Introduction

Stem cell treatment has been proposed for cardiac regeneration after myocardial infarction, but beneficial effects are moderate and inconsistent [1]. Since cells react to their mechanical environment [2], control over the local mechanical environment experienced by injected cells is expected to improve control over their behaviour. This can be achieved by injecting cells as part of micro-tissues also consisting of a material providing a controllable interface between environment and cells (fig 1). The aim of this study is to investigate the amount of control over the local mechanical environment possible by varying micro-tissue stiffness in a deforming macro-environment.

Method

An axisymmetric finite element model of a spherical micro-tissue in a cylindrical environment (fig 2) is developed. The stiffness of the environment was kept constant while micro-tissue stiffness was varied. A uniaxial strain of 10 % was applied to the environment in all cases.

Several versions of the model were made (table 1), varying in contact definition between micro-tissue and environment (either affine or cohesion in normal direction and frictionless shear) and (an)isotropy (isotropy or reduced stiffness perpendicular to loading direction), so these unknown factors would not adversely influence results.

Results

Maximal principal nominal strain (MPNS) in the micro-tissue was inhomogeneous (fig 3), with location of minima and maxima depending on model version.

When stiffness was varied within a model version, the distribution was similar. Therefore in figure 4 mean strain (line) and strain range (filled area) in the micro-tissue are plotted against stiffness.

Reducing micro-tissue stiffness increases mean strain and range of strain in the micro-tissue up to 1.5 to 2 times the strain applied to the environment. Inhomogeneity is increased in the frictionless shear simulations compared to affine contact. The effect of micro-tissue stiffness is slightly increased in an anisotropic environment.

Conclusion

- Control over the local mechanical environment is limited to a mean micro-tissue strain up to two times the environmental strain.
- Strain in the micro-tissue is inhomogeneous, possibly causing unwanted differences in cellular behaviour in different parts of the micro-tissue. This can be limited by fixing the micro-tissue to its environment (affine contact).