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Orthopaedic Biomechanics

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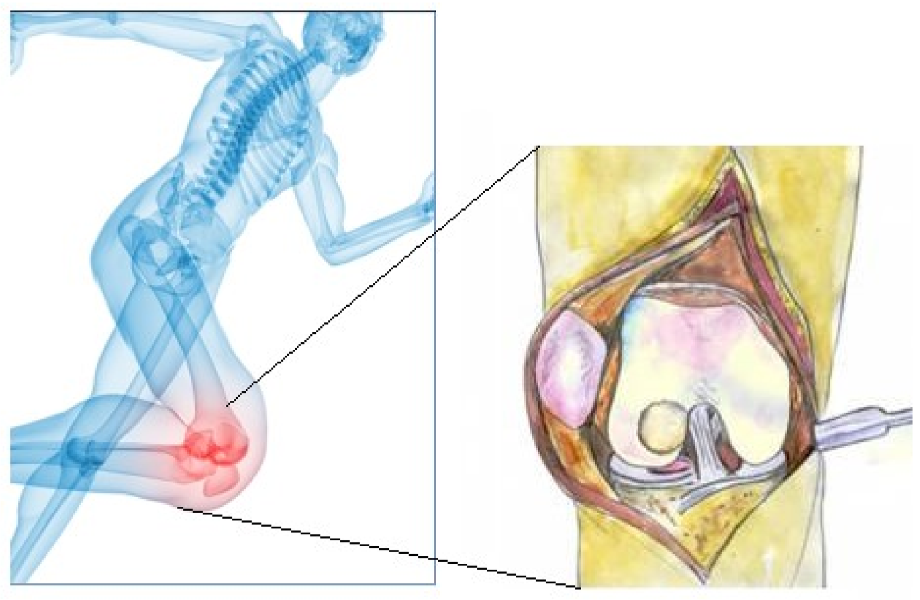

Introduction

Cartilage in our joints has a crucial role in our movement abilities. Unfortunately, no satisfactory treatment for damaged cartilage exists. Replacing damaged cartilage with tissue-engineered (TE) cartilage could be a promising solution (Fig.1). TE studies generally aim at improving the mechanical stability of the engineered cartilage.

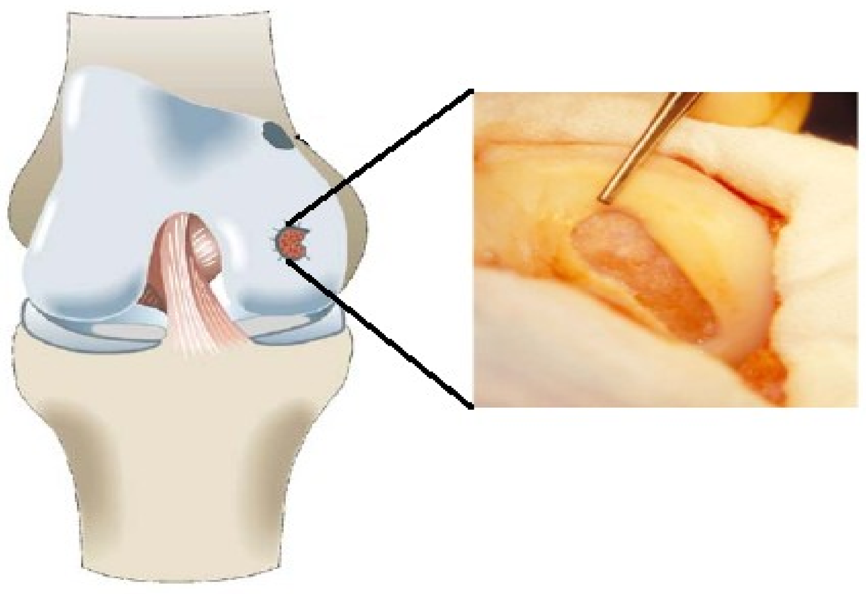

Figure 1. replacement of damaged cartilage with engineered cartilage [1]

A factor that may play a role for mechanical properties of TE cartilage which has been insufficiently explored, is the spatial distribution of the extracellular matrix (ECM). The aim of the present study was therefore to theoretically predict the influence of micro-scale ECM inhomogeneities on the mechanical behavior of TE cartilage.

Methods

Based on experimental observations [1] (Fig.2,top), two types of a representative volume element (RVE) were compared; (I), RVE containing randomly located cells embedded in homogeneously distributed surrounding matrix and agarose gel and (II), RVE containing randomly located cell-ECM inclusions embedded in agarose gel (Fig.2,bottom).

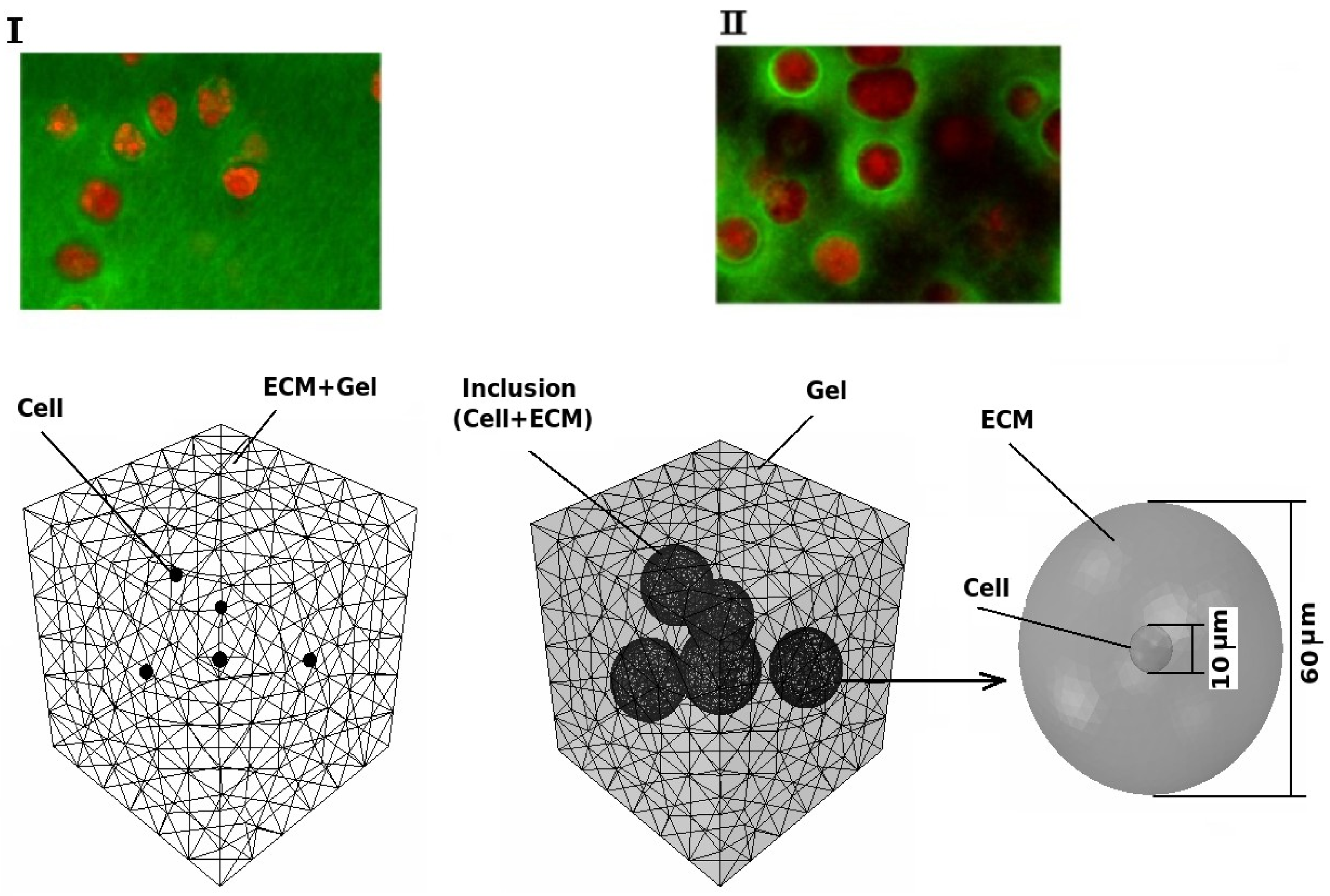

Figure 2. ECM (green, cell is red) distribution in experiments (top) and finite element model (bottom)

Finite element modeling was used and a poroelastic fibre-reinforced swelling material model was adopted to capture the mechanical behavior of agarose and cartilage ECM [2]. Young modulus and swelling behavior were evaluated as two mechanical characteristics of the TE cartilage construct.

Results

With the same total matrix content, the Young's modulus (Fig. 3a) was 5 times higher when ECM was homogeneously dispersed in the gel (I) compared to when it was localized around the cells (II). Average swelling pressure (Fig.3b) was one order of magnitude higher when ECM was localized around the cells inducing significantly different distribution of displacement in the two cases (Fig.3c).

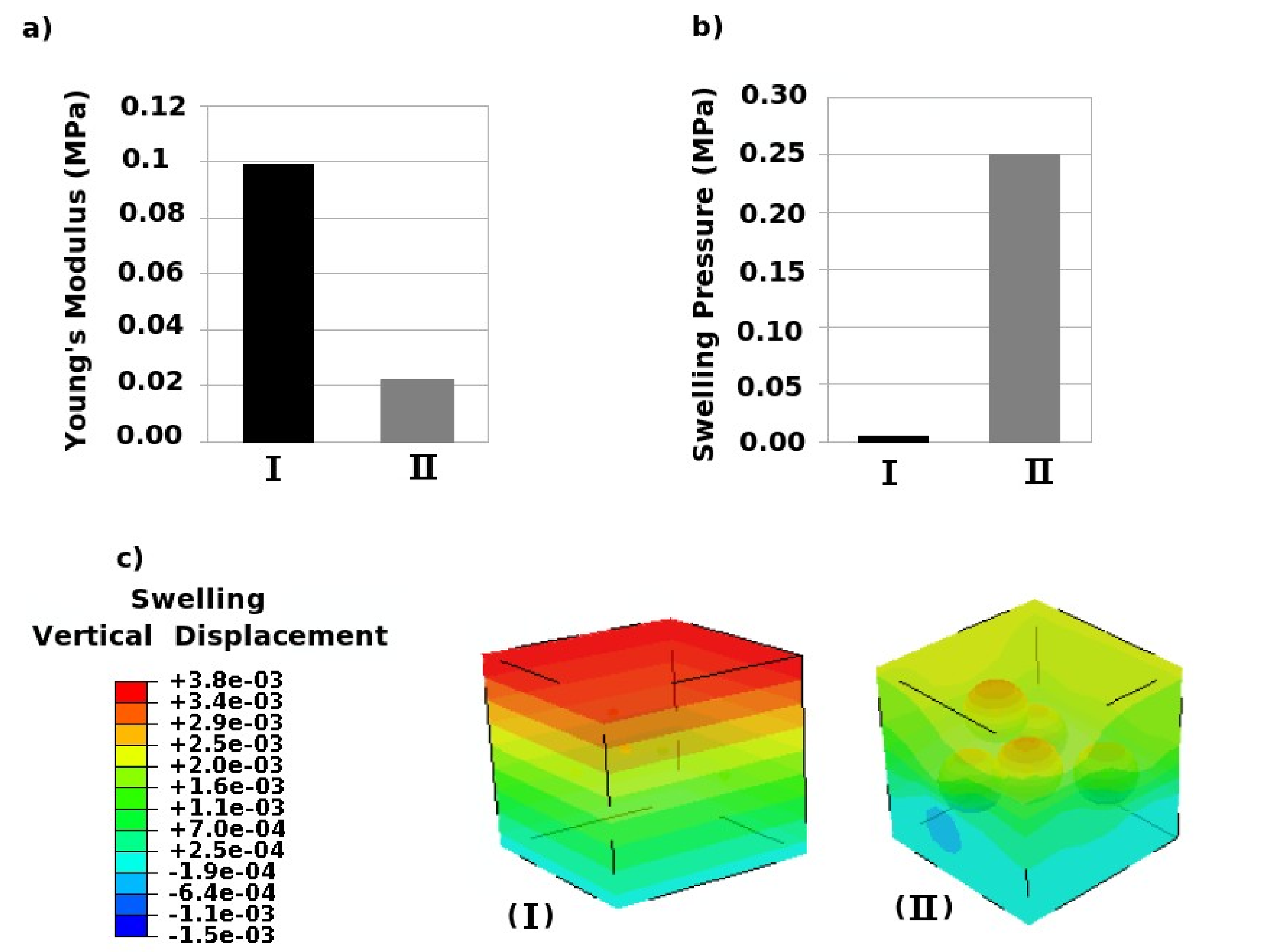

Figure 3. Young's modulus and swelling behavior depending on ECM distribution

Conclusion

Compared to a homogeneous matrix distribution, localization of the matrix constituents around the cells causes significant overall softening of the construct. Furthermore, localization of matrix will change cellular mechanical environment and mechanotransdution. Depending on spatial and temporal distribution of matrix, construct stimulatory mechanical loading protocols may need adjustment over time. Therefore, to improve the mechanical functionality of TE constructs, tissue engineering experiments should consider the matrix distribution as an important factor.

References

[1] L.M. Kock et al., (2011). SBC2011-53160.

[2] W. Wilson, et al., (2005). J Biomech, 38:1195-1204.