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# Title: A PATIENT-SPECIFIC MUSCULOSKELETAL MANDIBLE MODEL USING FORCE-DEPENDENT KINEMATICS

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## *Summary (max. 40 words)*

Force-dependent kinematics (FDK) was used to compute the joint reaction forces in the temporomandibular joint and the results compared to a planar constraint model. FDK model captured the change in reaction force direction due to the mandibular fossa shape.

## *Abstract body (max. 500 words)*

### *Introduction*

Although only few joints in the human body can reasonably be considered idealized joints, most inverse dynamics-based musculoskeletal models available in the literature apply such models [1,2]. One example is the model of the temporomandibular joint (TMJ) reported by de Zee et al. [2,3], where it was modelled as a planar constraint and a unilateral reaction force. However, in reality, the detailed joint mechanics are governed by the contact between the condyle and the mandibular fossa, the ligaments, the muscle forces and the external load.

To enable modeling of complex joints in terms of force elements and still allow computation of muscle forces, joint reactions and ligament forces in an inverse dynamics-like manner, Andersen et al. [4] recently proposed the Force-dependent kinematics (FDK) analysis framework. FDK computes the detailed joint motions as well as the muscle and joint reaction forces under an assumption of static force equilibrium within the joint.

In this study, we extended the previously reported patient-specific mandible model of de Zee et al. [3] with a detailed TMJ joint model taking into account the joint contact forces and the Temporomandibular ligaments using the FDK methodology.

### *Patients & Methods*

A patient-specific mandible model was built in the AnyBody Modelling System v. 5.1 using the FDK solver. The model is illustrated in Fig. 1.

Detailed information about the patient, the Computed Tomography (CT) scan, muscle insertions and mechanical properties are described in de Zee et al. [3].

The TMJ was modelled with four FDK degrees-of-freedom (DOF); the three rotational DOF between the skull and the mandible as well as medial/lateral translation. Both temporomandibular ligaments were modelled as three nonlinear springs [5] and contact forces computed based on the bone surfaces using a rigid contact model.

Three clenching tasks with 0.0, 1.0 and 2.0 cm mouth opening and a 150 N bite force were simulated and the resulting joint reaction forces compared between the two models.

## Results

The computed joint reaction forces using the detailed FDK-based model and the planar constraint model are depicted in Fig. 2. Both models show asymmetric loading due to the patient impairment with largest joint reactions on the unaffected side. Independent of mouth opening, the planar constraint model only has a compression force component. Contrary, the FDK model has joint reaction force components in all three directions, which changes direction and magnitude as a function of mouth opening.

## Discussion/Conclusion

In this study, we demonstrated the use of FDK to construct a detailed TMJ model. It will be possible now with this model to analyse the effects of joint morphology during different tasks and predict the detailed effects of interventions on the loading of the joint like distraction and orthodontic treatments.

## References

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Figures to be attached:

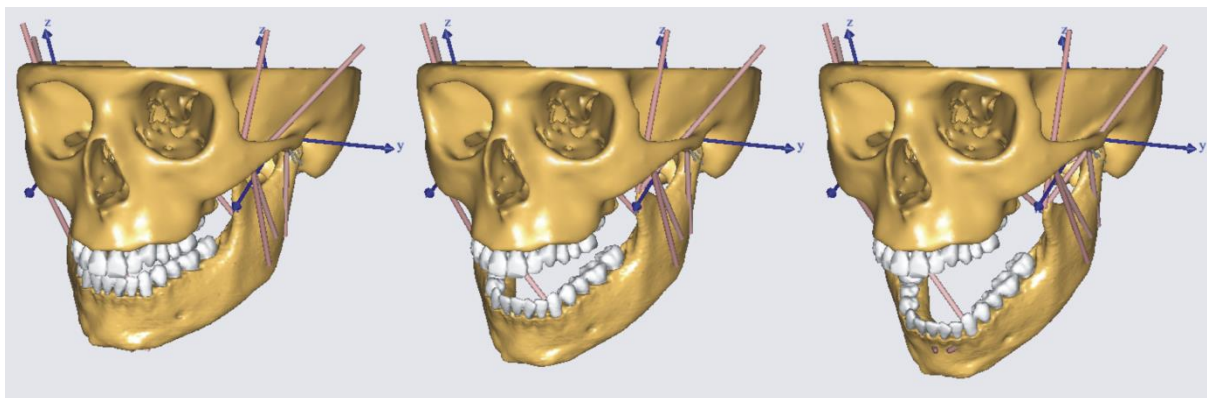


Figure 1: The mandible model. The blue skull-fixed reference frames were used to represent the joint reaction forces. From left to right: 0.0, 1.0 and 2.0 cm mouth opening.

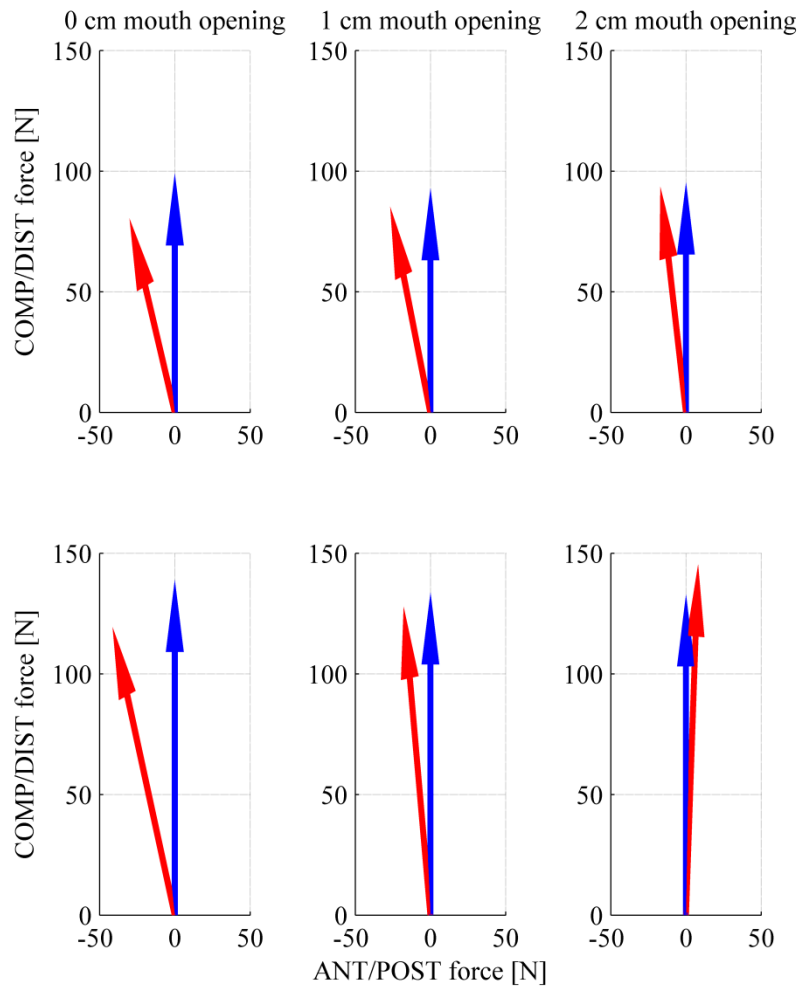


Figure 2: Computed compressive forces plotted against anterior/posterior reaction forces for 0.0, 1.0 and 2.0 cm mouth opening and a bite force of 150 N. Top row: the right TMJ. Bottom row: the left TMJ. The red arrows show the TMJ reaction forces obtained using the FDK-modelled TMJ and the blue the results using the planar constraint model.