Institute of Medical & Biological Engineering

The Importance of Tension-Compression Nonlinearity in a Biphasic Hip Model: A Comparison to Experiment

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INTRODUCTION

- Biphasic study of the hip can improve understanding of the function, pathology of joint degeneration and potential interventions.
- The authors developed a new method of biphasic whole joint modelling that overcame previous convergence issues [1]
- The solid phase of the cartilage is nonlinear in tension-compression (T-C), owing to fibers [2].
- The effect of the T-C nonlinearity on the hip joint mechanics is unknown.
- The necessity to consider the T-C nonlinearity in future hip models is unclear.

AIMS

- To develop a specimen-specific biphasic finite element (FE) model of a porcine acetabular cup in contact with a metallic femoral head using the new biphasic methodology
- To evaluate the effect of the T-C nonlinearity for the solid phase in the hip joint by comparing the results to those of a isotropic solid phase model and to experimental results on the same specimen.

METHODS

- An acetabulum dissected from a 2.4 year old pig and microCT-scanned.
- The acetabulum was loaded (100 N, 200 N and 400 N) against a metal head (Figure 1).
- An FE model was generated from the microCT data.
- Cartilage was modelled as biphasic. The solid phase was assumed to be 1) isotropic; 2) T-C nonlinear.
- Contact area was experimentally measured by a thin layer of fluid polymer and compared to the predictions of the two FE models.

Table 1: Material properties adopted in the models [2, 3].

	Isotropic	T-C
Aggregate modulus (MPa)	0.562	0.562
Tensile modulus (MPa)	N/A	5.62
Poisson's ratio	0	0
Permeability (mm^4)/Ns	0.00157	0.00157

Figure 1: Experimental set-ups.

RESULTS

- Different patterns in contact stress distribution and contact area were observed between the isotropic model and T-C model (Figure 2).
- Under 100 N, two separated contact locations were observed in the experiment and T-C model, but not in the isotropic model.
- Better agreement in the location, size and shape of the contact area was obtained for the T-C model than the isotropic model.

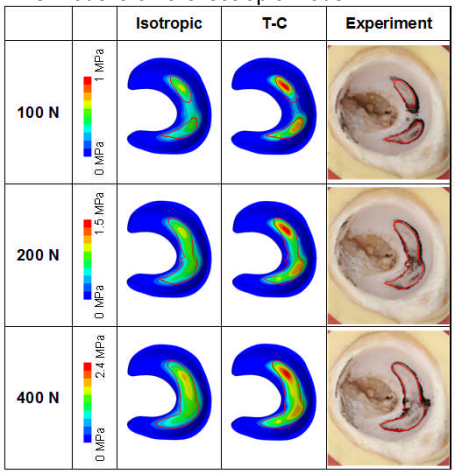

Figure 2: Contour of contact stress of the isotropic model and T-C model in comparison to the experiment.

Discussion

- The results demonstrated the importance of the T-C nonlinearity of the solid phase to the contact mechanics within the hip joint.
- The good agreement between the experiment and modelling provides some confidence that the new biphasic methodology for modelling the cartilage was able to predict the contact mechanics of the hip joint.
- Limitations include material properties taken from the literature and limited parameters measured experimentally.
- Future studies will extend the studies from the porcine model to the human hip.

Significance

- The methodology presented provides a substantial step toward practical applications of biphasic cartilage modelling on a subject specific level.
- It also serves as a basis for its applications to the pathology of joint degeneration and potential interventions.

References

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