Aalborg Universitet

AALBORG UNIVERSITY
DENMARK

Prediction of Post-operative Joint Instability Following Total Knee Arthroplasty

Pedersen, Dennis; Vanheule, Valentine; Wirix-Speetjens, Roel; Taylan , Orçun; Delport, Hendrik Pieter; Scheys, Lennart; Andersen, Michael Skipper

Published in:
Program & Abstracts from the 11th Annual Meeting of the Danish Society of Biomechanics

Publication date:
2019

Document Version
Accepted author manuscript, peer reviewed version

PREDICTION OF POST-OPERATIVE JOINT INSTABILITY FOLLOWING TOTAL KNEE ARTHROPLASTY

D Pedersen[1,Ph.D. student], V Vanheule[2], R Wirix-Speetjens[2], O Taylan[3], H P Delport[3], L Scheys[3], M S Andersen[1]
[1]Aalborg University, Denmark, [2]Materialise N.V., Leuven, Belgium, [3]KU Leuven, Belgium

INTRODUCTION

Total Knee Arthroplasty (TKA) is a common surgery for late-stage osteoarthritis. However, complications can lead to implant failure, decreased functionality and/or severe pain. Studies have found that over 20% of patients are dissatisfied with the surgery and 13% need revision. Joint instability is considered the leading cause of early implant failures and accounts for a significant amount of late implant failures primarily due to wear. If we were able to predict post-operative joint instability following TKA by utilizing musculoskeletal (MS) modelling and patient-specific information, we might be able to provide the surgeon with a preoperative planning tool that could help predict the optimal surgical procedure for the individual patient and thereby reduce the patient dissatisfaction and revision rate. However, a model is only as good as its asumptions and we know that the mechanical properties of ligaments and soft tissue around the joint displays high intersubjective variablity, that can have detrimental effect on the predictability of the model. This renders the current MS modelling approach, that assume generic ligament properties from the litterature, inapplicable for preoperative planning where high subject-specificity is present. We propose a novel method combining a non-invasive arthrometer and a MS modelling approach to predict patient-specific post-operative joint instability following TKA.

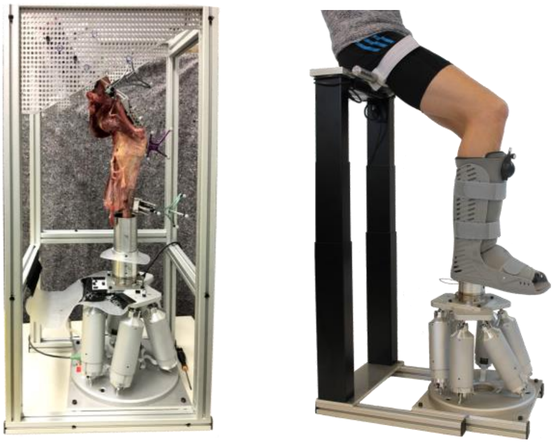

Fig. 1 - The *in vitro* version (left) of the 3D arthrometer used in the study and the *in vivo* version (right).

METHODS

As a proof-of-concept, a preoperative 3D laxity profile was obtained from a cadaveric specimen using a novel arthrometer presented in [1] (Figure 1). Twelve monoplanar and four multiplanar load cases were applied to the knee in 30 degrees of flexion. The knee pose from each load case were obtained using motion-capture and bone pin markers. Subsequently, a posterior-stabilized TKA was performed on the specimen and a postoperative laxity profile was obtained. A preoperative MS model of the cadaveric knee was constructed in the AnyBody Modelling System (AnyBody Technology, Denmark) displaying subject-specific bone geometry, cartilage, ligament insertion and origin points gathered from magnetic resonance imaging and computed tomography scans (Figure 2). Anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), lateral collateral ligament (LCL), medial collateral ligament (MCL), popliteus tendon/popliteofibular ligament complex (PLT), posterior oblique ligament (POL) and anterior lateral ligament (ALL) were modelled as single bundle nonlinear line elements. Force-dependent kinematics [2] was applied to solve the pose of the knee joint during each laxity measurement. A Complex optimisation [3] implemented in MATLAB (MathWorks, USA) was wrapped around the model to optimise ligament slack length to minimize residual error between model and experimental kinematics. For validation, the optimised ligament parameters were applied in a postoperative MS model, where bone and cartilage geometry were replaced with the posterior stabilized TKA implant and both ACL and PCL resected. Model-predicted post-operative laxity was then validated against experimental post-operative laxity measurements.

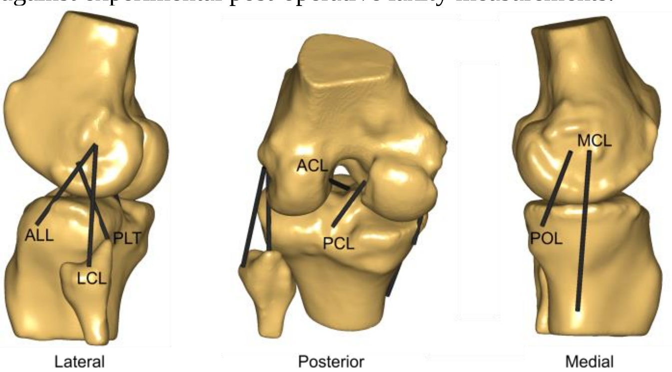

Fig. 2 – The preoperative MS model used to optimize patient-specific ligament parameters.

RESULTS AND DISCUSSION

The model predictions displayed an average error for the postoperative laxity of 0.76 mm, 3.49 mm, 4.66 mm, 0.19°, 0.48° and 3.58° for proximodistal translation, mediolateral translation, anteroposterior translation, flexion/extension rotation, varus/valgus rotation and internal/external rotation. Compared to an identical MS model using generic ligament properties from the literature, the optimized MS model improved the postoperative predictability by an average of 18 % and 54 % for translations and rotations respectively.

CONCLUSIONS

The proposed method did significantly improve the predictability of post-operative instability following TKA compared to current modelling methods. This approach advances the subject-specificity of MS models, potentially making them applicable in preoperative surgical planning.

ACKNOWLEDGEMENTS

The Danish Council for Independent Research funded this study under the Sapere Aude program. DFF-4184-00018.

REFERENCES

1. Pedersen, et al. *J Biomech*, **82**:62-69, 2019.
2. Andersen, et al. *J.Biomech.Eng*, **139**:091001, 2017.
3. Box. *The Computer Journal*, **8**:42-52, 1965.