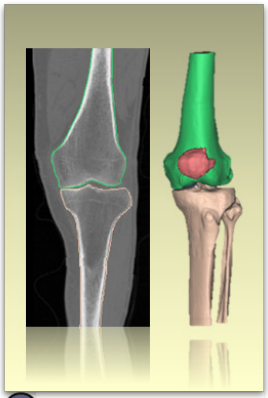
Grand Challenge Winner 2014

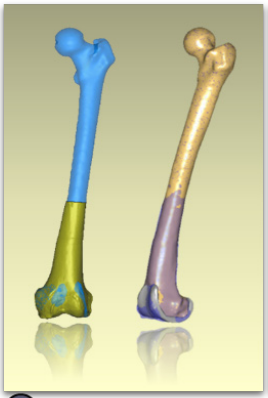
using The AnyBody Modeling System™ to predict in vivo knee loads

From medical images to knee joint loads in AnyBody

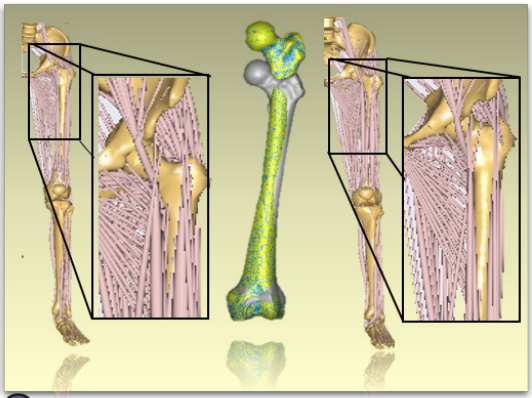
A methodology to develop patient-specific models able to simultaneously predict muscle, ligament, and knee implant contact forces along with secondary knee kinematics.



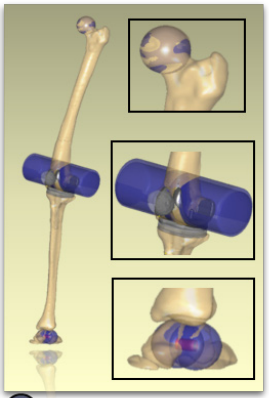
1 Pre-op segmentation



2 Pre-/post-op registration

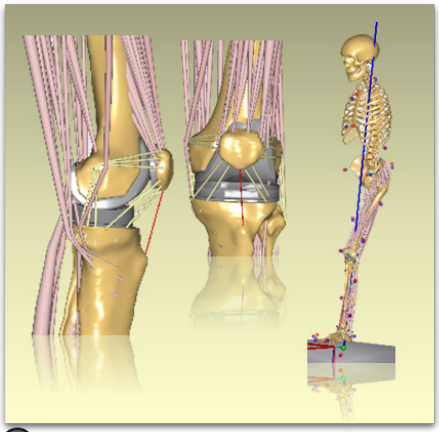


3 *Before* Bone morphing *After*

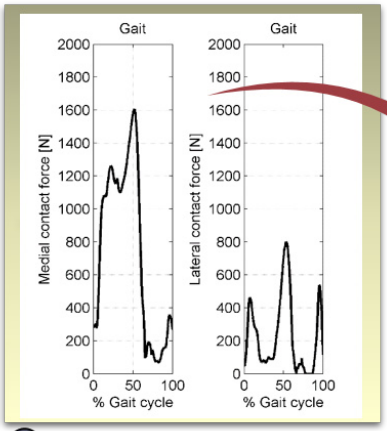


4 Analytical joint fitting

5 Marker tracking



6 Joint modelling and force-dependent kinematics



7 Results

See overleaf for more comparative results

Challenge

The fifth Grand Knee Challenge Competition to Predict In Vivo Knee Loads by Fregly et. al., 2012, was to predict the medial and lateral knee contact forces during gait and right turn trials for a patient with an instrumented implant, measuring the actual implant loading.

Solution

1. Segmentation of medical images.
2. Registration of the pre- and post-operative scans.
3. Full-body subject-specific model from anthropometric scaling and morphing of the lower limb using segmented data.
4. Analytical joint fitting for the hip, knee and ankle.
5. MOCAP data drives model.
6. Implant integrated into patient-specific model.
7. Simulated implant loading.

Benefits

- Accurate estimates of knee implant contact forces and secondary joint kinematics.

Perspectives

- Automated workflow with clinically available data including ligament calibration and implant positioning.
- Prediction of implant performance depending on implant, patient and surgical parameters.

Winning team: *MS Andersen[1], MA Marra[2], V Vanheule[3], N Verdonschot[2] and J Rasumussen[1]*

[1]Aalborg University [2]Radboud University Medical Centre, [3]Materialise, [4]University of Twente

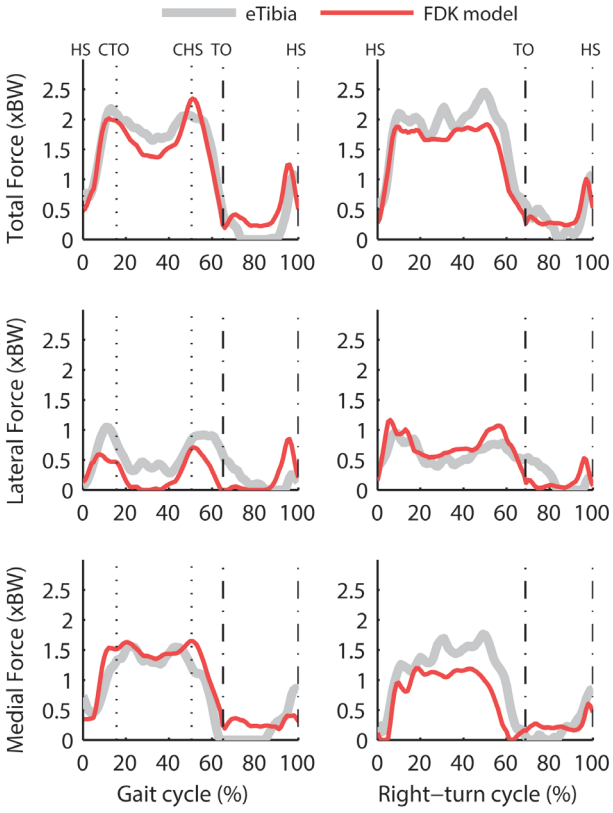
ANYBODY™ TECHNOLOGY

Results

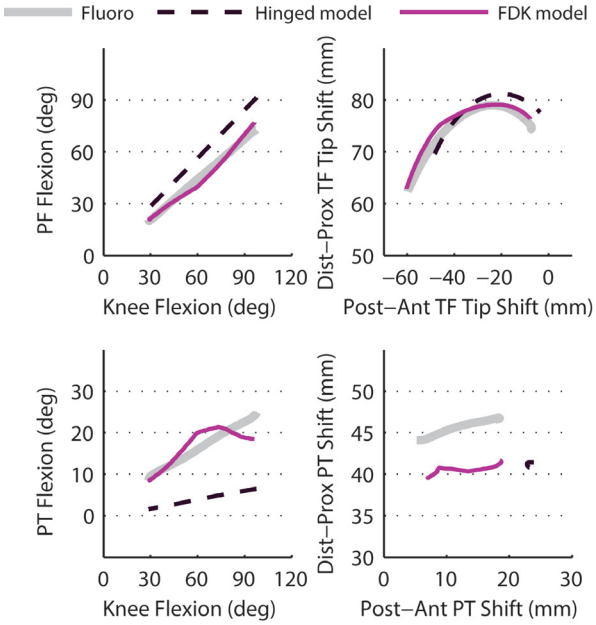
For the competition, the participants had to prepare two sets of results. Initially, blinded predictions without any knowledge of the measured knee joint forces and unblinded predictions. When all blinded results had been submitted, the measured knee forces were revealed to the competitors, who had an additional four months to analyze their results and improve their model. Subsequently, unblinded predictions were submitted. The results illustrated on the front page are the blinded predictions, whereas the results shown in the following are unblinded results published in Marra et al. 2015.

The full-body model was based on the AnyBody Managed Model Repository, including the TLEM lower extremity model, which was updated with the new TLEM 2.0 data set (Carbone et. al, 2015).

This year's winner was better than ever before, according to the chairman of the Grand Challenge, Professor B.J. Fregly.



Results predicted by AnyBody's FDK solver compared to actual compressive loads measured by the instrumented implant (Marra et. al, 2015).



Predicted internal knee joint movements compared to single plane fluoroscopy during unloaded flexion/extension (Marra et. al, 2015). Internal joint movements are quantified by patellofemoral (PF) flexion, patellotibial (PT) flexion, tibiofemoral (TF) tip shift, and PT shift. The FDK model predictions are generally more accurate than hinged model predictions.

References

- *"Grand Challenge Competition to Predict In Vivo Knee Loads". B.J. Fregly, T.F. Besier, D.G. Lloyd, S.L. Delp, S.A. Banks, M.G. Pandy, and D.D. D'Lima. Journal of Orthopaedic Research, volume 30, issue 4, 2012, pages 503–513.*
- *"A Subject-Specific Musculoskeletal Modeling Framework to Predict in Vivo Mechanics of Total Knee Arthroplasty". M. Marra, V. Vanheule, R. Fluit, H.F.J.M. Koopman, J. Rasmussen, N. Verdonschot and M.S. Andersen. Journal of Biomechanical Engineering, volume 137, issue 2, 2015, pages 1-12.*
- *"TLEM 2.0 – A comprehensive musculoskeletal geometry dataset for subject-specific modeling of lower extremity". V. Carbone, R. Fluit, P. Pellikaan, M.M. van der Krogt, D. Janssen, M. Damsgaard, L. Vigneron, T. Feilkas, H.F.J.M. Koopman and N. Verdonschot. Journal of Biomechanics, volume 48, issue 5, 2015, pages 734–741.*

The runner up also used The AnyBody Modeling System™

Y. Jung and S. Koo of Chung-Ang University won second place in the competition with the paper: "Estimation of knee intra-articular force using distributed force-reaction elements and inverse dynamics simulation" .

Check out the "Grand Challenge Knee..." webinar on AnyBody Technology's YouTube channel. (youtube.com/user/anybodytech)