

Mechanical chondrocyte damage thresholds

Citation for published version (APA):

Turnhout, van, M. C., Vries, de, S. A. H., Donkelaar, van, C. C., & Oomens, C. W. J. (2012). *Mechanical chondrocyte damage thresholds*. Poster session presented at Mate Poster Award 2012 : 17th Annual Poster Contest.

Document status and date:

Published: 01/01/2012

Document Version:

Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

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Mechanical chondrocyte damage thresholds

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1. Questions

- How much deformation can a chondrocyte endure, and for how long, before it damages
- How does the PCM affect chondrocyte deformations and damage

2. Methods

Bovine chondrocytes are cultured in 3-D agarose constructs for 1, 3, 5, 7, and 10 days. After staining with CTG and PI to stain living cells green and dead cells red [1], they are subjected to nonuniform compression [2] at a confocal microscope, and imaged every hour for 24 hours. Histology is used to assess PCM development over culture time, and to measure cell deformation at 25 % strain.

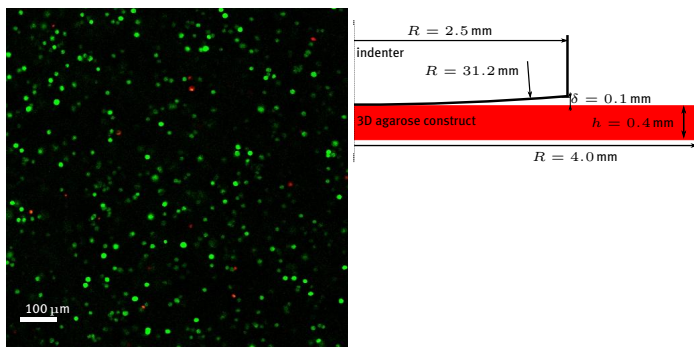


Figure 1: Example of confocal microscopy image of viability (left) and schematic of the indentation set-up (right).

3. Results

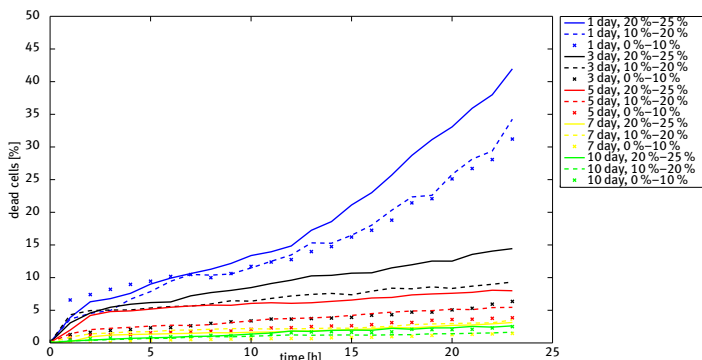


Figure 2: Percentage dead cells increases with applied strain and compression time, and decreases with culture time.

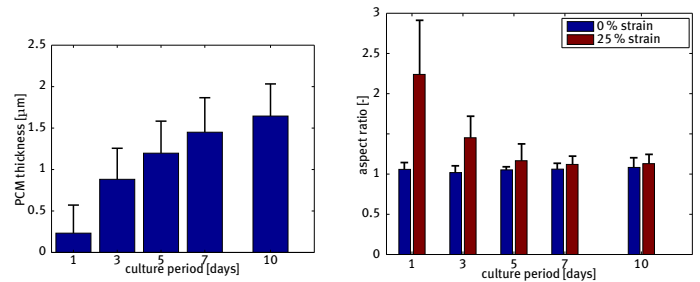


Figure 3: PCM thickness increases (left) and cells deform less (right) with increasing culture time.

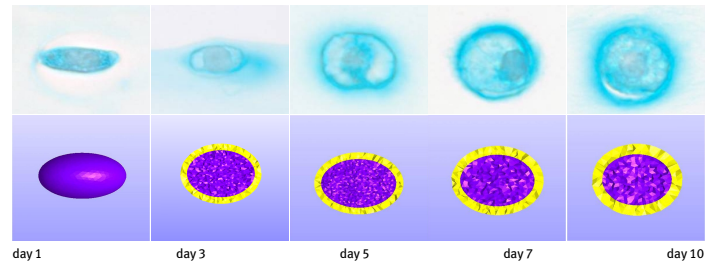


Figure 4: Alcian Blue staining of deformed cells at 25% strain (top) and FE simulations with the FEBio package [3] illustrating the strain shielding effect of the PCM (bottom, 25% strain, agarose: $E = 4 \text{ kPa}$, $\nu = 0.12$; cells (purple): $E = 350 \text{ Pa}$, $\nu = 0.43$; PCM (yellow): $E = 38.7 \text{ kPa}$, $\nu = 0.04$).

4. Conclusions

- Cell death increases with increasing cell deformation, and with increasing strain duration
- Cell deformation and cell death decrease as the amount of PCM increases
- In our experiments we find that (not shown):

$$\text{cell death [\%]} = c(t) \cdot (\text{aspect ratio} - 1),$$
 with $c(t)$ a function of culture time t
- These data strongly indicate that the PCM shields the cells from deformations and (therefore) from damage due to compression

References

- [1] D. Gawlitta et al. (2004). *Cryotechnology*, 46:139–150.
- [2] A. Gefen et al. (2008). *J. Biomech.*, 41:2003–2012.
- [3] <http://mrl.sci.utah.edu/software/febio>

Acknowledgements

This study was supported by the National Institute of Biomedical Imaging and Bioengineering, National Institutes of Health grant R01EB009643 (Principal Investigator: Ahmet Erdemir).