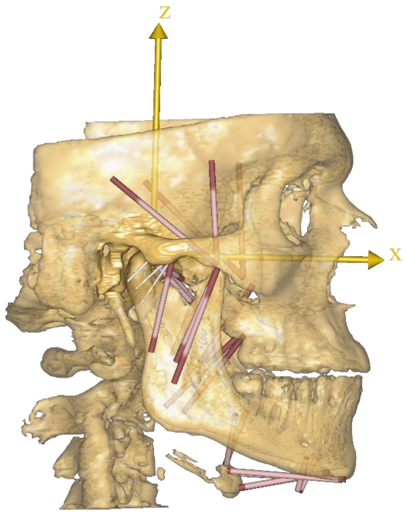


The webcast will start in a few minutes….

Validation of a new AnyBody mandible model

February 4th 2016

Outline

- Introduction by the Host
- Validation of a mandible model
  - Different models for TMJ
  - Validation of model predictions
- Final words from the host
- Questions and answers

Michael Skipper Andersen
Associate professor
Aalborg University
(Presenter)

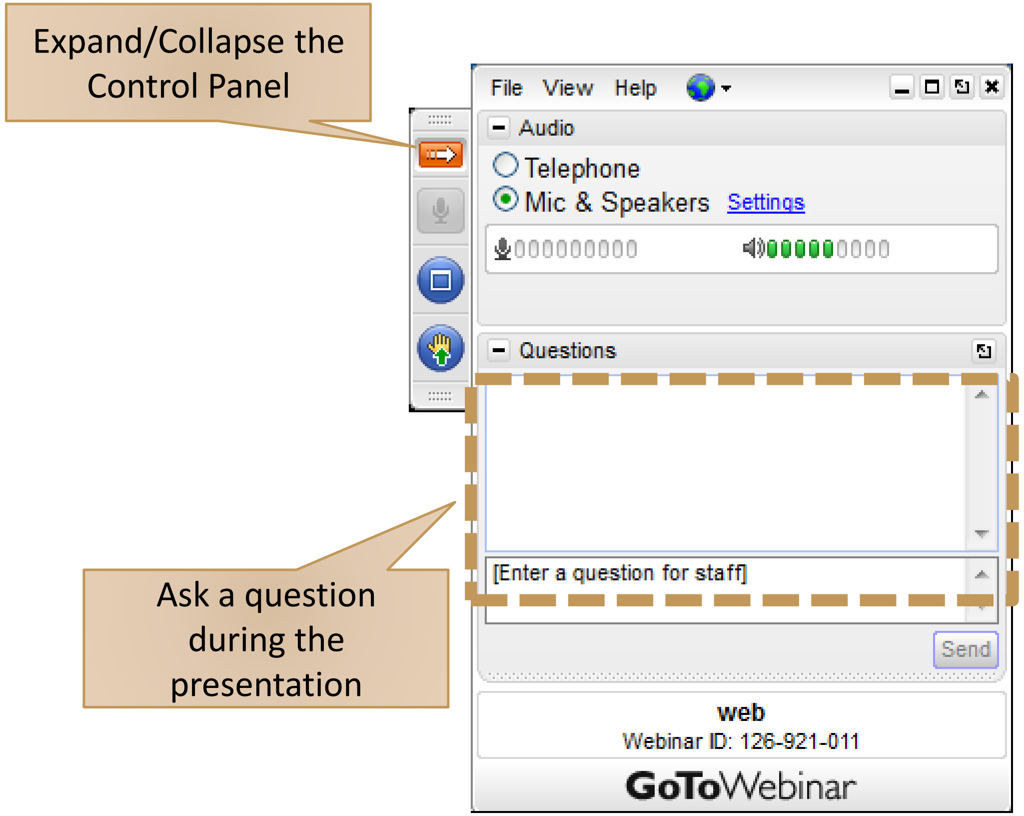
Ananth Gopalakrishnan
(Host)

Control Panel

The Control Panel appears on the right side of your screen.

Submit questions and comments via the Questions panel.

> *Questions will be addressed at the end of the presentation. If your question is not addressed we will do so by email.*



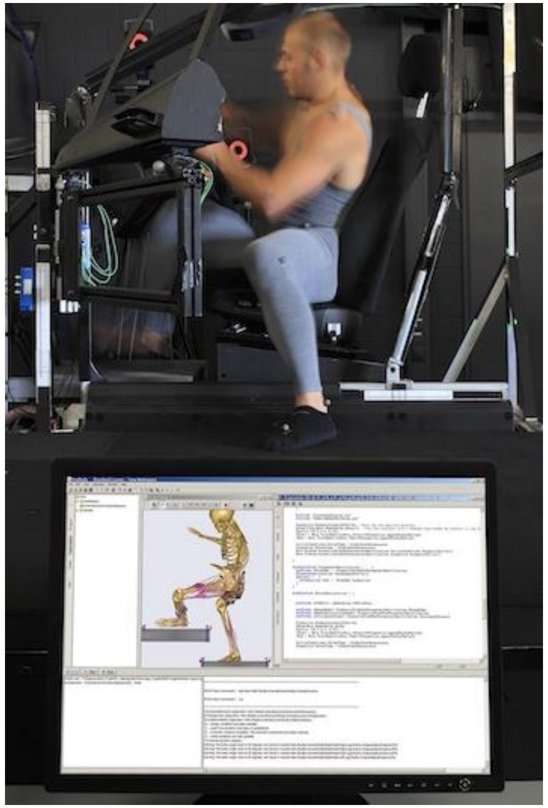
AnyBody Modeling System

Musculoskeletal analysis

AnyBody Managed Model Repository

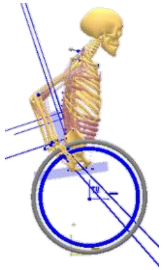
Wide range of simulation options

- Motion capture
- Ground reaction force prediction
- Imaging → Patient-specific anatomy
- Man-machine simulations



Rasmussen et. al. (2011), ORS Annual Meeting

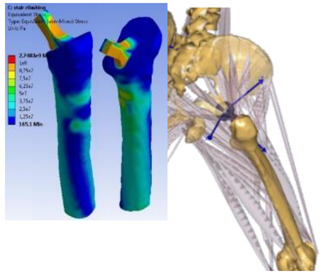
Movement Analysis



Product Design Optimization

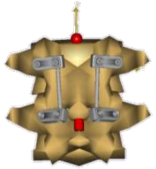
AnyBody Modeling System

Ergonomic Analysis



Load Cases for Finite Element Analysis

Surgical Planning and Outcome Evaluation

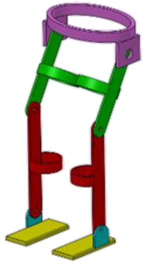


AnyBody Modelling System

Motion and Forces

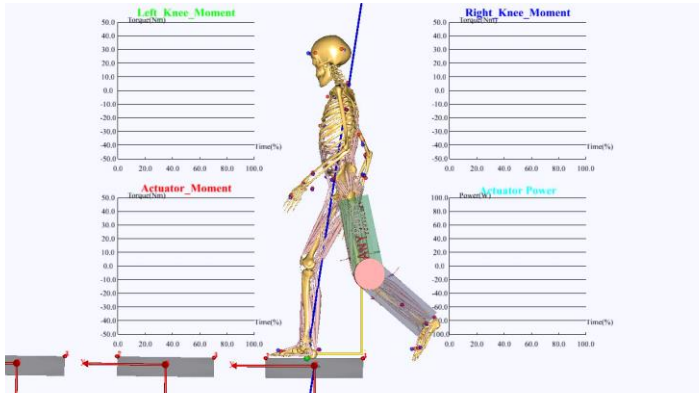
Body model

Environment model



Inverse dynamics
Muscle recruitment

Simulation

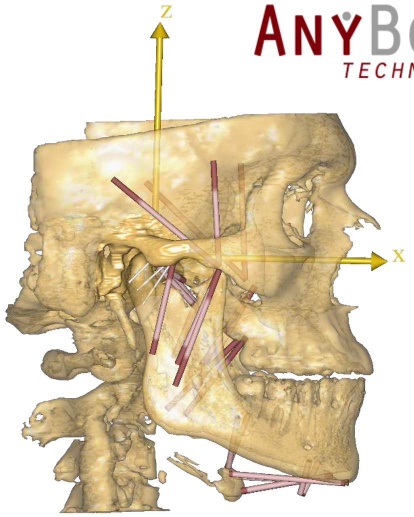


Internal body loads
- Muscle forces
- Joint forces

Design Optimization

Post Processing (e.g. FE tools)

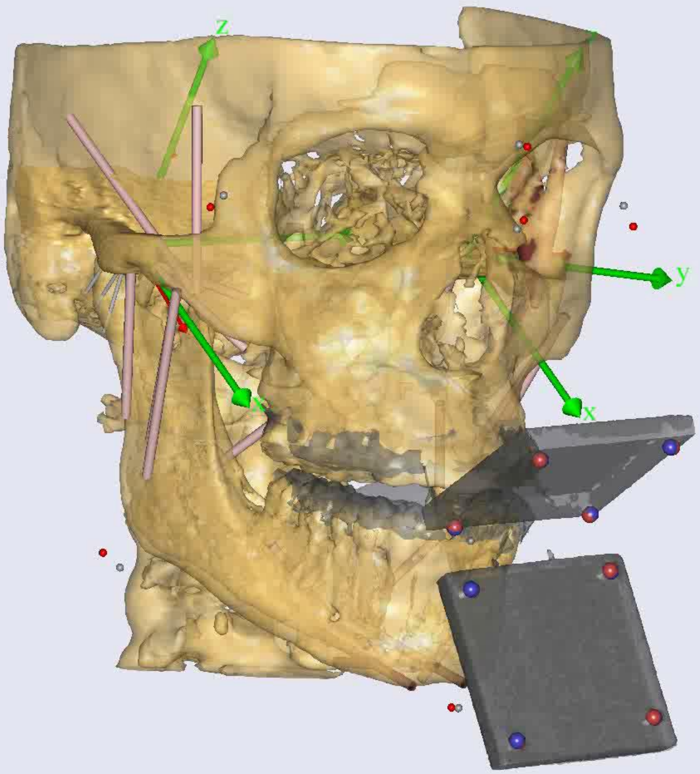
Michael Skipper Andersen, Ph.D
Associate professor
Aalborg University
(Presenter)

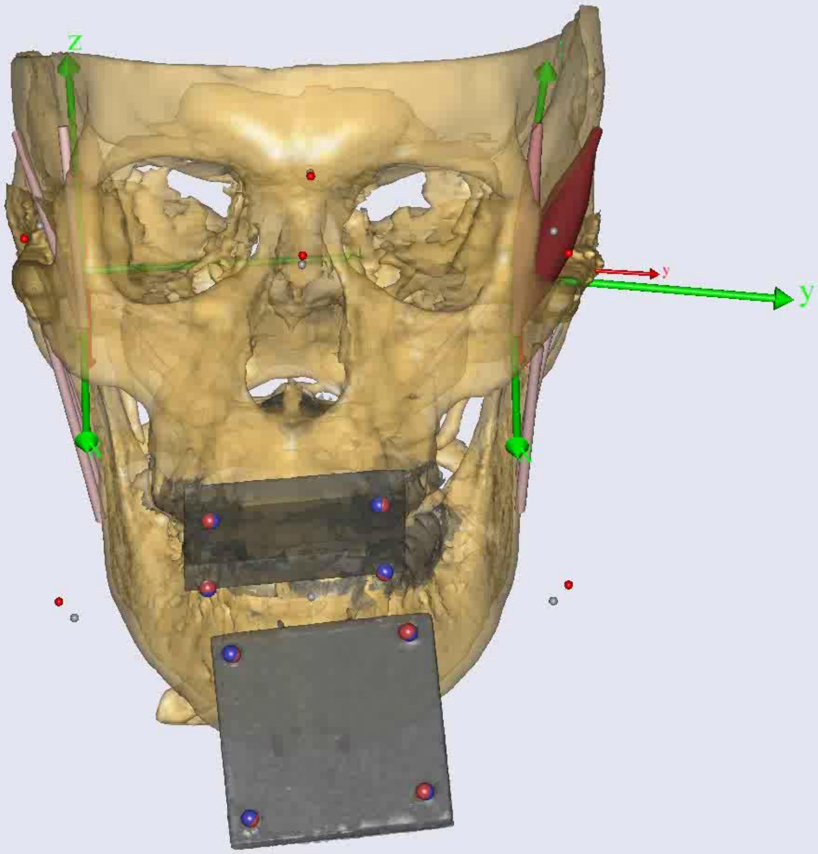


ANYBODY TECHNOLOGY

Validation of a new AnyBody mandible model

Validation of a new AnyBody mandible model





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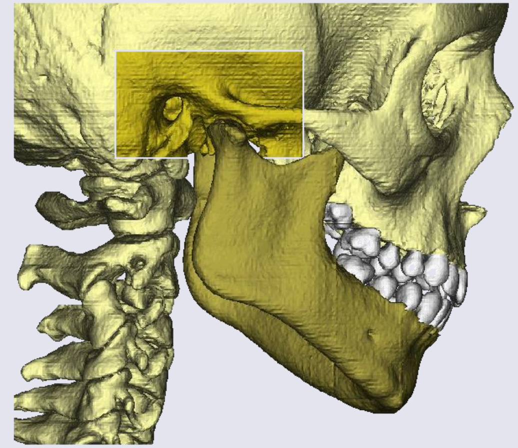
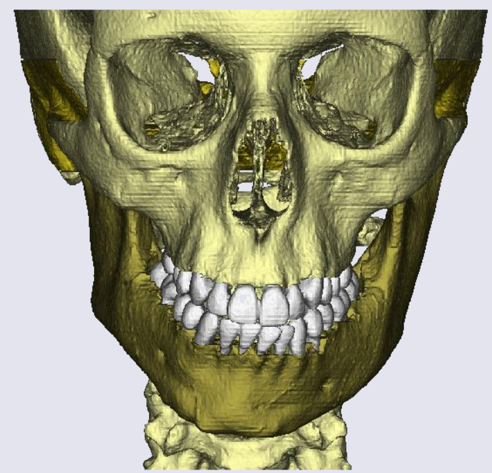
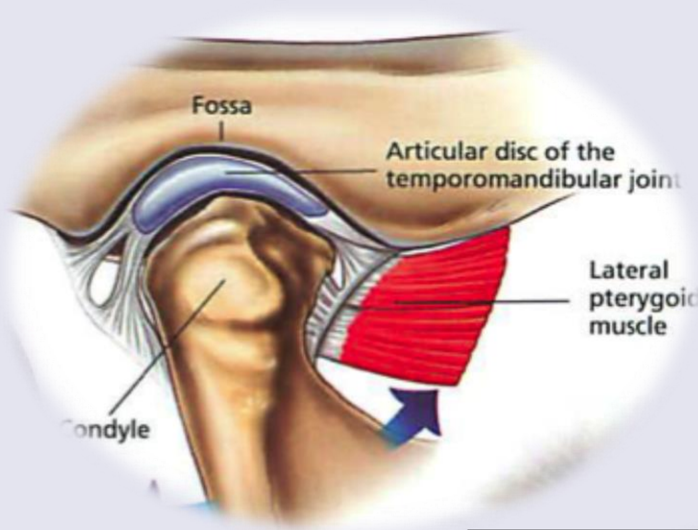
Motivation

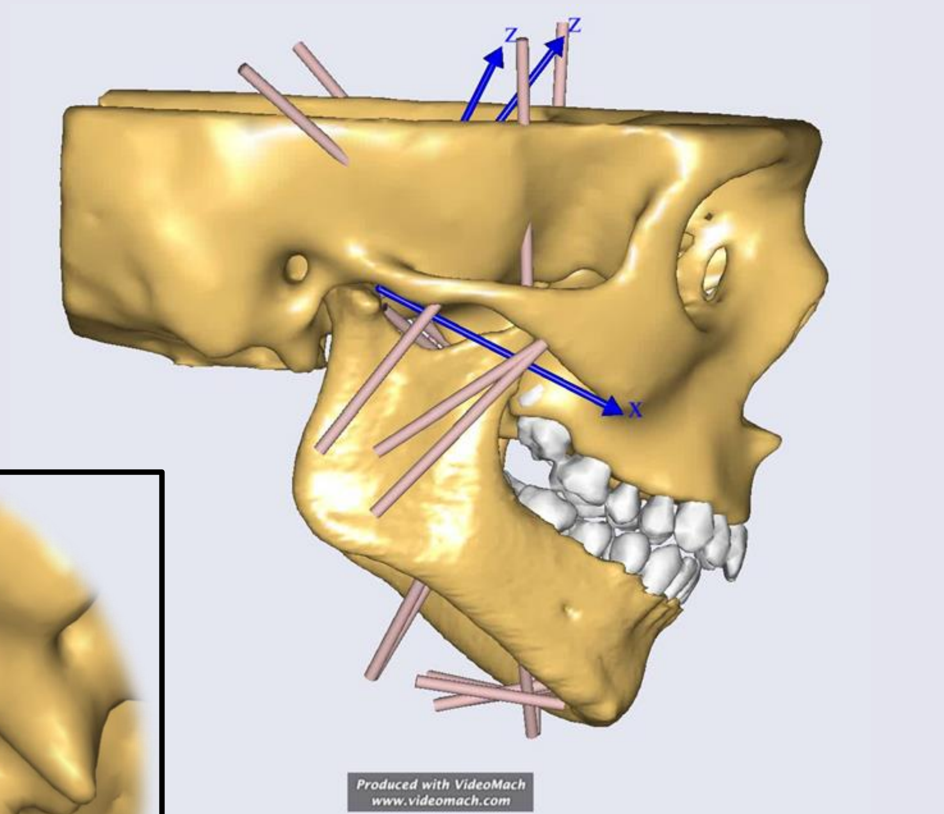


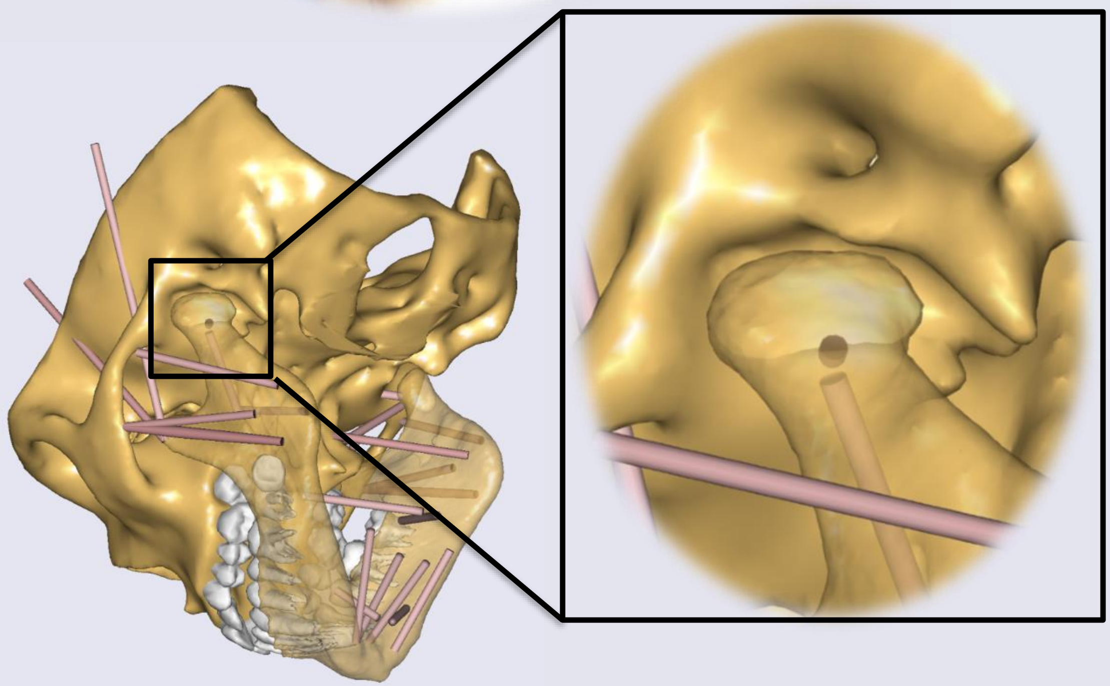


Understanding the complex biomechanics of the mandible has multiple applications

How to model the Temporomandibular joint (TMJ)?







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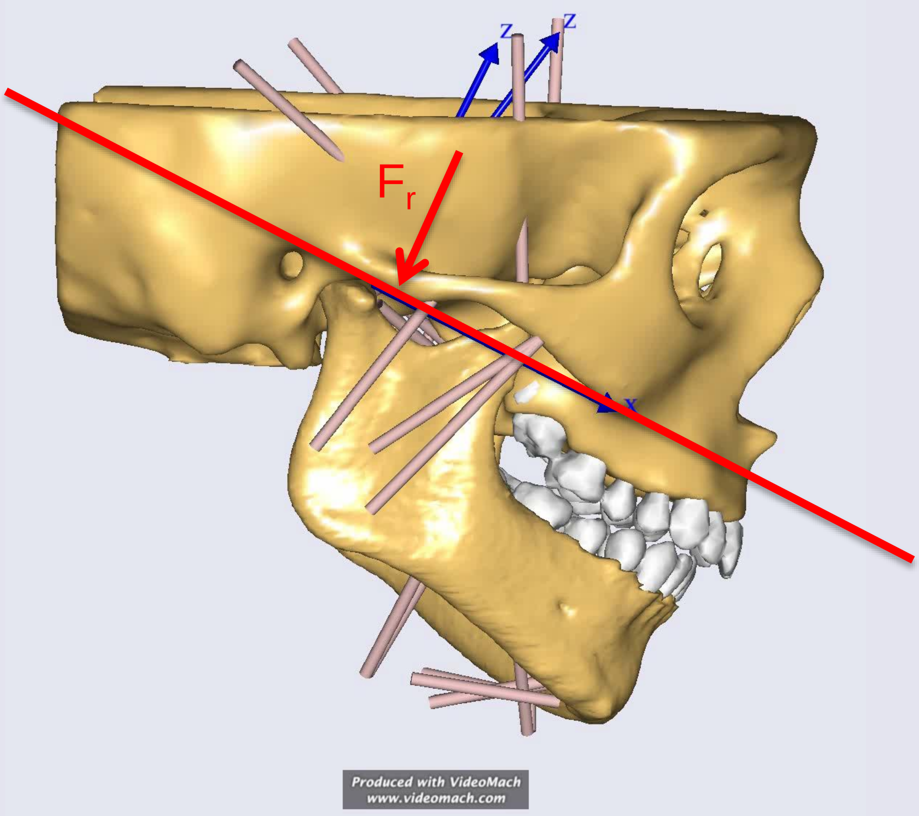
How to model the Temporomandibular joint (TMJ)?



Planar constraint model

- Point-on-plane model.
- Unilateral reaction force
- Inverse dynamics model

de Zee et al., *J. Biomech*, 40 (2007) 1192–1201.

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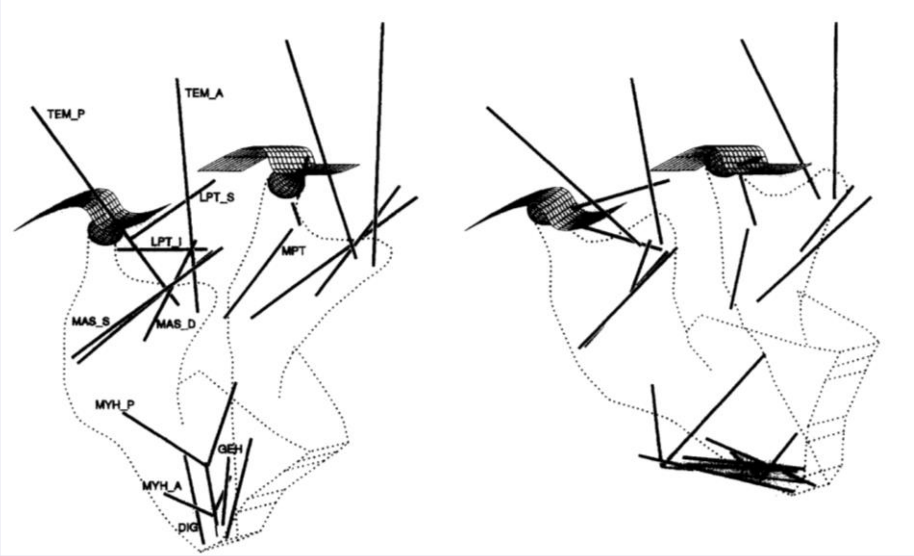
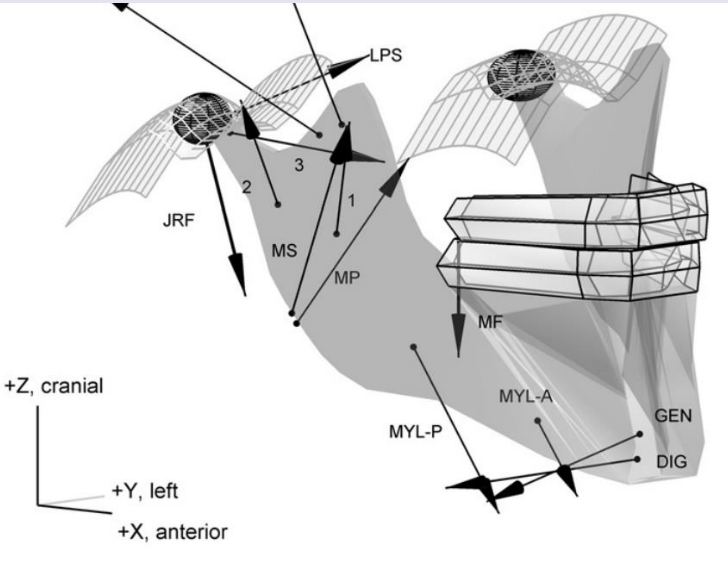
How to model the Temporomandibular joint (TMJ)?



Koolstra and Eijden *J. Biomech*, 30 (1997) 943–950.



Tuijt et al *J. Biomech*, 43 (2010) 1048–1054.

Penetration of approximate surface

- Forward dynamics-based models.
- Assumed muscle activations.

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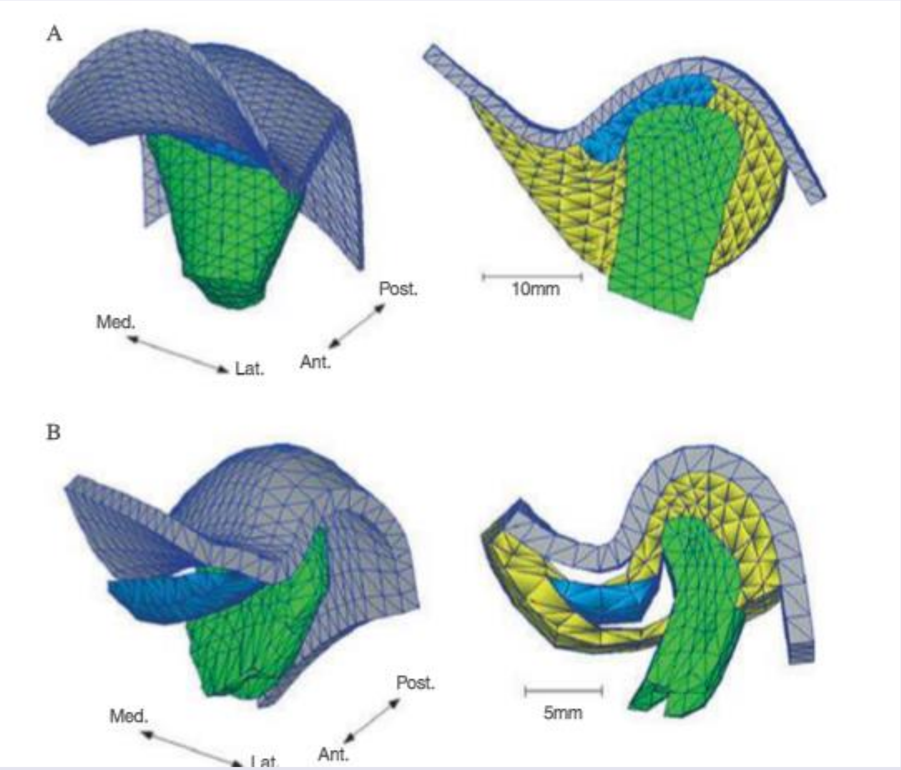
How to model the Temporomandibular joint (TMJ)?



Hirose *et al. Eur J Oral Sci*, 114 (2006) 441–448.

Finite element models

- Detailed joint and disc model
- Requires loading conditions

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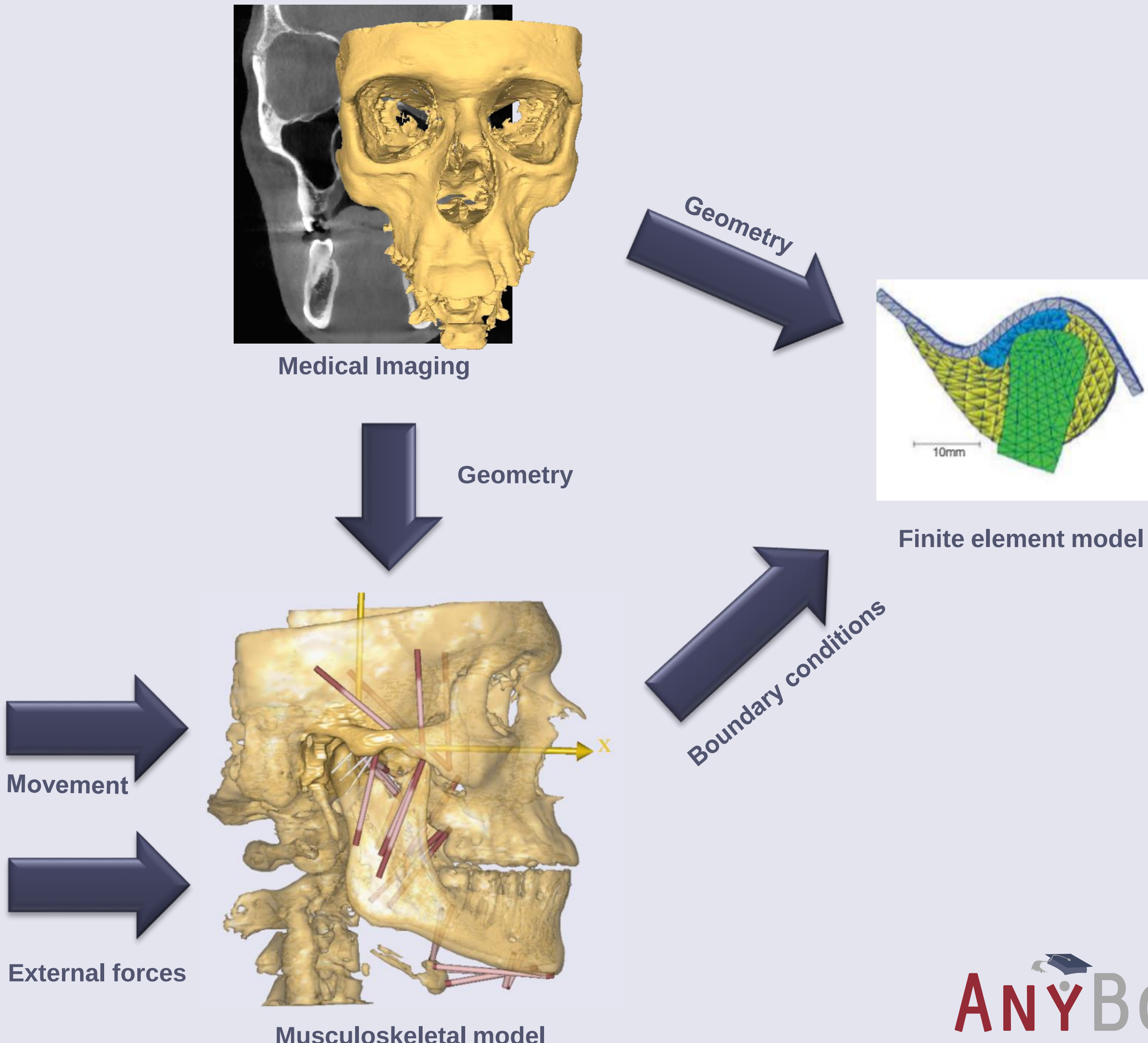
Envisioned analysis workflow



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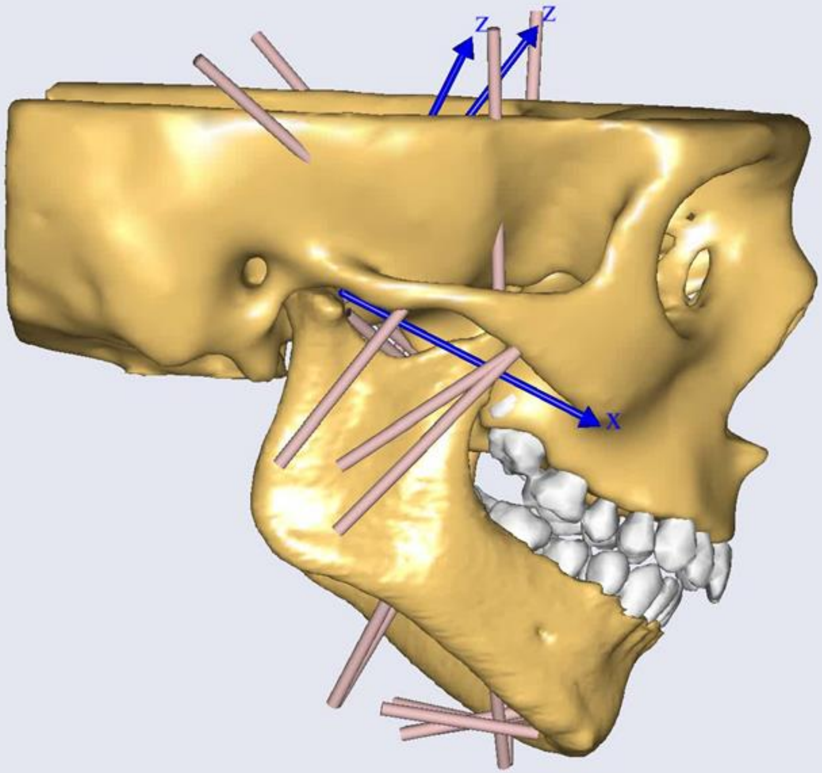
Aim

Develop and validate an inverse dynamics-based subject-specific musculoskeletal mandible model

Enable prediction of
- Muscle forces
- Joint reaction forces
- Joint kinematics



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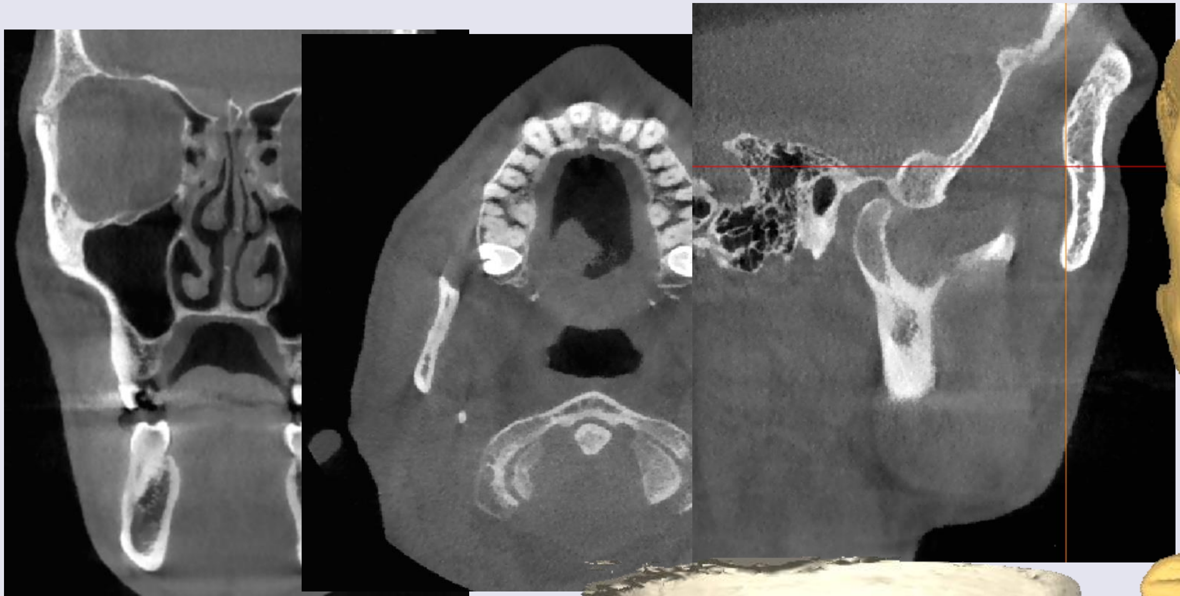
Methods



Cone beam CT scan
NewTom 5G, QR Verona, Italy

Segmentation done in Mimics 14.12.
Materialise, Leuven, Belgium

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Musculoskeletal model

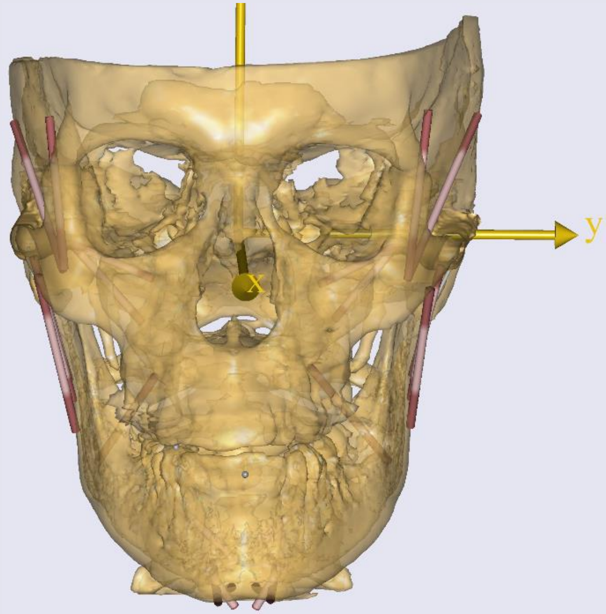
Muscles

- 24 Hill-type muscles (de Zee et al, 2007, Koolstra and Van Eijden, 2005)

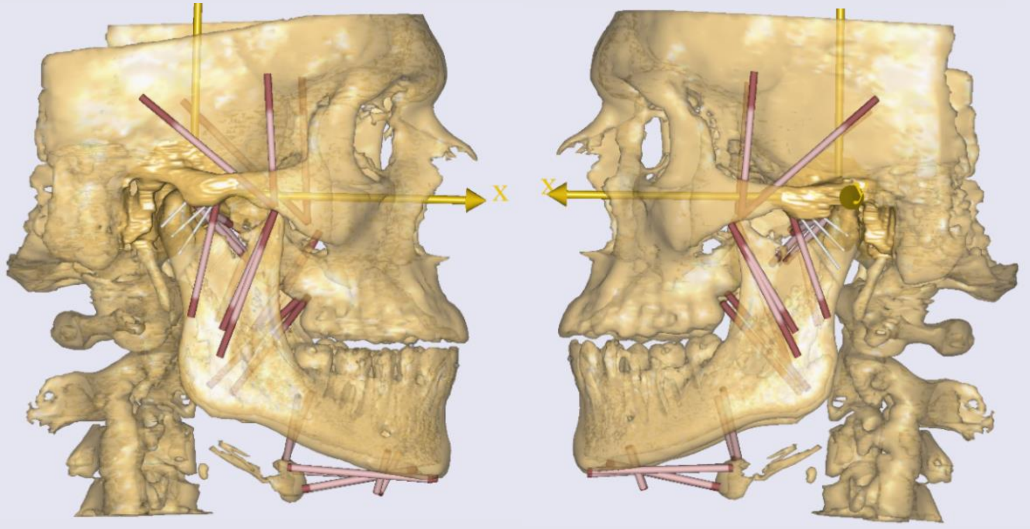
TMJ

- Point-on-Plane model (de Zee et al, 2007).

- Force-dependent Kinematics (FDK) model
  - Surface contact-based TMJ.
  - TMJ ligaments.



Anatomical skull reference frame (Frankfurt horisontal plane)



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Point-on-Plane TMJ model

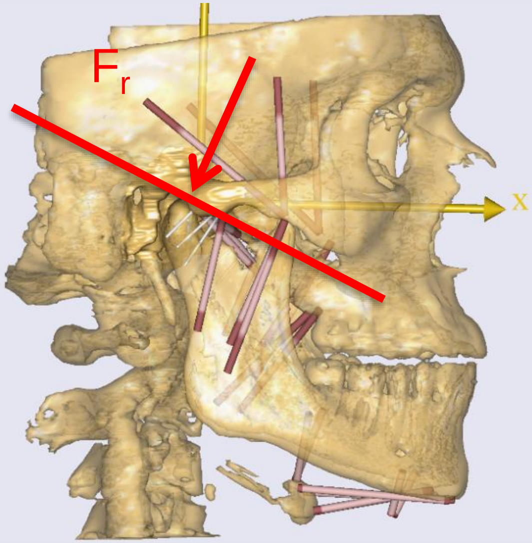
Inverse dynamics

Constraints

- Left and right TMJ point-on-plane
- Medial/Lateral movement constrained

Required movement input

- 3 DOF between mandible and skull



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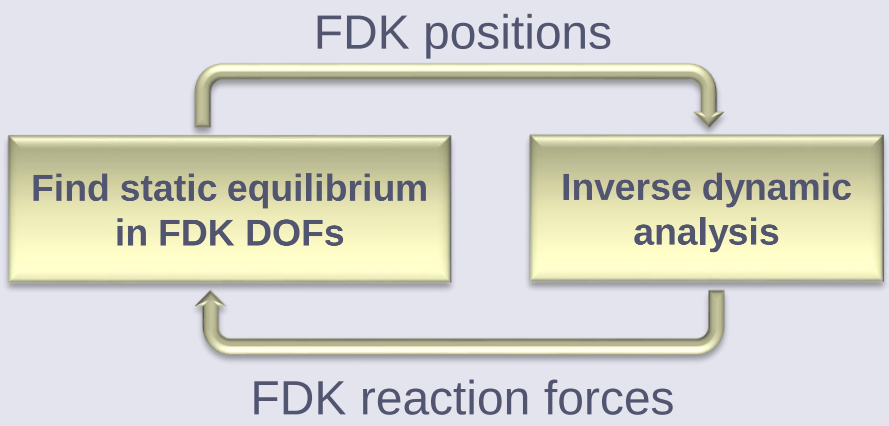
Force-dependent kinematics (FDK)

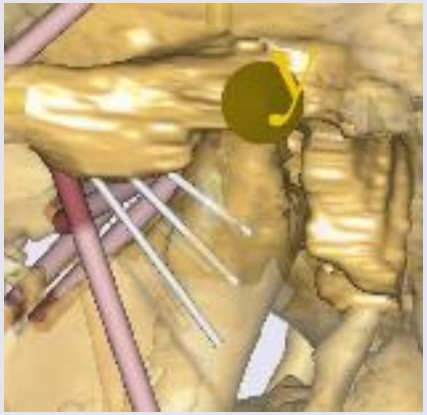


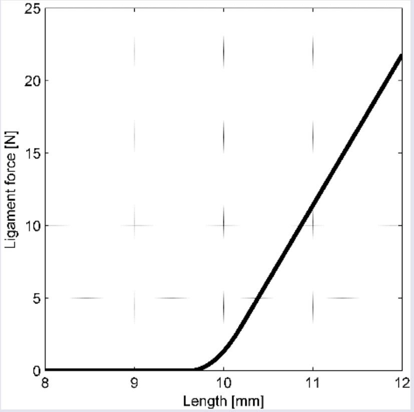
FDK (Andersen et al, 2011)

- Simultaneously computes muscle, joint and ligament forces and internal joint kinematics.
- Uses *inverse dynamics* and *quasi-static force equilibrium* in selected DOFs.

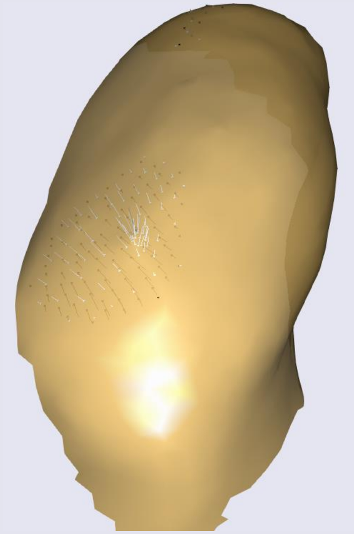
FDK model

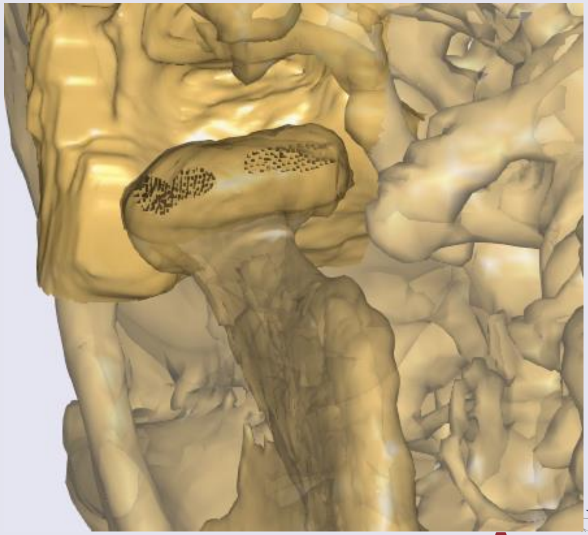
TMJ ligaments





TMJ contact





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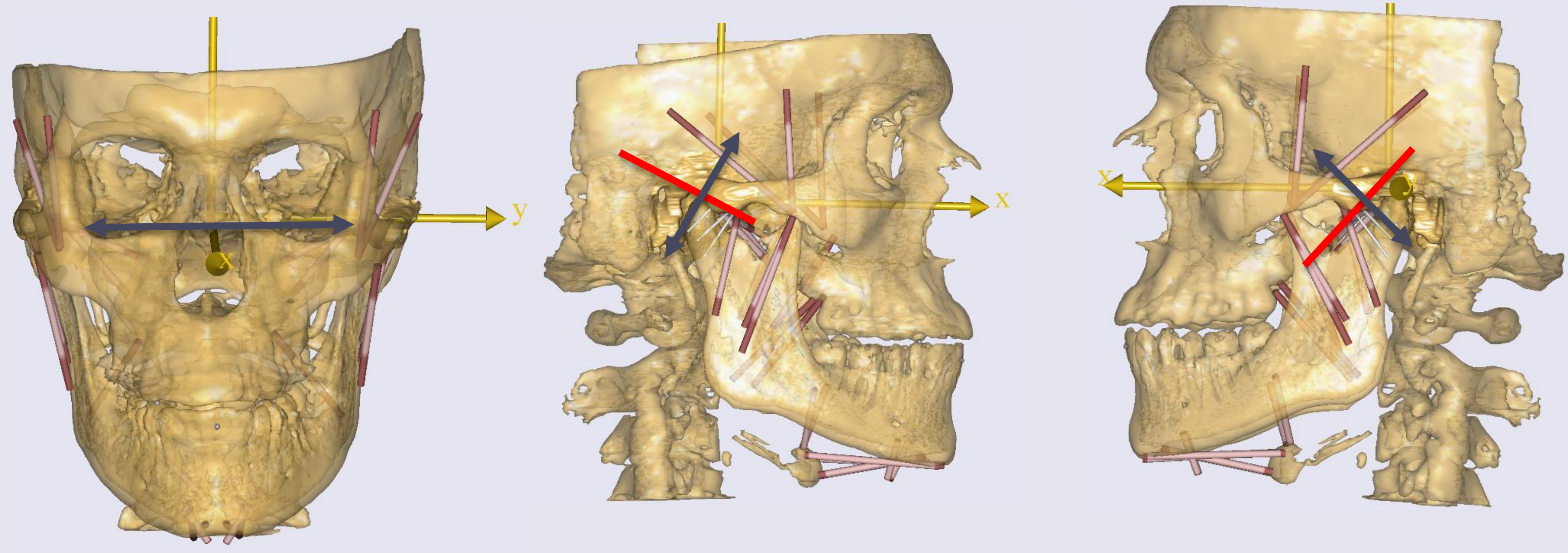
FDK model

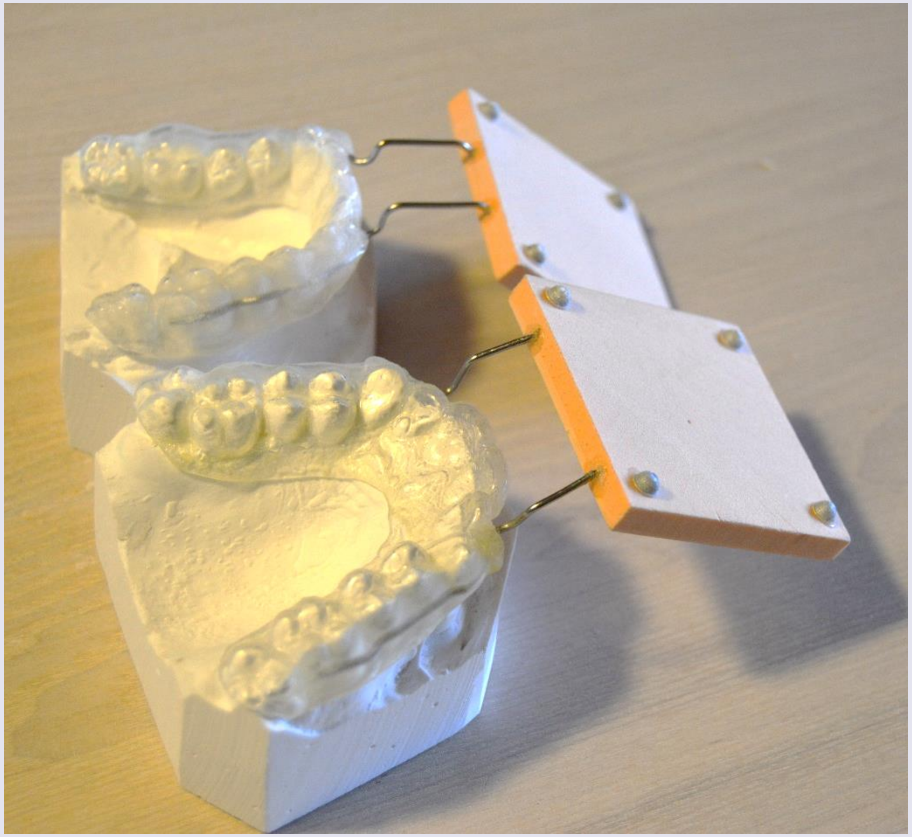


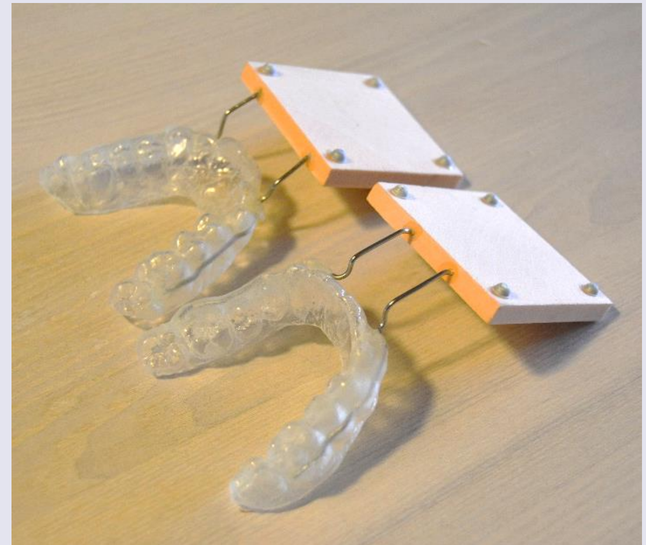
FDK dofs

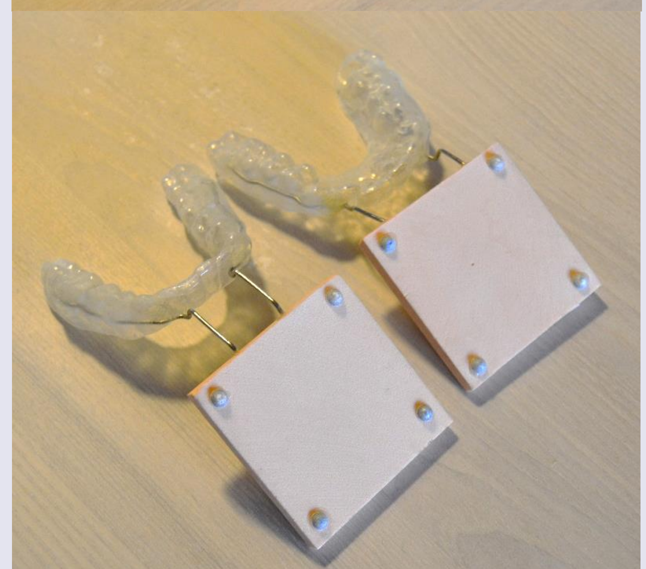
Required movement input

- 3 DOF between mandible and skull

Custom brace







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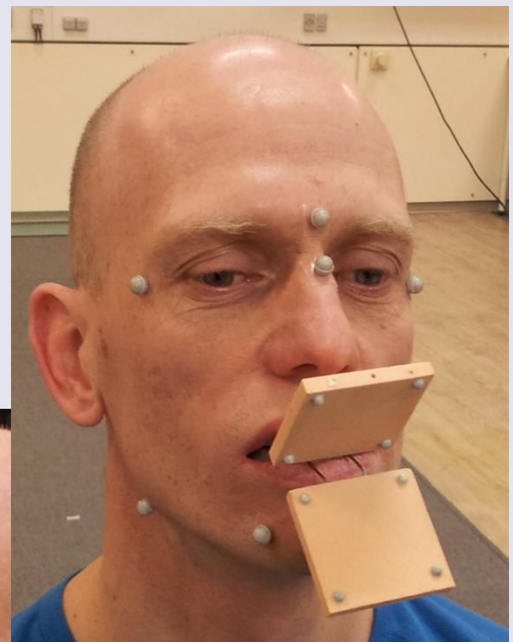
Eight camera Qualysis system

Qualysis, Gothenburg, Sweden

Nine skin markers

Eight markers on the braces



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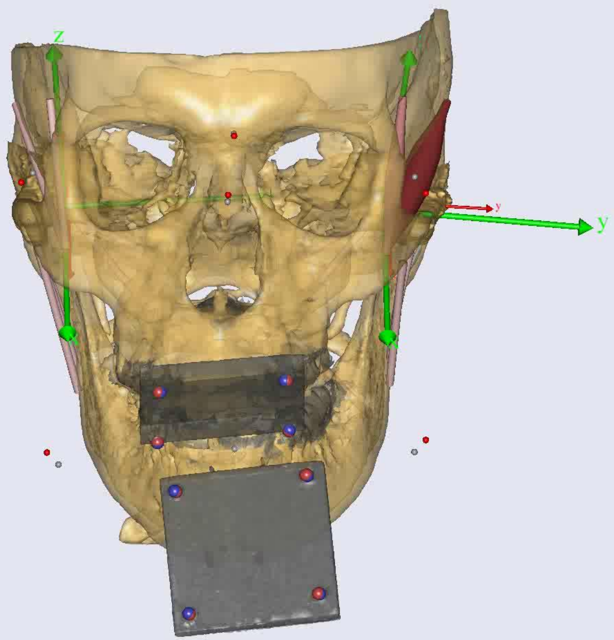
Dynamic tasks

Tasks (5 repetitions used for the analysis):

1. A cycling opening/closing of the mouth to a half-open position.
2. A cyclic movement from side to side.
3. Empty chewing movement, without producing a bite force (~1 Hz).
4. A cyclic protrusion movement (~0.5 Hz).



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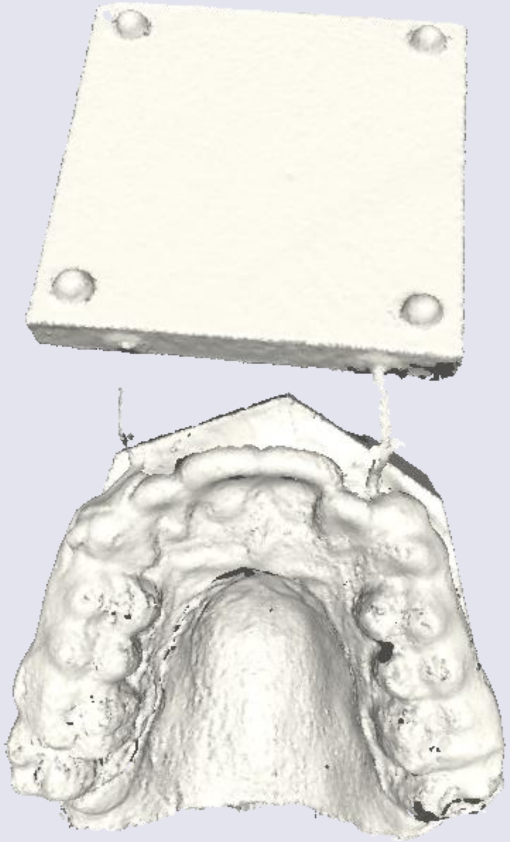
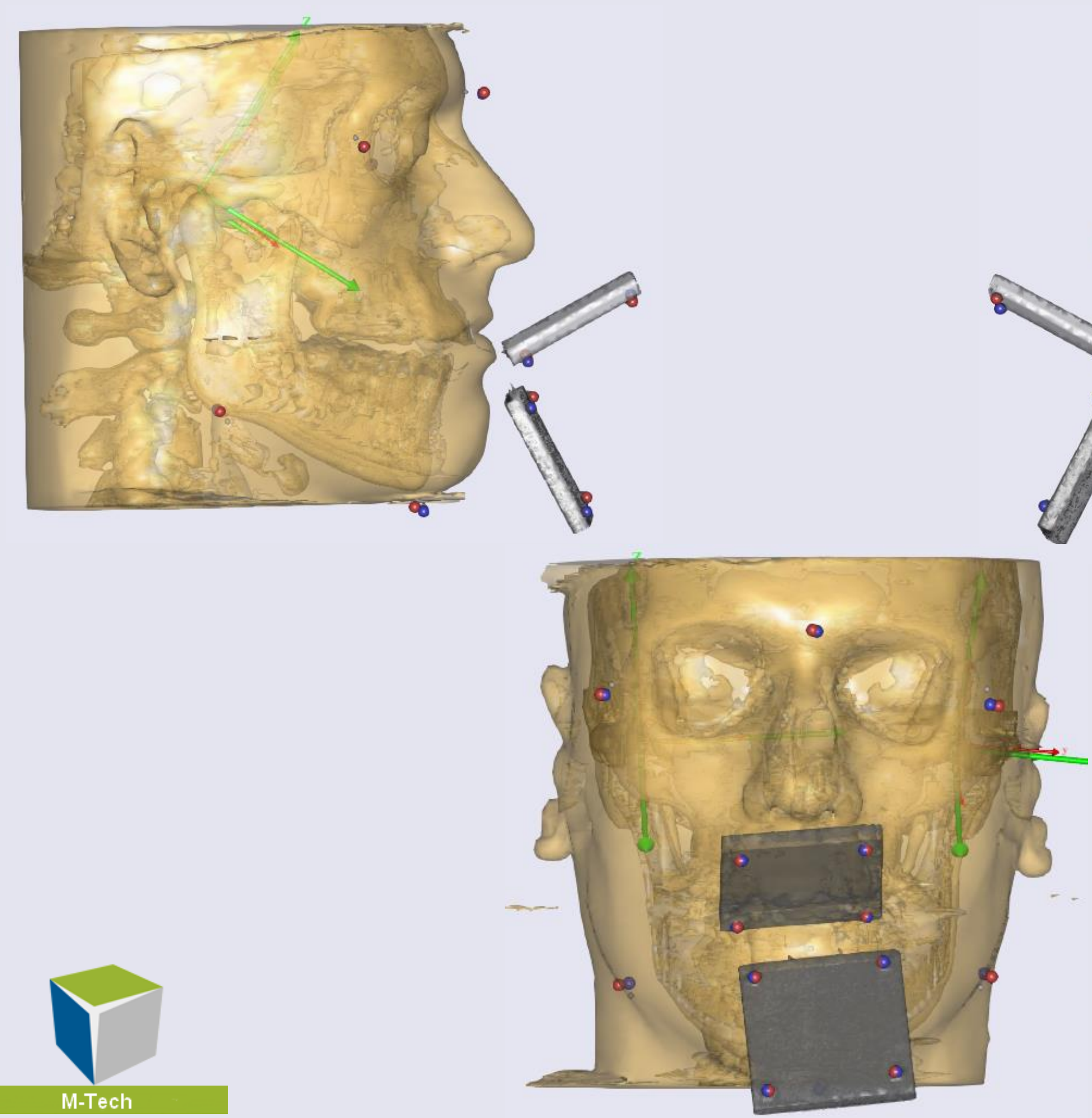
Laser scan

NextEngine Ultra HD 3D scanner
NextEngine, Inc, Santa Monica, California



Brace and scan registration



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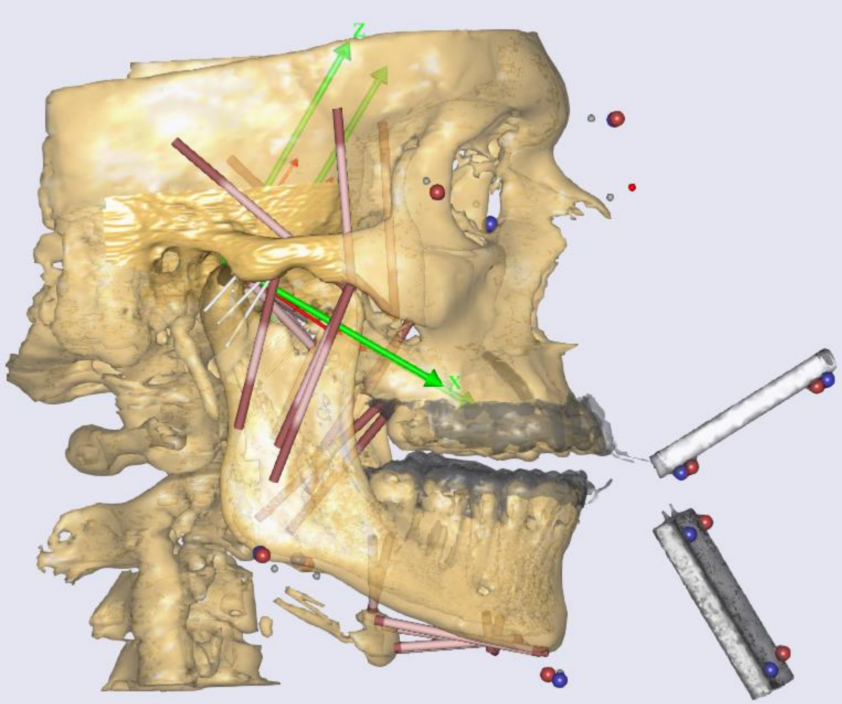
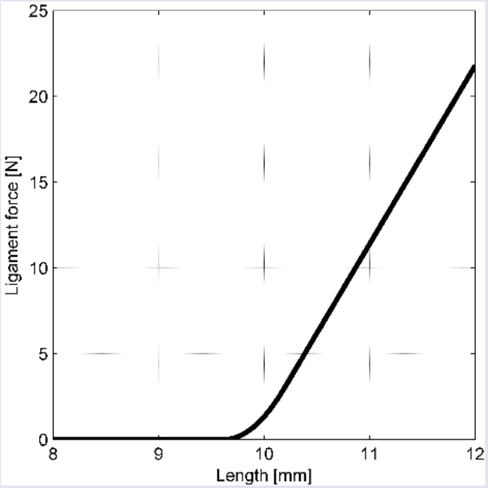
Parameter study





TMJ ligament properties

- Stiffness: 136.2, 272.4, 544.8 [N/m].
- Reference strain: -0.04, -0.02, 0.0, 0.02, 0.04

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(272.4 N/m: Chen et al. *Med Eng Phy* 20 (1998) 565-572)

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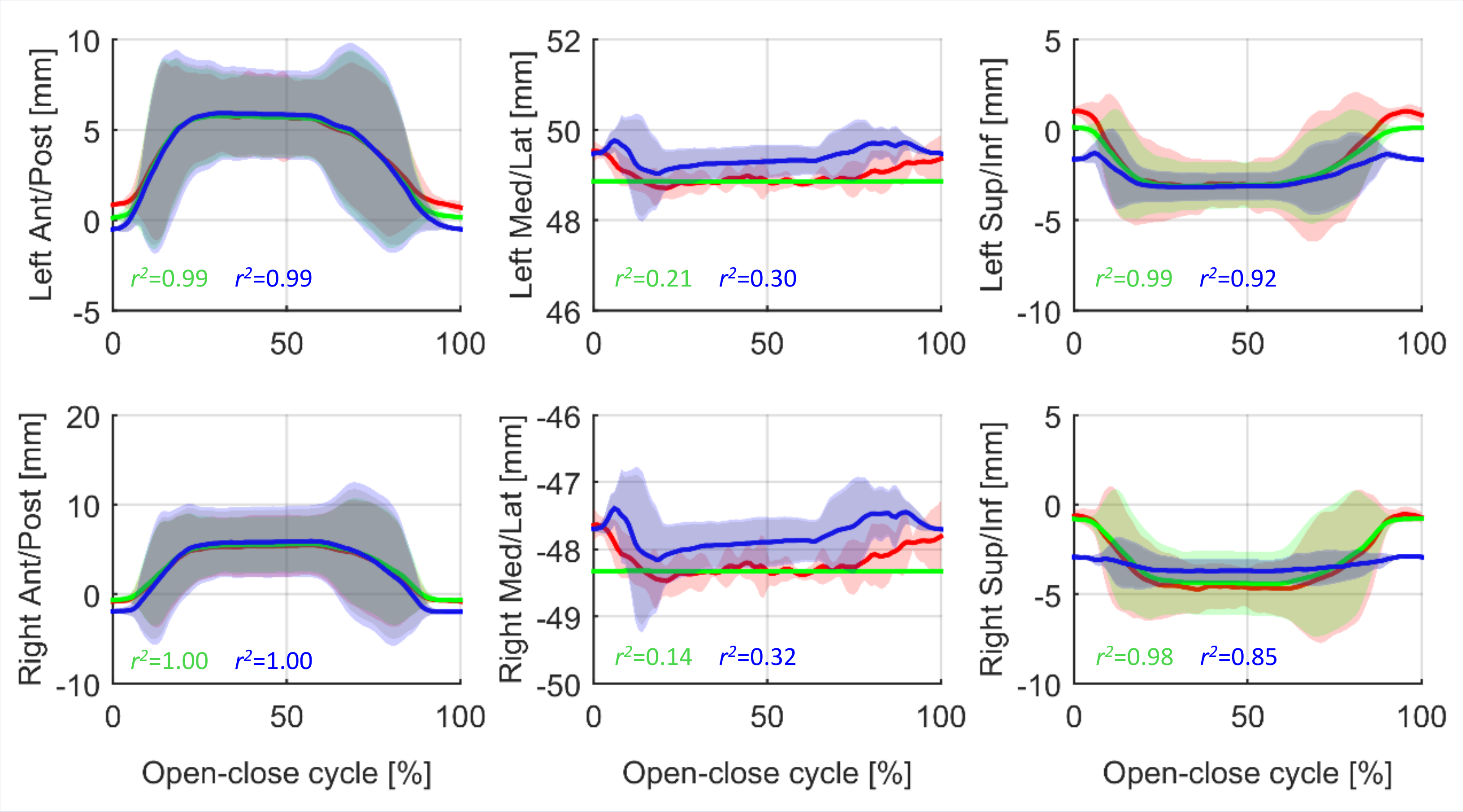
Results

Open-close: Kinematics



Brace
Point-on-plane
FDK
Ligament variation

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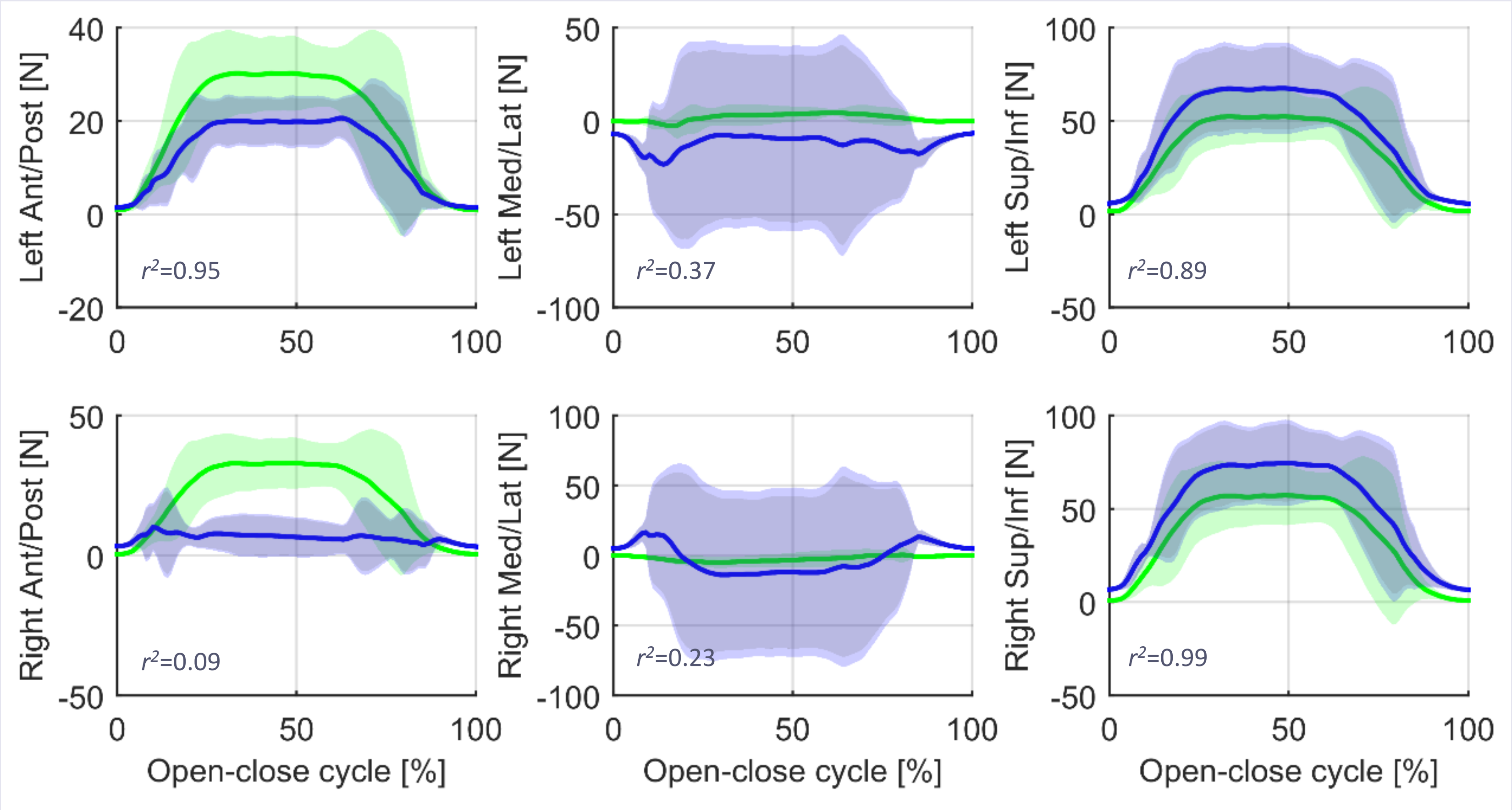
Open-close: Reaction forces



Point-on-plane
FDK
Ligament variation

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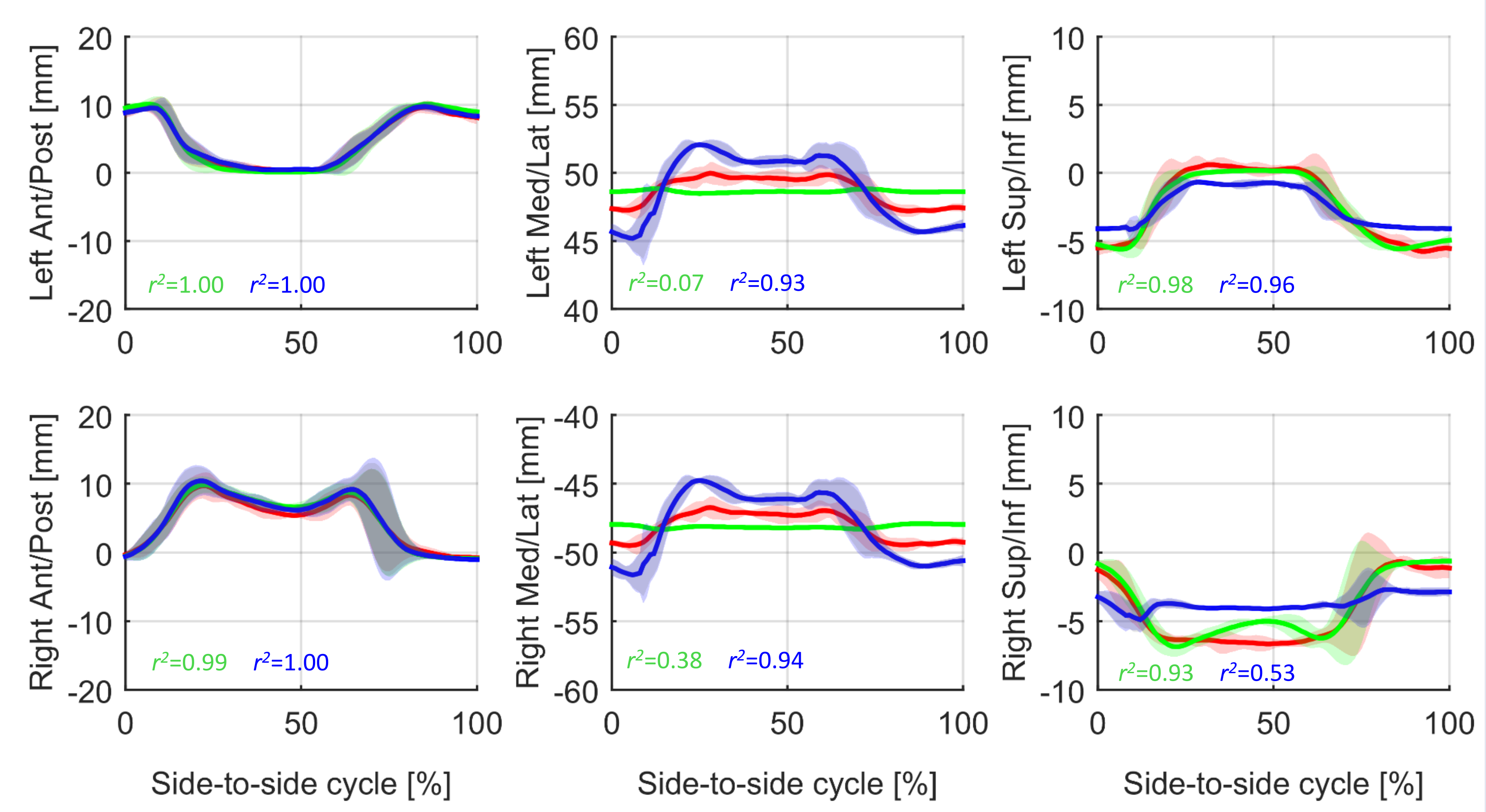
Side-to-side: Kinematics



Brace
Point-on-plane
FDK
Ligament variation

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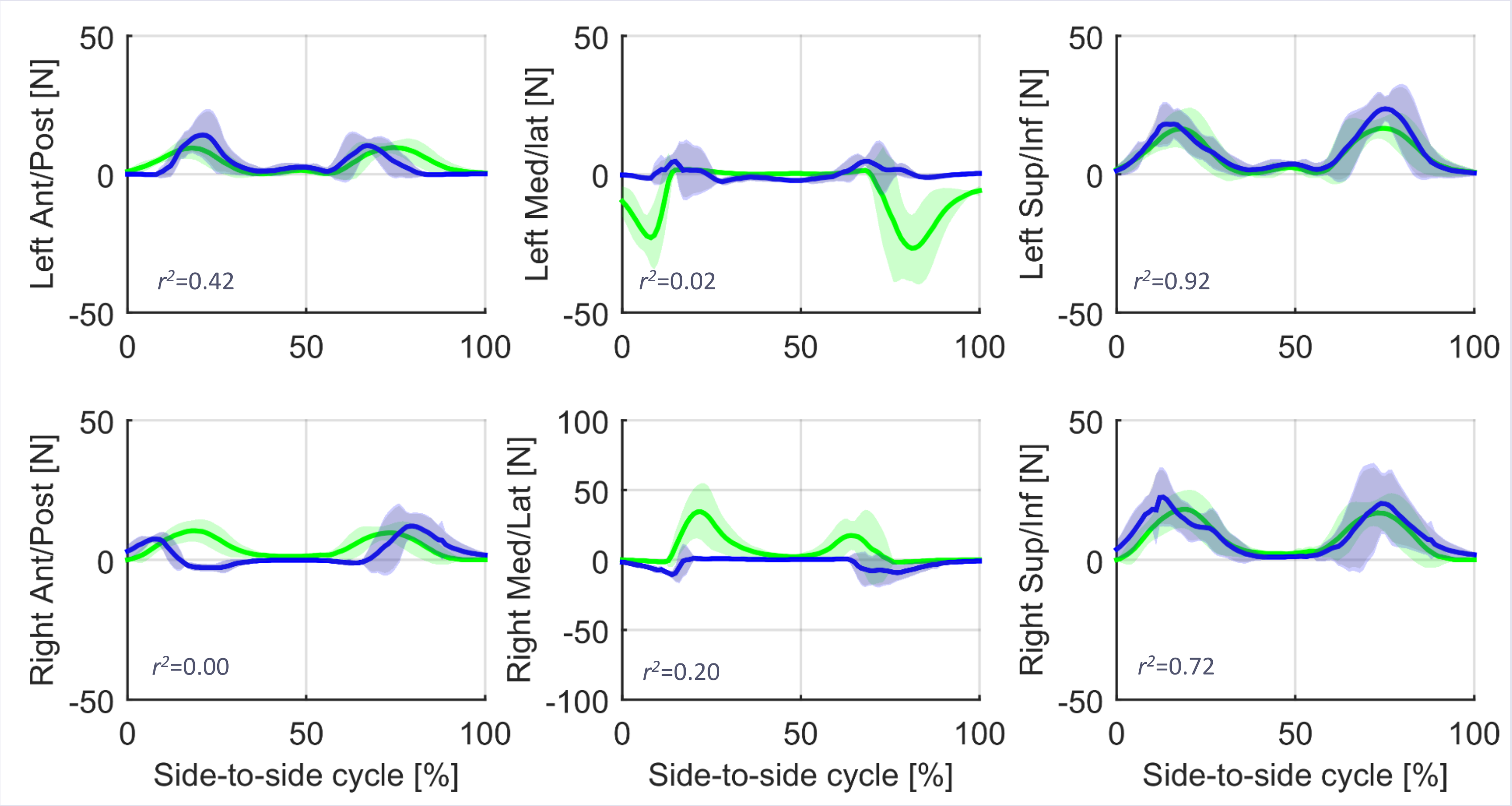
Side-to-side: Reaction forces



Point-on-plane
FDK
Ligament variation

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Conclusion

- We developed a subject-specific musculoskeletal model of the mandible.
- In general, good estimates of joint kinematics were obtained with both TMJ models.
- Differences in joint reaction force estimates were seen between the models.
- The joint kinematics and reaction forces were not more sensitive to variation in ligament properties than repeating the task five times.

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Future work

- Improve the TMJ model in the FDK model.
- Develop a method to automically estimate muscle origin and insertions.
- Validate the model for more subjects.
- Apply the model to study the biomechanics of pathological cases.

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Thank you!

Michael Skipper Andersen, Ph.D.
Associate Professor
Department of Mechanical and Manufacturing Engineering
Aalborg University
msa@m-tech.aau.dk

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Webcasts

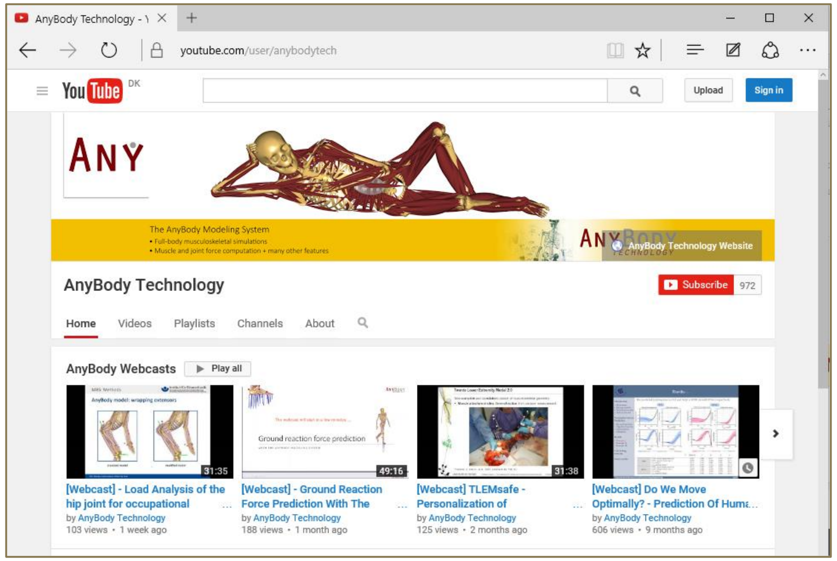
- Next webcast 15th March 2016
  - "Simulating man-machine symbiosis: Improved design solutions, from ergonomics to assistive technology"
- Check our YouTube channel for previous webcast
  - Search channels for 'AnyBody Technology'
- Relevant webcasts from 2011
  - Modeling and analysis of non-conforming joints in AnyBody (I and II)
  - Analyzing non-conforming anatomical and prosthetic joints in the AnyBody Modeling System

www.anybodytech.com

- Events, dates, publication list, ...

www.anyscript.org

- Wiki, Forum



Time for questions: