In vitro assessment of surface congruency and integration of chondrocytes at adjacent edges of micro-fabricated cleft on cartilage

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Osteochondral grafts are common treatment options for joint focal defects due to their excellent functionality. However, the difficulty is matching the topography of host and graft(s) surfaces flush to one another. Incongruence could lead to disintegration particularly when the gap reaches subchondoral region. The aim of this study is therefore to investigate cell response to gap geometry when forming cartilage-cartilage bridge at the interface. The question is what would be the characteristics of such a gap if the cells could bridge across to fuse the edges? To answer this, osteochondral plugs devoid of host cells were prepared through enzymatic decellularization and artificial clefts of different sizes were created on the cartilage surface using laser ablation. High density pellets of heterologous chondrocytes were seeded on the defects and cultured with chondrogenic differentiation media for 35 days. The results showed that the behavior of chondrocytes was a function of gap topography. Depending on the distance of the edges two types of responses were generated. Resident cells surrounding distant edges demonstrated superficial attachment to one side whereas clefts of 150 to 250 µm width experienced cell migration and anchorage across the interface. The infiltration of chondrocytes into the gaps provided extra space for their proliferation and laying matrix; as the result faster filling of the initial void space was observed. On the other hand, distant and fit edges created an incomplete healing response due to the limited ability of differentiated chondrocytes to migrate and incorporate within the interface. It seems that the initial condition of the defects and the curvature profile of the adjacent edges were the prime determinants of the quality of repair; however, further studies to reveal the underlying mechanisms of cells adapting to and modifying the new environment would be of particular interest.

References

1. Pethrick RA, Zaikov GE, Pielichowski J. Monomers, oligomers, polymers, composites and nanocomposites research: synthesis, properties and applications. Nanotechnology Science and Technology. New York: Nova Science Publishers; 2009.
2. Jiménez A, Zaikov GE. Recent advances in research on biodegradable polymers and sustainable composites. Nanotechnology Science and Technology, Vol 1. New York: Nova Science Publishers; 2009.
3. Heidarkhan-Tehrani A, Singh S, Xiao Y, Oloyede A. Fast Fourier Analysis of Structural Organization in Decellularized Cartilage-on-Bone Laminates. Proceedings of the IASTED International Symposia on Imaging and Signal Processing in Health Care and Technology (ISPHT 2012); Baltimore, USA: Acta Press; 2012. p. 71-77.
4. Heidarkhan-Tehrani A, Singh S, Xiao Y, Oloyede A. Anisotropy of Articular Cartilage Reflects the ECM Gradient Architecture: Hough-Radon Transform Analysis. Proceedings of the IASTED International Symposia on Imaging and Signal Processing in Health Care and Technology (ISPHT 2012); Baltimore, USA: Acta Press; 2012. p. 64-70.
5. Tehrani AH, Zadhoush A, Karbasi S. Preparing nanocomposite fibrous scaffolds of P3HB/nHA for bone tissue engineering. 2010 17th Iranian Conference of Biomedical Engineering (ICBME); Isfahan, Iran: IEEE; 2010. p. 1-4.
6. Heidarkhan Tehrani A, Zadhoush A, Karbasi S, Sadeghi-Aliabadi H. Scaffold percolative efficiency: in vitro evaluation of the structural criterion for electrospun mats. Journal of Materials Science: Materials in Medicine. 2010;21(11):2989-2998.
7. Mehraban M, Zadhoush A, Abdolkarim Hosseini Ravandi S, Bagheri R, Heidarkhan Tehrani A. Preparation of porous nanofibers from electrospun polyacrylonitrile/calcium carbonate composite nanofibers using porogen leaching technique. Journal of Applied Polymer Science. 2013;128(2):926-933.
8. Tehrani AH, Zadhoush A, Karbasi S, Khorasani SN. Experimental investigation of the governing parameters in the electrospinning of poly(3-hydroxybutyrate) scaffolds: Structural characteristics of the pores. Journal of Applied Polymer Science. 2010;118(5):2682-2689.
9. Heidarkhan-Tehrani A, Davari P, Singh S, Oloyede A. Fine tuning of elasticity via crosslinking collagen-based materials to mediate mechanotransduction and stability using corona treatment. Proceedings of the 23rd Annual Conference of the Australian Society for Biomaterials and Tissue Engineering; 2014 22-24 April; Mantra Resort Lorne, Victoria, Australia: ASBTE.
10. Heidarkhan-Tehrani A, Singh S, Oloyede A. Local stress-strain distribution and load transfer across cartilage matrix at micro-scale using combined microscopy-based finite element method. Proceedings of the 23rd Annual Conference of the Australian Society for Biomaterials and Tissue Engineering; 2014 22-24 April; Mantra Resort Lorne, Victoria, Australia: ASBTE.
11. Heidarkhan-Tehrani A, Singh S, Jaiprakash A, Oloyede A. Correlating flow induced shear stress and chondrocytes activity in micro-porous scaffold using computational fluid dynamic and rapid prototyping. Proceedings of the 23rd Annual Conference of the Australian Society for Biomaterials and Tissue Engineering; 2014 22-24 April; Mantra Resort Lorne, Victoria, Australia: ASBTE.

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