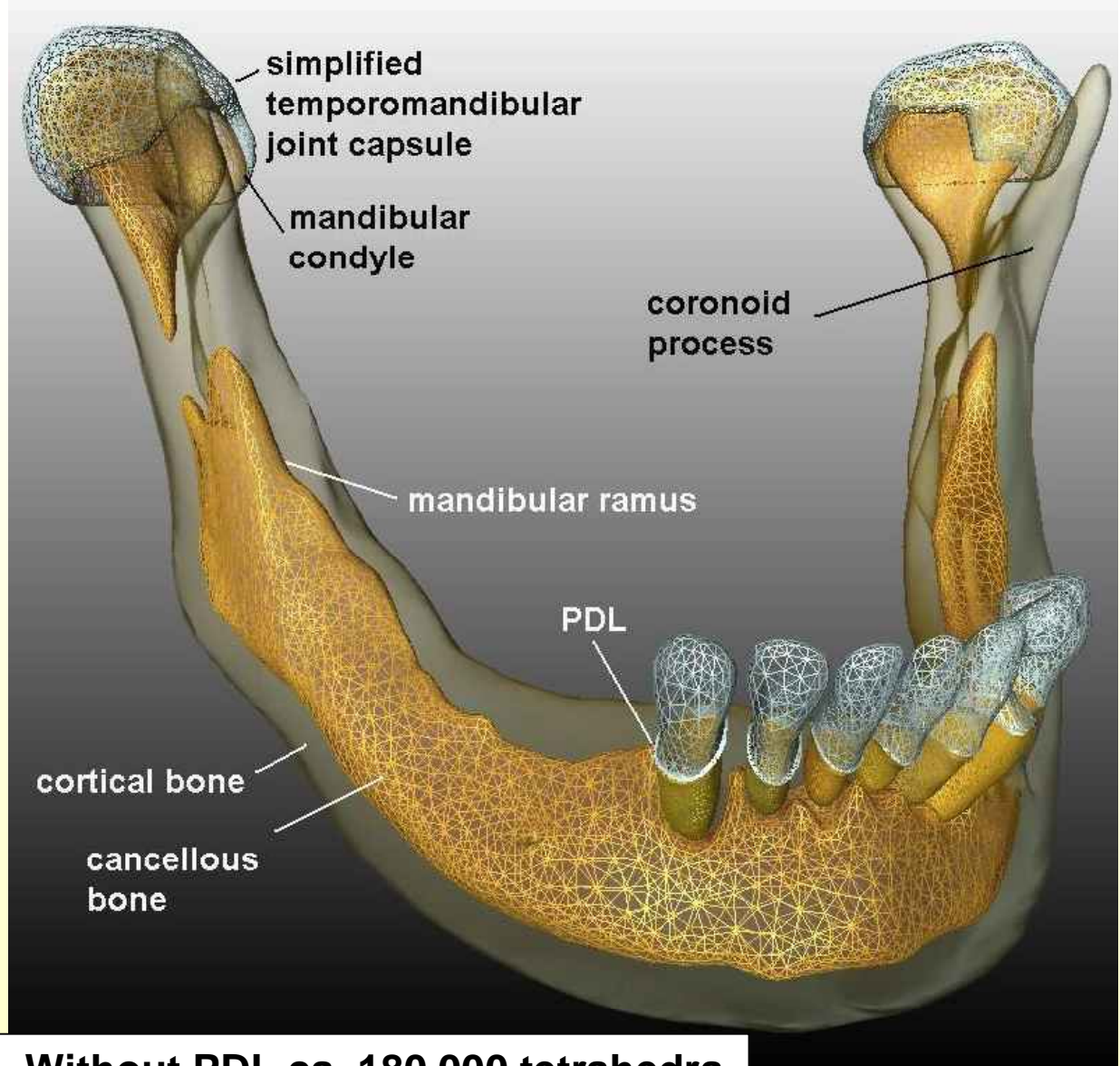
Problem:
strongly
varying
dimensions

PerioDontal Ligament:
between bone and tooth,
of about 0.2 mm thickness

semiautomatic
reconstruction
of the PDL



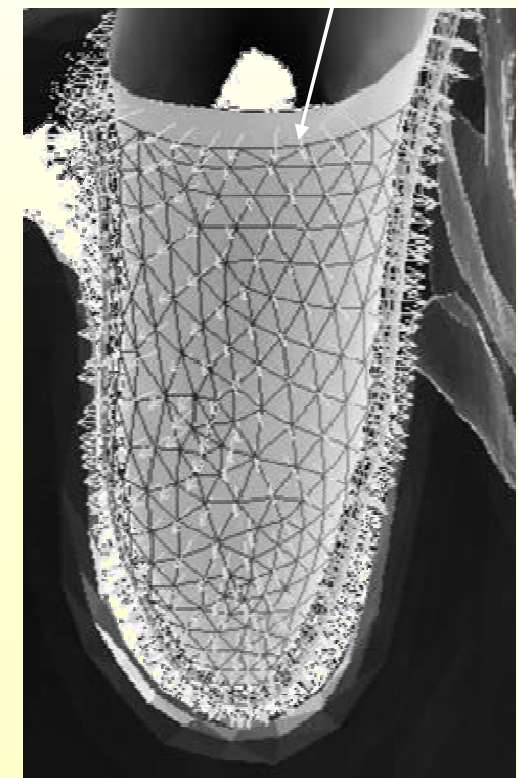
Resulting FE Model:



Without PDL ca. 180.000 tetrahedra
PDL included ca. 360.000 tetrahedra

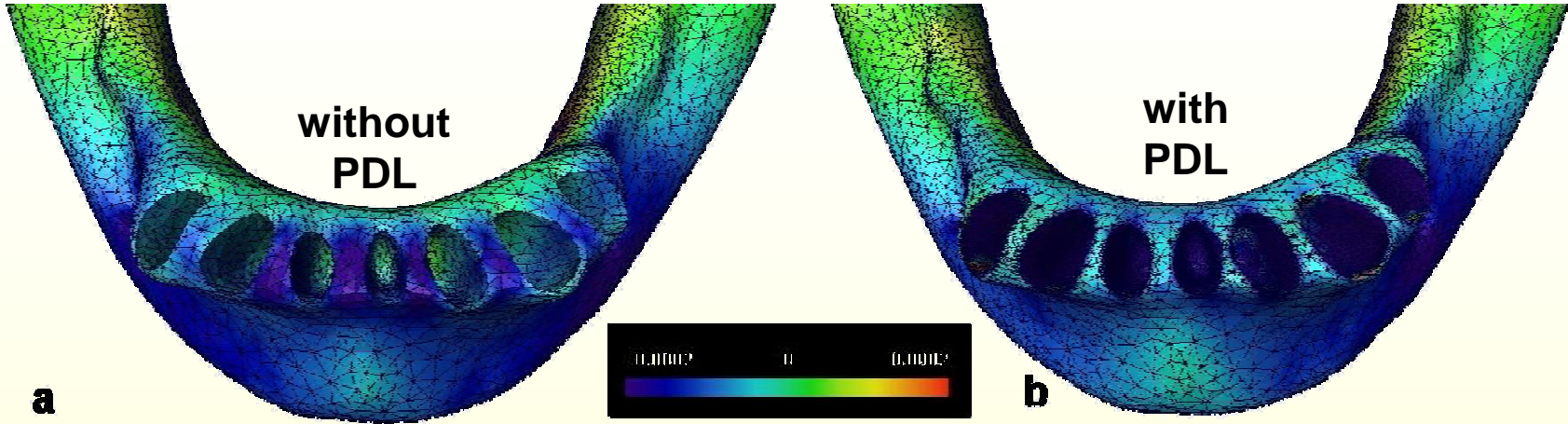


outlook: introduction of Sharpey's fibres via anisotropic simulation of the PDL

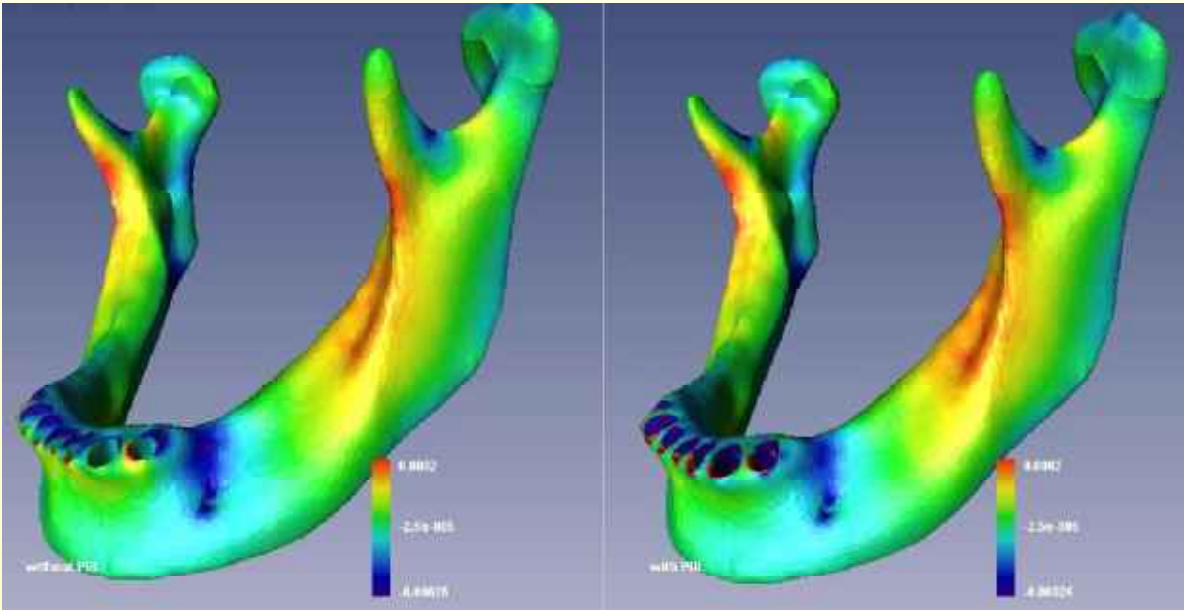


Result in Periodontology / Implantology:

regionally qualitatively relevant ...

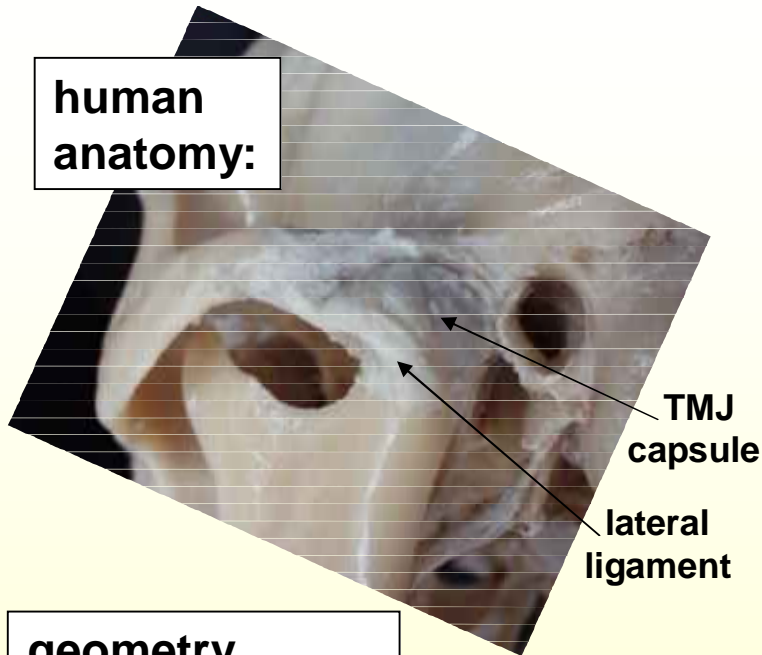


... but not globally:

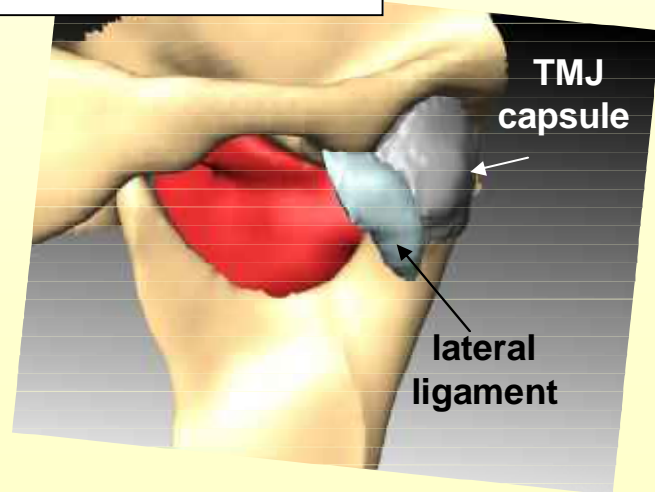


The temporomandibular joint (TMJ)

human anatomy:

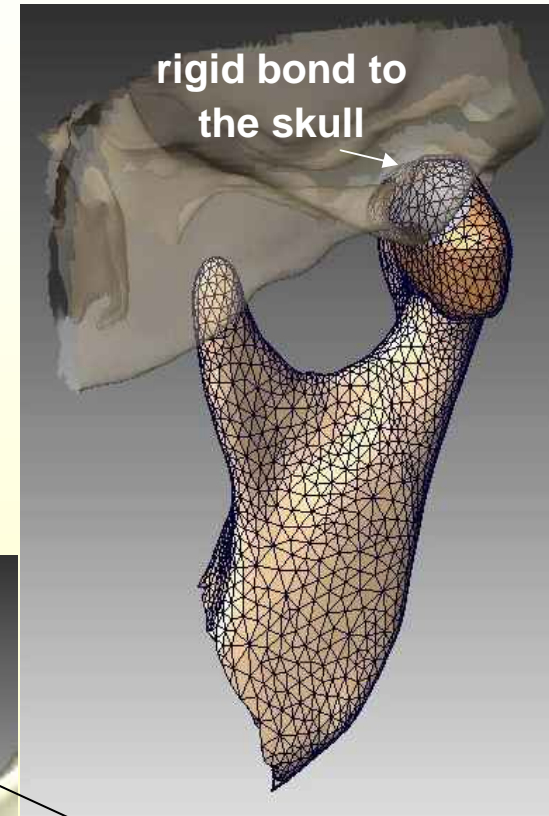
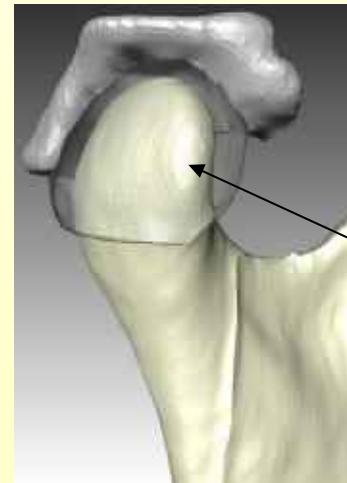


geometry reconstruction:



FE-model:

Key idea: simplification of the TMJ structures to simplified (homog., isotropic) TMJ capsules

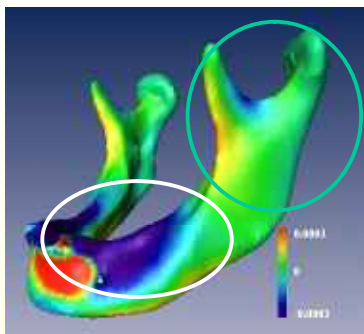


The condyle is freely mobile in the capsule.

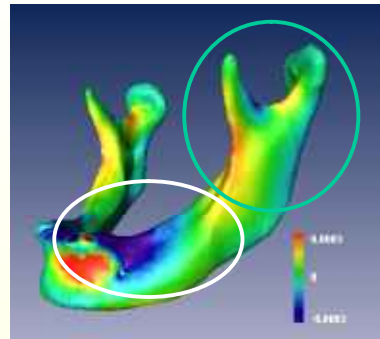
Result: temporomandibular joint (TMJ)



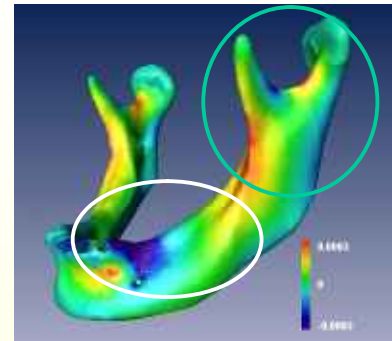
Variation of the E-modulus of the capsule



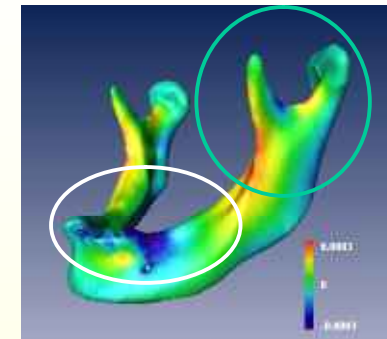
E = 0.1 MPa



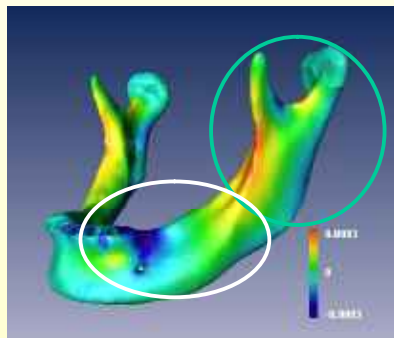
E = 1 MPa



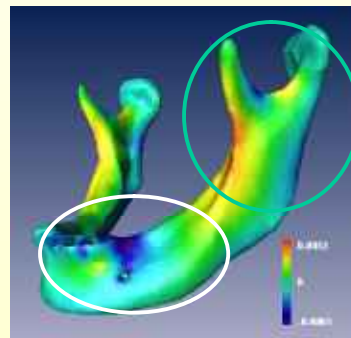
E = 5 MPa



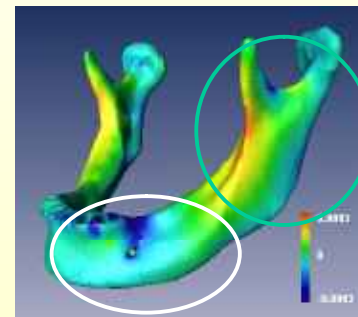
E = 10 MPa



E = 15 MPa



E = 20 MPa



E = 50 MPa

volumetric strain

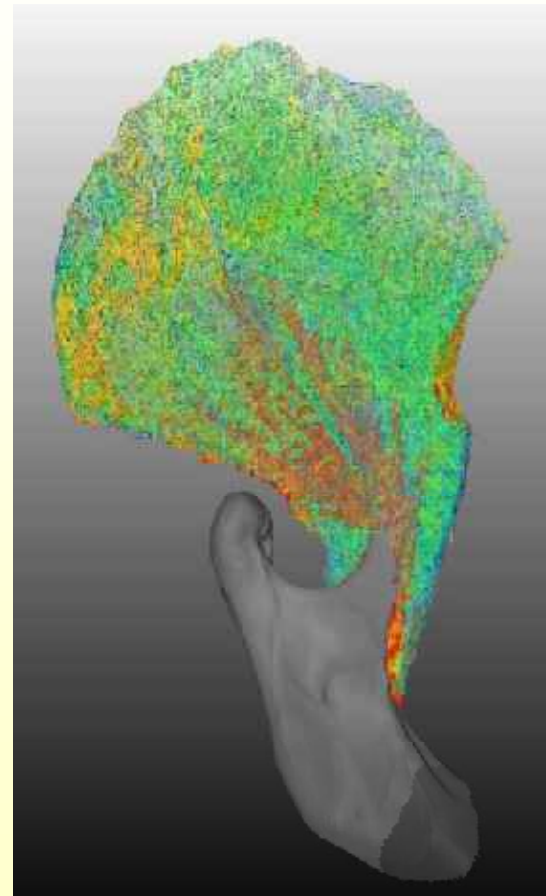
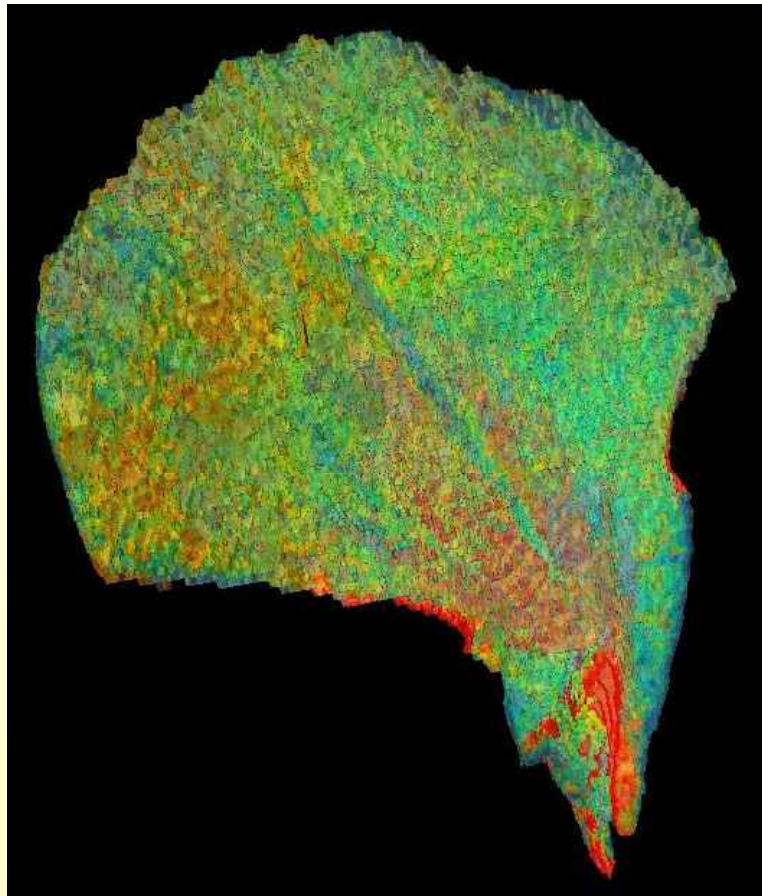
comparison with the clinical situation: alterations in TMJ cause problems of the whole jaw bone

Observations:

- **adjacent** bone: first increase, then decrease
- **overall** profile: decrease with increasing Young's modulus

Masticatory muscles

Approach: visualization of the inner structure of the muscles



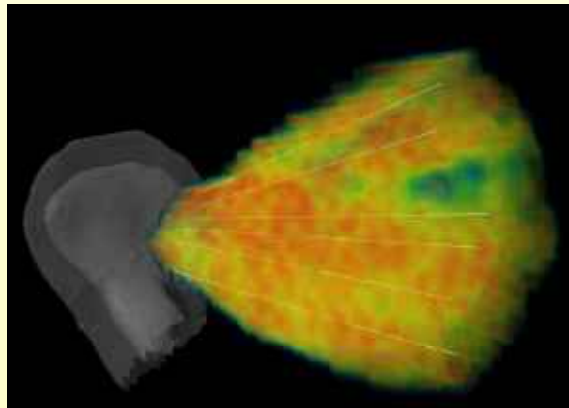
see [Kober,
Sader, Zeilhofer,
cars2003]

-> extraction of the individual directions of the tendons

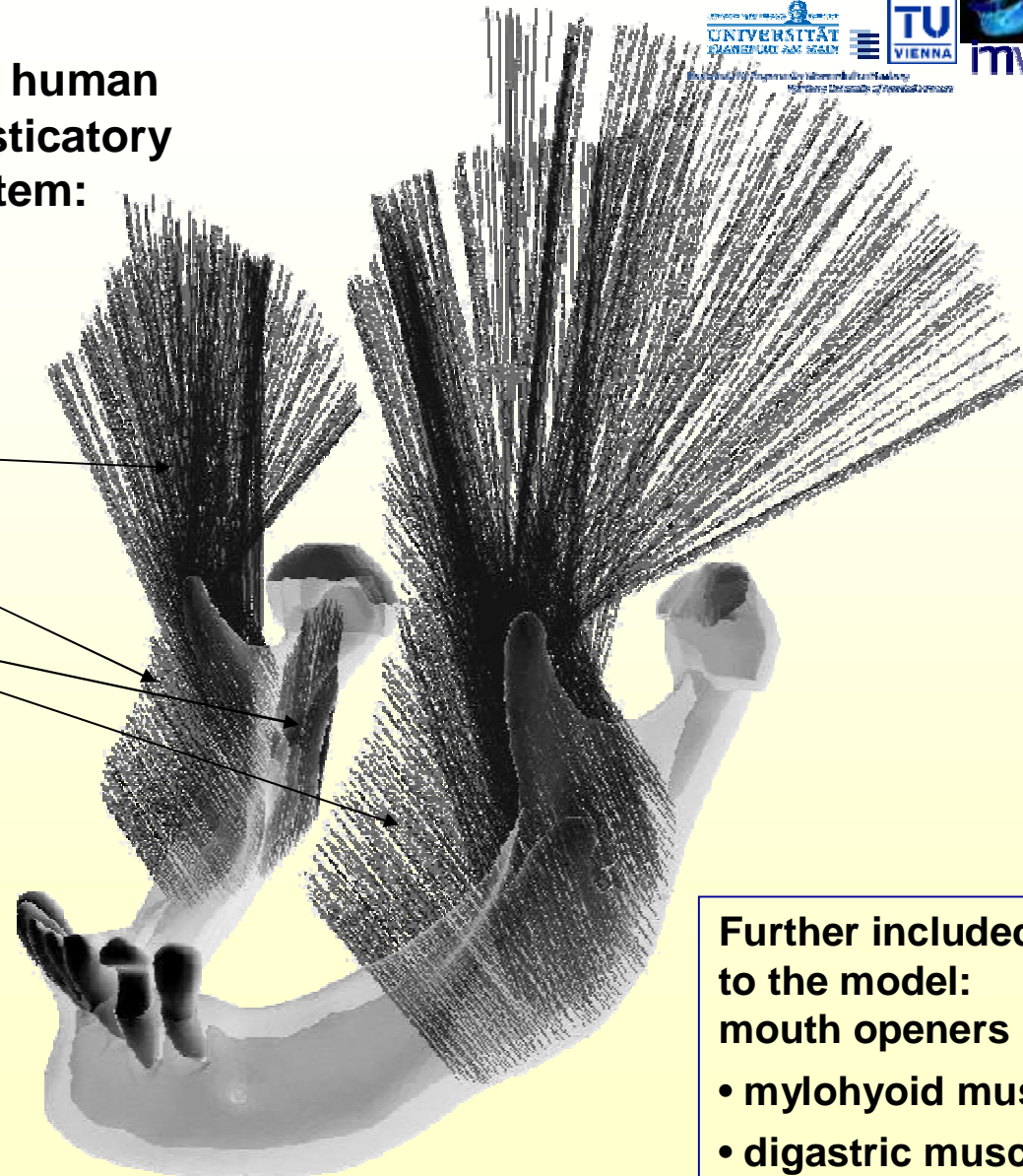
By further processing:
continuous vector
fields of individual
muscles' traction

see [kober,erdmann,
sader,zeilhofer, 2004]

- temporal muscles
- masseter muscles
- medial pterygoid m.
- lateral pterygoid muscles:



The human
masticatory
system:



Further included
to the model:
mouth openers

- mylohyoid musc.
- digastric musc.



Step 5

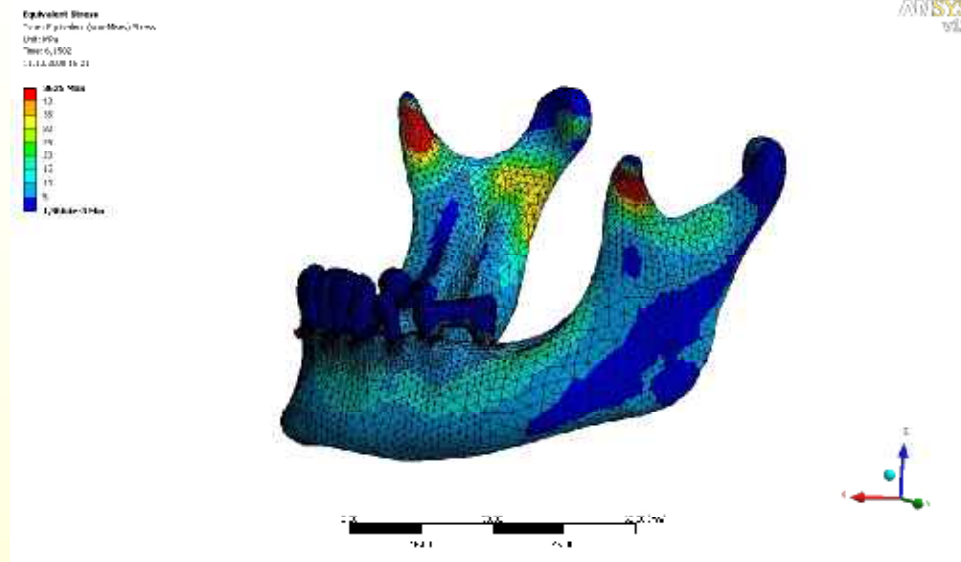
2007

Technical product management



**New Input from the
CADFEM GmbH,
Graing:**

**Compilation of an
“innovative product”
for planning of dental
implants for use in
dental practices**



New tool used in the project: ANSYS

Highly under construction !

Step 6

2009



New Input from

...

...

...

...

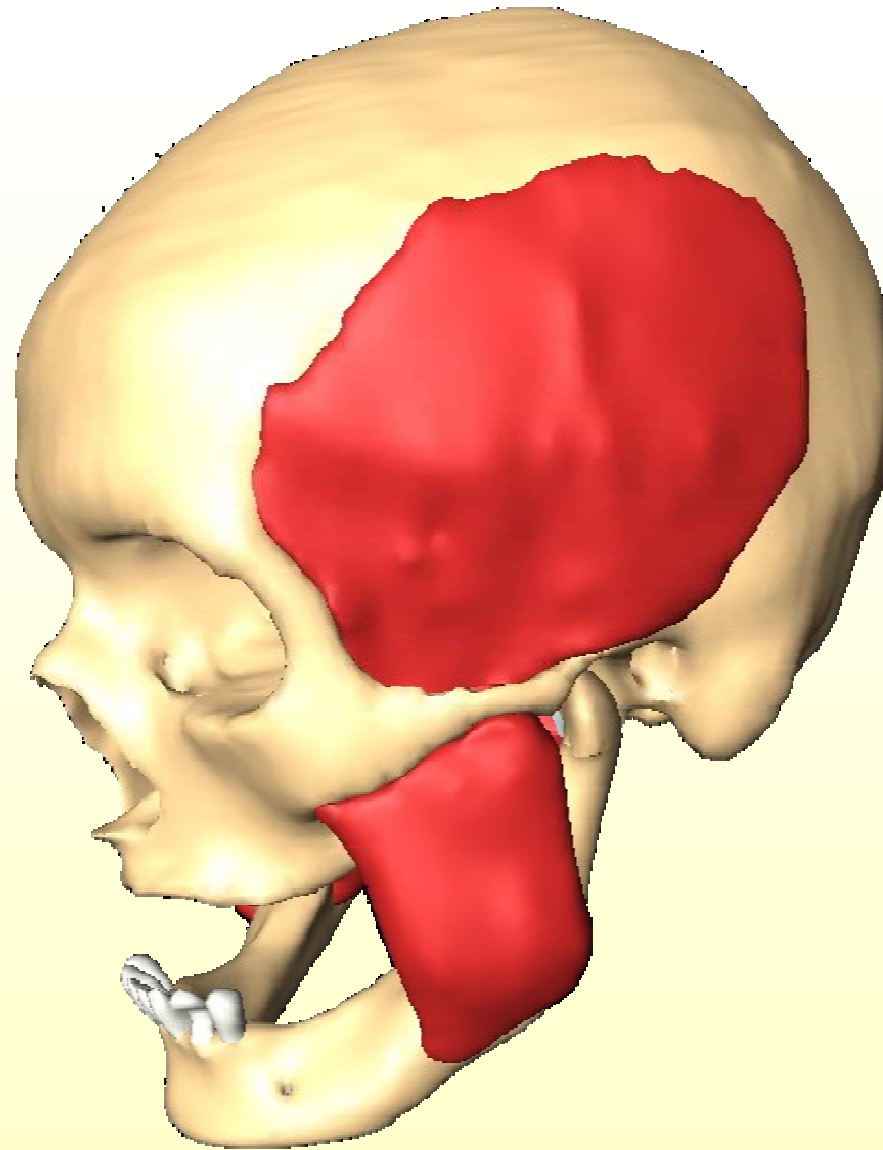


C) Summary and conclusion

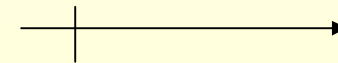


- Ø The project started from theoretical medical research, namely functional anatomy.
- Ø Decisive input of basic research from several branches was provided.
- Ø A bundle of applications is available.
- Ø A special application, namely implantology, was selected for development of an innovative project.
- Ø The project did take some time.
- Ø Two years steps of innovation were observed.
- Ø We will look to 2009 !

Outlook:



2008



Acknowledgement:

Fujitsu Siemens Computers
for supporting our research
with computer equipment
for effective 4D-Visualizations

- ... and you for
your attention,
thank you !

