

Modeling for Dynamics of the Human Jaw: A Critical Review

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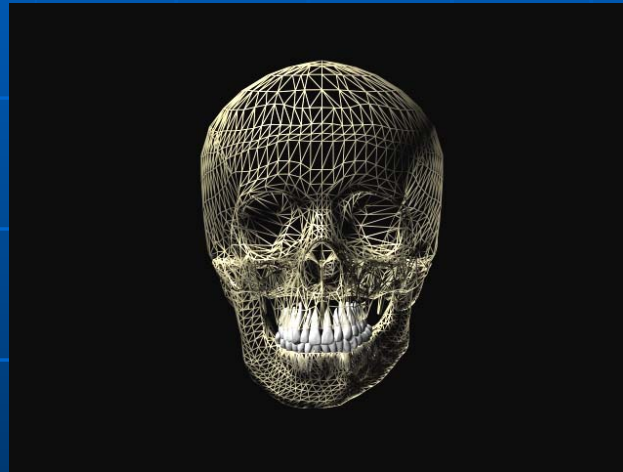
Osaka University

Difficulties in analyzing the human jaw dynamics:

1. *A large number of muscles of various shapes and sizes*
2. *A complex architecture*
3. *Articulation through two very complexly shaped temporomandibular joints (TMJ)*
4. *Separated the articular surfaces by a cartilaginous articular disc*

Aims of numeric modeling

To provide a way to synthesize anatomy with physical properties and functional attributes, and to express these relationships quantitatively.



And to help

- 1. evaluate un-measurable performance in vivo***
- 2. predict extreme condition***
- 3. generate working hypothesis and drive further studies***

Determinants of Jaw Movement

ACTIVE ELEMENTS:

Muscle lines of action

Muscle dynamics

Contribution of muscle action to jaw movements

PASSIVE STRUCTURES:

Articular surfaces

Articular capsule and ligaments

Teeth and food

Muscles

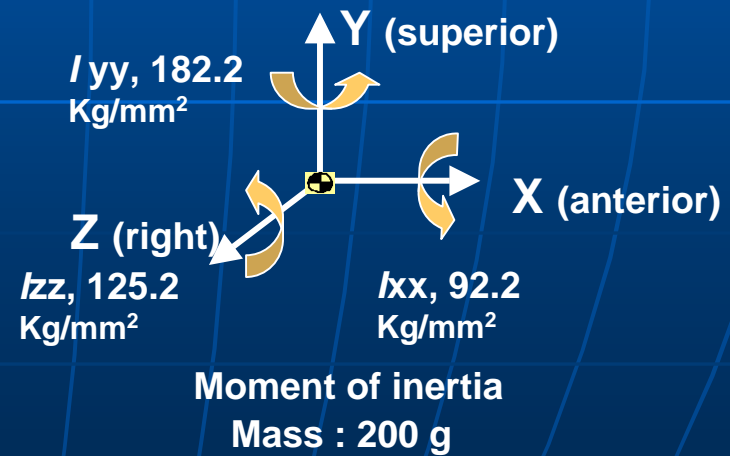
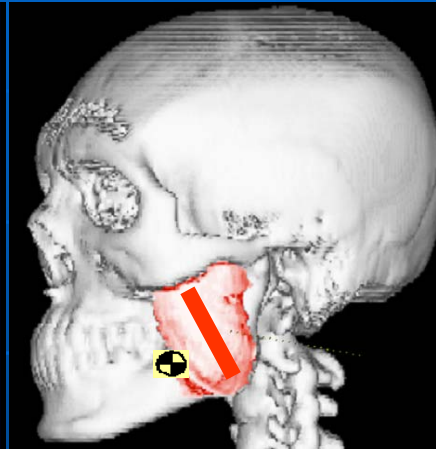
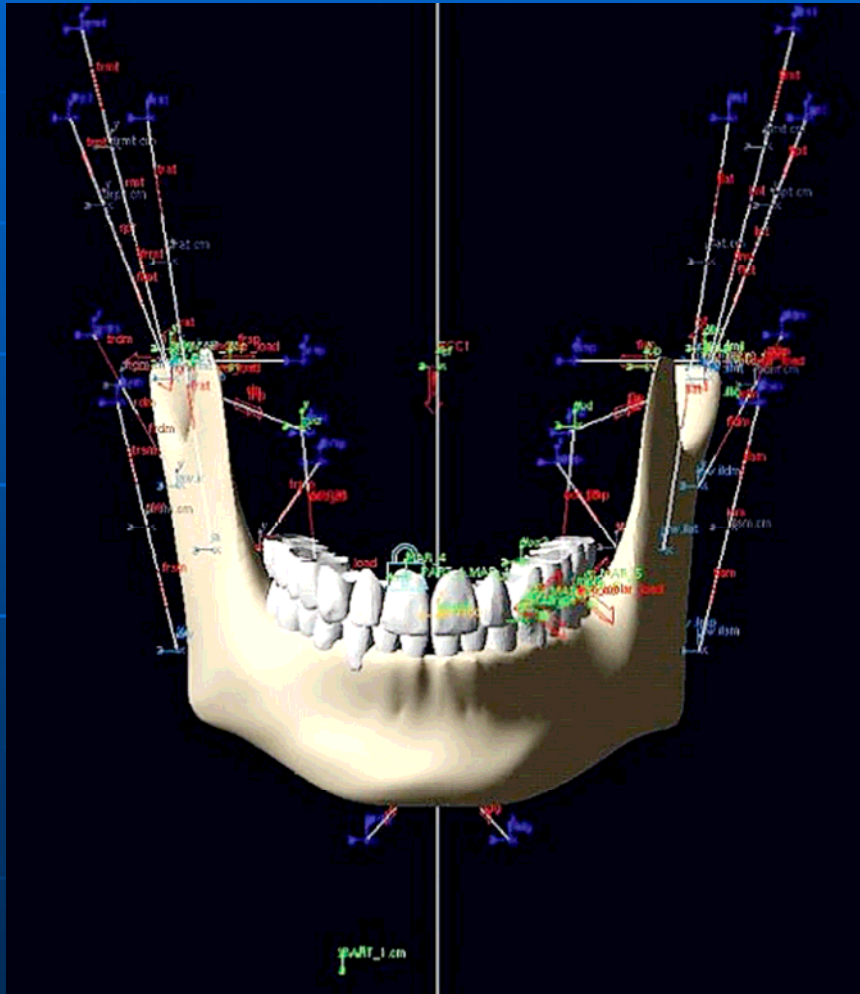
INTERPLAY OF PASSIVE AND ACTIVE STRUCTURES

Kinetic simulation

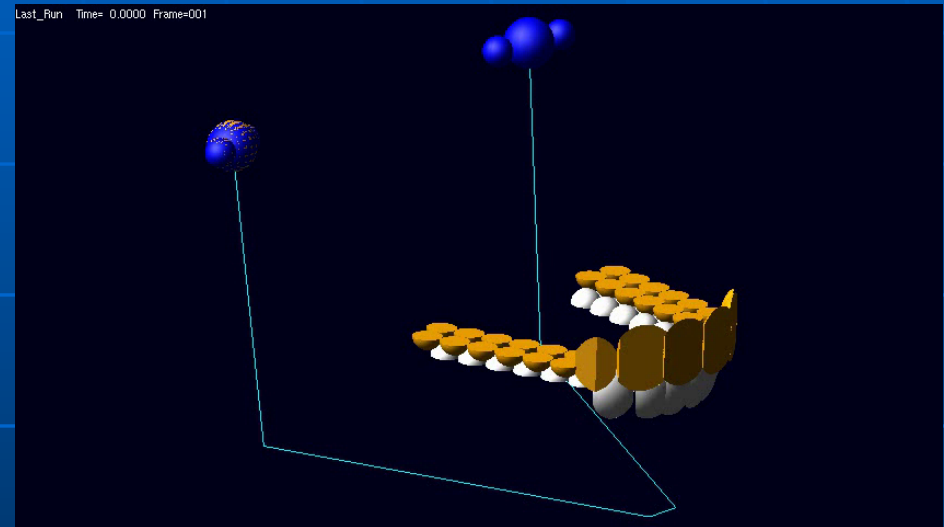
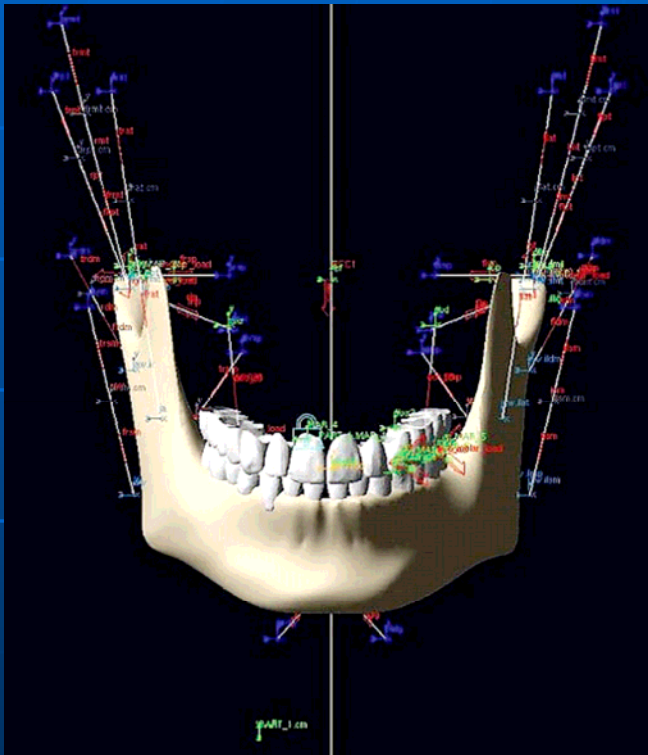
Anatomical component:

- 1. locations and angulations of the major jaw muscles, muscle cross-sectional sizes, muscle fiber, and tendon-length ratios.***
- 2. the locations of the mandibular condyles, the condyle–disc–fossa boundaries guiding jaw motion.***
- 3. bite-point locations, and the orientation of occlusal reaction.***
- 4. the viscoelastic properties of the joints and teeth.***

Dynamic human jaw model



Simulation of dynamic changes in occlusal/articular force vectors in space



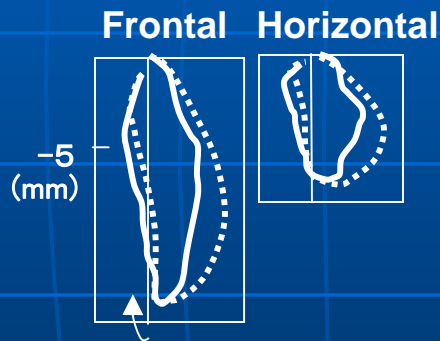
Theoretical modeling of jaw movement trajectory and its application to the clinical diagnosis

Patient 8

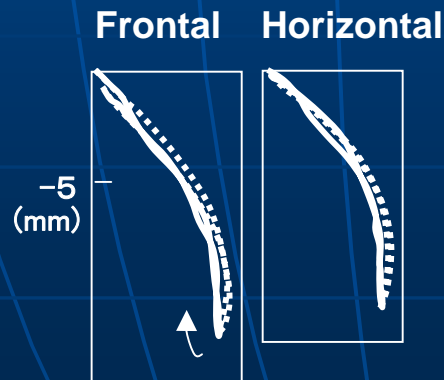
Trajectory — : Data
..... : Model

Velocity profile — : Data
—— : Model

Before treatment



After treatment



0.1 (m/s)
Velocity

5 (mm) Pathway length (mm)

Inter articular space



: Normal vector of condyle 3D surface

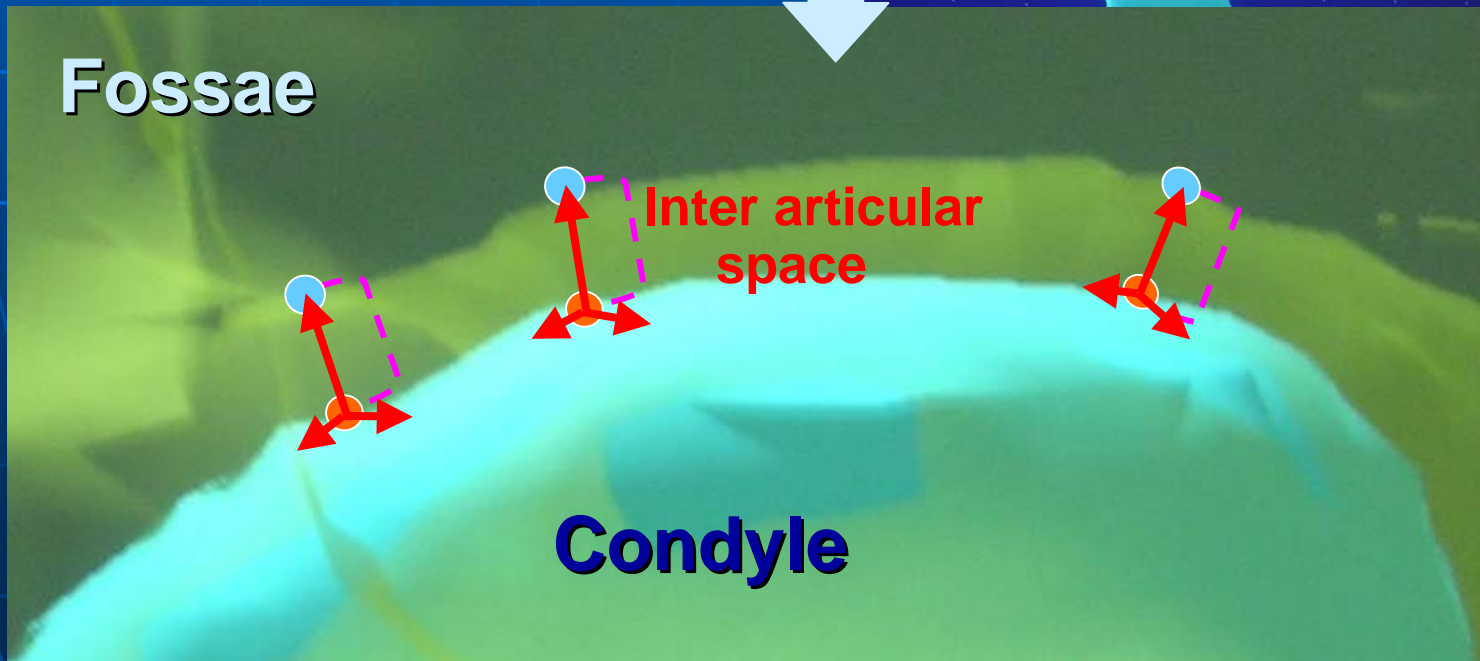


: Condyle point



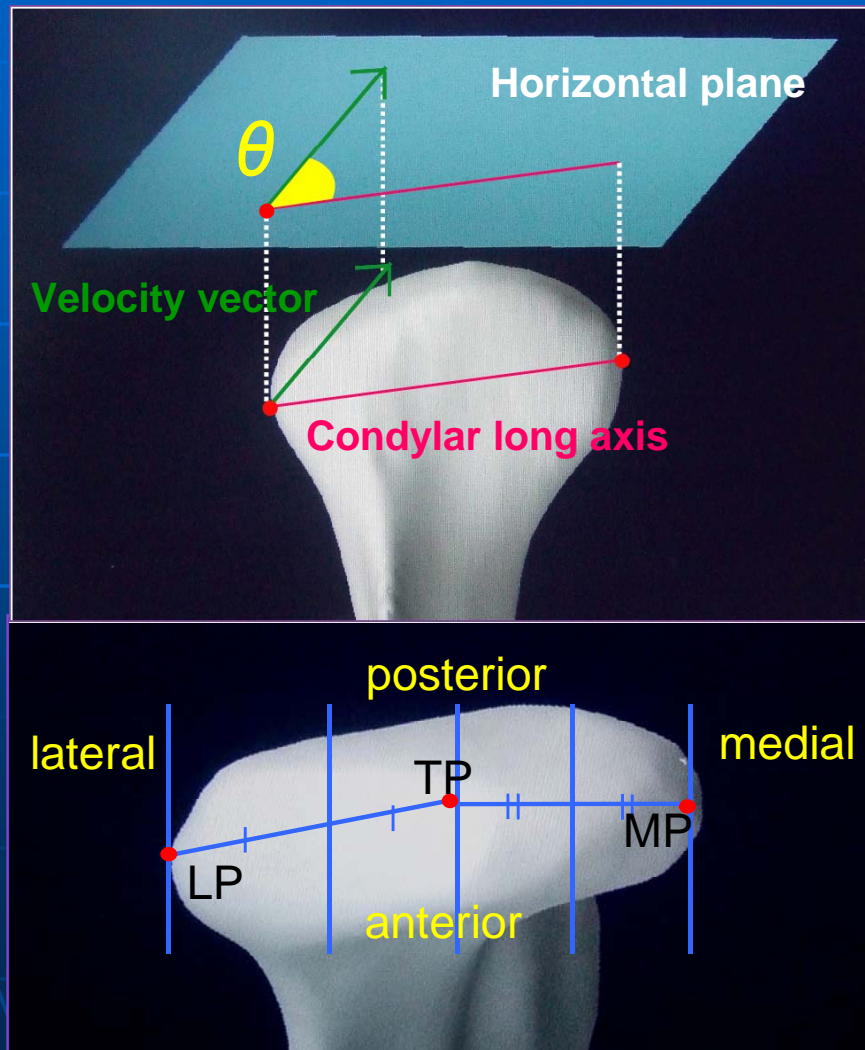
: Inter articular space

Close up



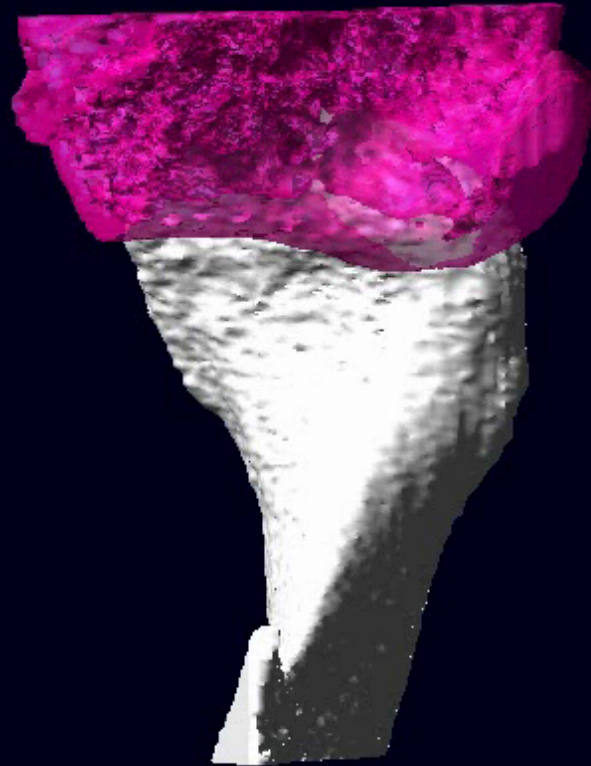
Selection of key variable:

The angle between velocity vector and condylar long axis projected on the horizontal plane during chewing.



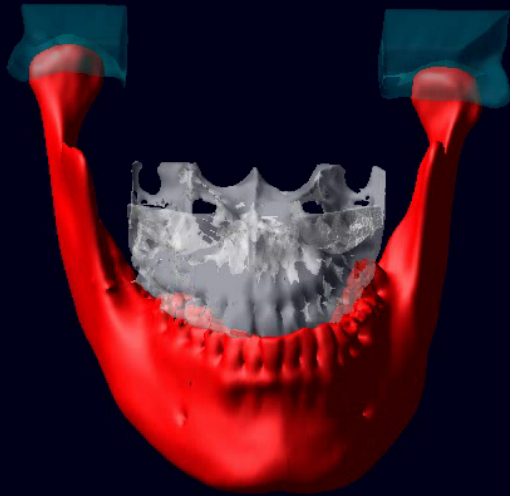
Condylar motion during contra-lateral shift with tooth guidance

Last_Run Time= 0.0000 Frame=0001



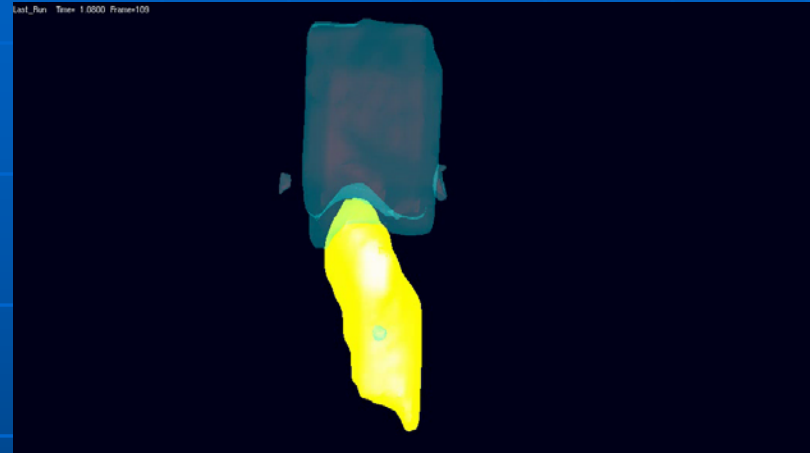
6dof mandibular movements of the patients with asymmetry

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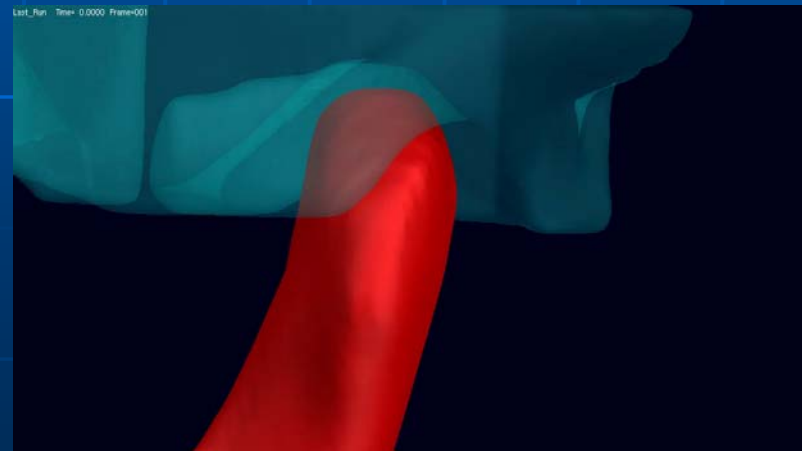


TMJ articulation during chewing: working-side condylar movements in relation to fossae

Control subject

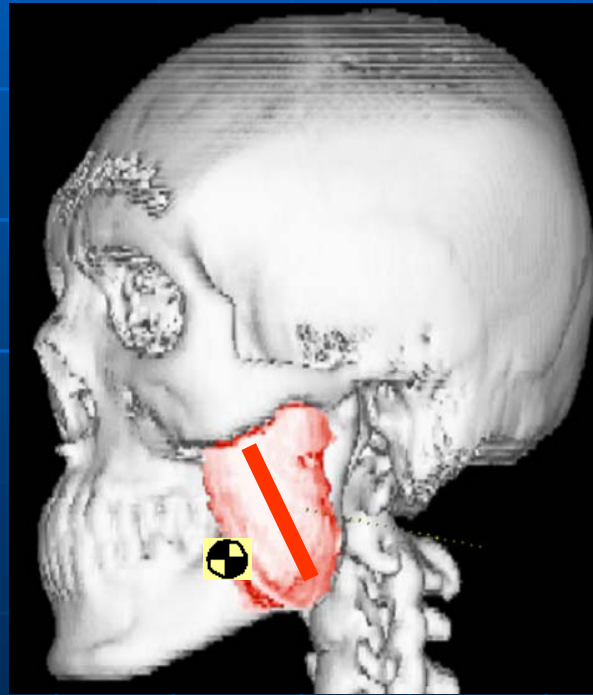


Deviated-side condyle of
the patient with skeletal asymmetry



Development of patient specific FEM

Using CT voxels of each patient.



Analyses by inverse kinematic modeling

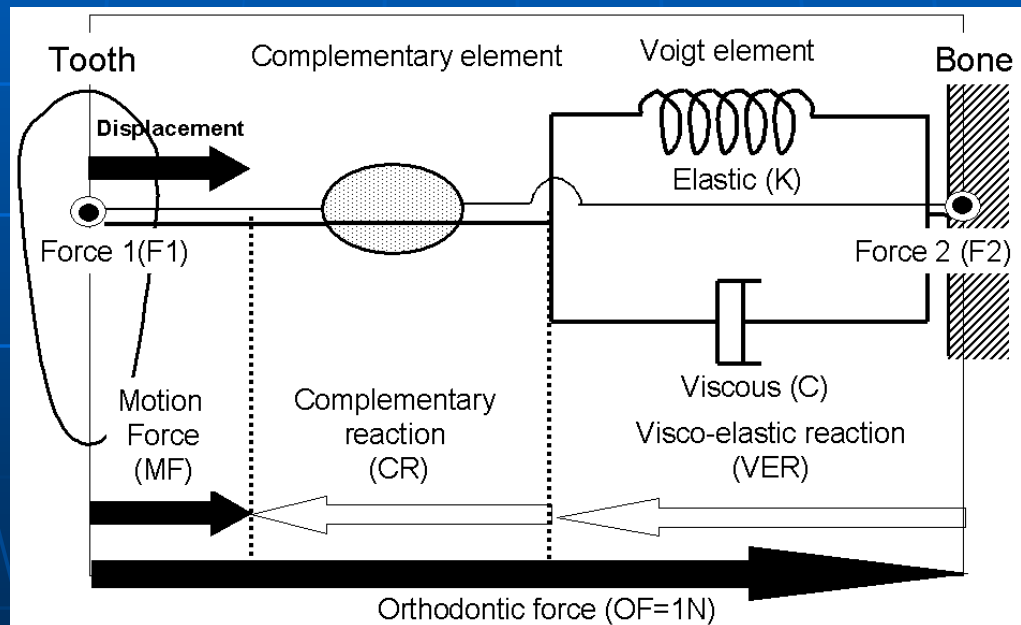
In put:

**Kinematic parameters,
e.g., 6DOF movements (roll, pitch, yaw angles)**

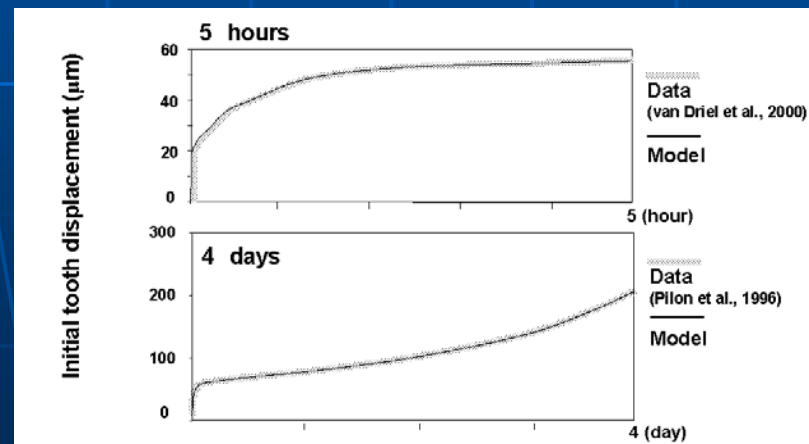
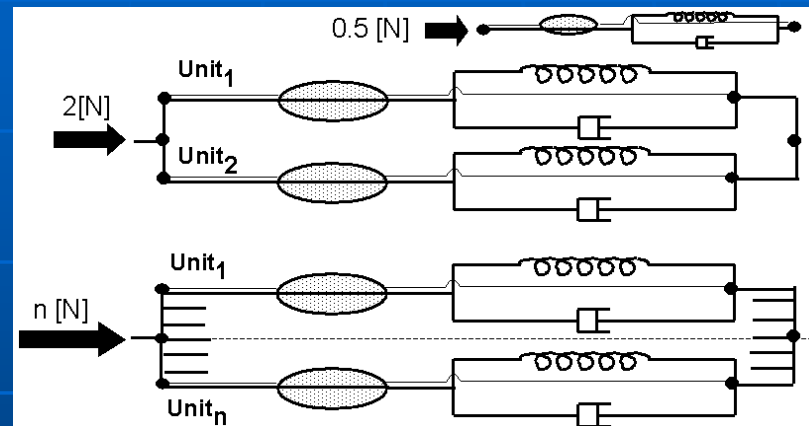
Prediction:

**Unmeasurable biological properties
,e.g., visco-elasticity(non-linear), poroelasticity
thixotropy(flowability)**

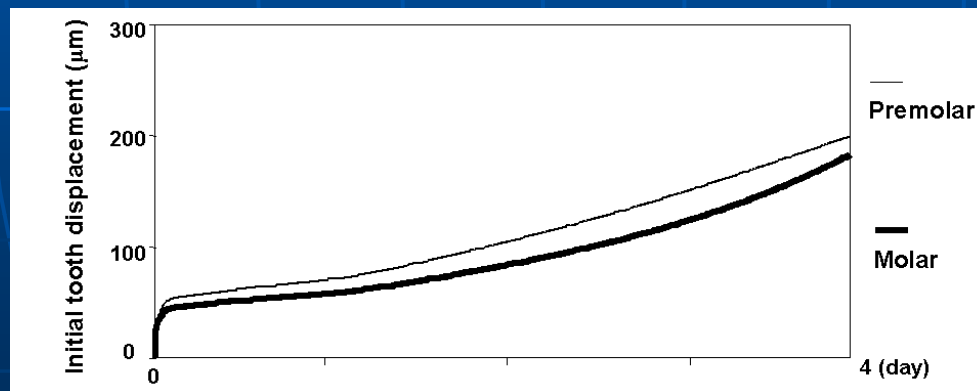
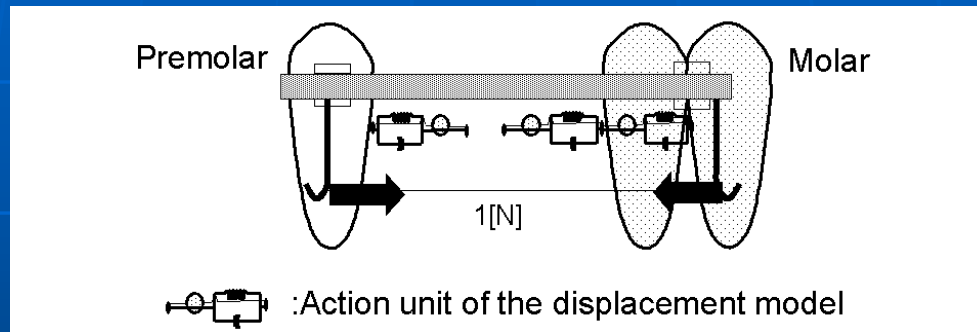
Dynamic model of orthodontic tooth movement



Inverse kinematic model of initial tooth movement



Simulation of anchor-loss



Future study should be directed toward:

1. **Dynamic analyses by modeling of TM Joint function using MRI/CT and jaw-tracking**



2. **Subject-specific non-linear finite element model by using CT**



3. **Inverse kinematic analyses**



4. **Prediction of the dynamics of jaw dysfunction (e.g., anterior disk dislocation)**

