Institute of Medical & Biological Engineering

The Effects of Geometric Uncertainties on the Computational Modelling of Knee Biomechanics

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Background

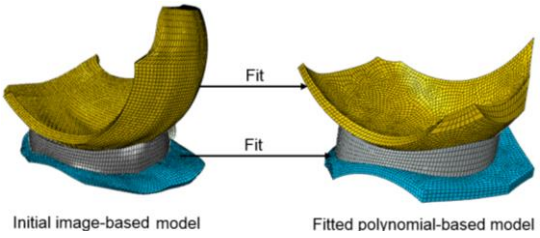
- The geometry of cartilage and meniscus in computational knee models is a critical factor for predicting knee mechanics.
- A number of factors will cause geometric uncertainties in cartilage and meniscus in computational knee models, such as the resolution of MR images and the application of simpler mathematical geometric descriptors.
- Evaluating the effects of these geometric uncertainties is fundamental to understanding the level of reliability of the current and future knee models.
- Aim of this study: to evaluate the sensitivity of the mechanics of the knee to the uncertainties in the geometry of cartilage and meniscus.

Materials & Methods

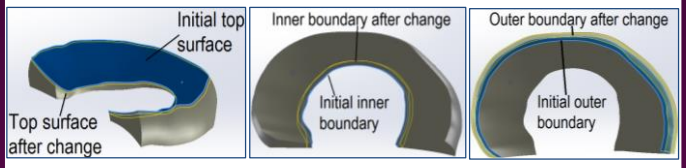
- Both image-based (IB) and polynomial-based (PB) FE models were adopted.

IB models: Open Knee project (MR images acquired with a resolution of 0.29 mm/pixel) [1].

PB models: polynomial functions fitted to the IB surfaces; three degrees of polynomial function were investigated (3rd, 4th, and 5th).



- The sensitivity of knee mechanics to geometric uncertainties was first investigated by comparing the PB and IB menisectomy models.
- The effect of geometric uncertainties was investigated further by slightly varying the size of meniscus. The investigated variations were -0.2 to 0.2 mm in the height and up to 1.0 mm in the inner and outer radius of the meniscus.



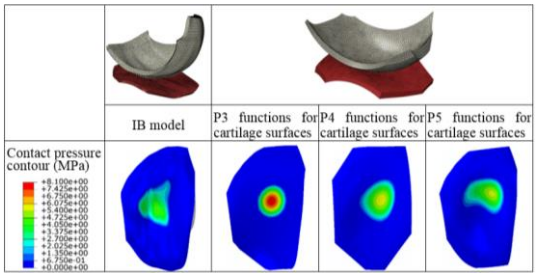
- Cartilage and meniscus were assumed to be linear isotropic and transversely isotropic, respectively [2].

Results & Discussion

- With the increase in the degree of the polynomial function, the fitted PB surfaces approached the IB surfaces.

The root mean square error between the fitted polynomial surfaces and the initial image based surfaces			
	3-degree	4-degree	5-degree
Tibial cartilage	0.740	0.510	0.366
Femoral cartilage	0.437	0.310	0.206

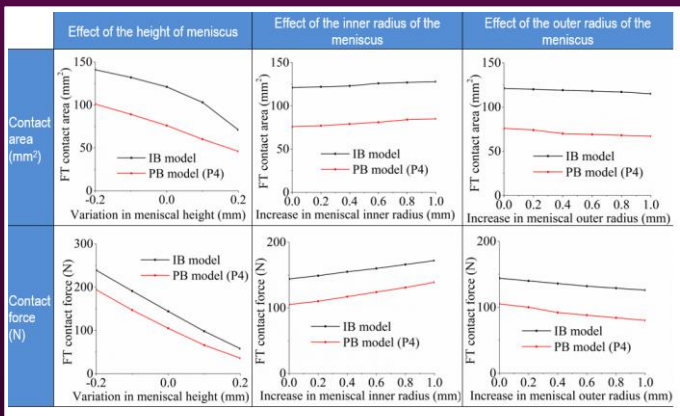
- However, the contact pressure contours of all the PB models differed from that of the IB model.



Implications:

1. Simplified geometries can not produce same contact pressure as the image based models. Similar to the conclusion for a study of the hip [3].
2. Geometric uncertainties caused by the resolution of MR have considerable effects on knee mechanics prediction.

- Knee mechanics are very sensitive to the small variation in the meniscal height, confirming that the geometric uncertainties caused by the resolution of MR have considerable effects on knee mechanics prediction.
- Knee mechanics are less sensitive to the inner and outer radius of meniscus than the height. This finding has important implications for reducing the uncertainties caused by the resolution of MR.
- The trends predicted by the PB model were similar to those of the IB model. Therefore, the models based on simple geometric descriptors can predict reliable qualitative trends.



Significance

- This study is important for us to understand the reliability of the current and future knee computational models and provides guidelines for developing future models.

References
[1] Erdemir and Sibole 2010: Open knee user's guide. [2] Yang et al., Ann Biomed Eng, 2009 (37): 2360-2372. [3] Anderson, et al., J Biomech, 2010 (43): 1351-1357.

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