Geometry as a Factor for Tissue Growth: Towards Shape Optimization of Tissue Engineering Scaffolds

Abstract

Scaffolds for tissue engineering are usually designed to support cell viability with large adhesion surfaces and high permeability to nutrients and oxygen. Recent experiments support the idea that, in addition to surface roughness, elasticity and chemistry, the macroscopic geometry of the substrate also contributes to control the kinetics of tissue deposition. In this study, a previously proposed model for the behavior of osteoblasts on curved surfaces is used to predict the growth of bone matrix tissue in pores of different shapes. These predictions are compared to in vitro experiments with MC3T3-E1 pre-osteoblast cells cultivated in two-millimeter thick hydroxyapatite plates containing prismatic pores with square- or cross-shaped sections. The amount and shape of the tissue formed in the pores measured by phase contrast microscopy confi rms the predictions of the model. In cross-shaped pores, the initial overall tissue deposition is twice as fast as in square-shaped pores. These results suggest that the optimization of pore shapes may improve the speed of ingrowth of bone tissue into porous scaffolds.

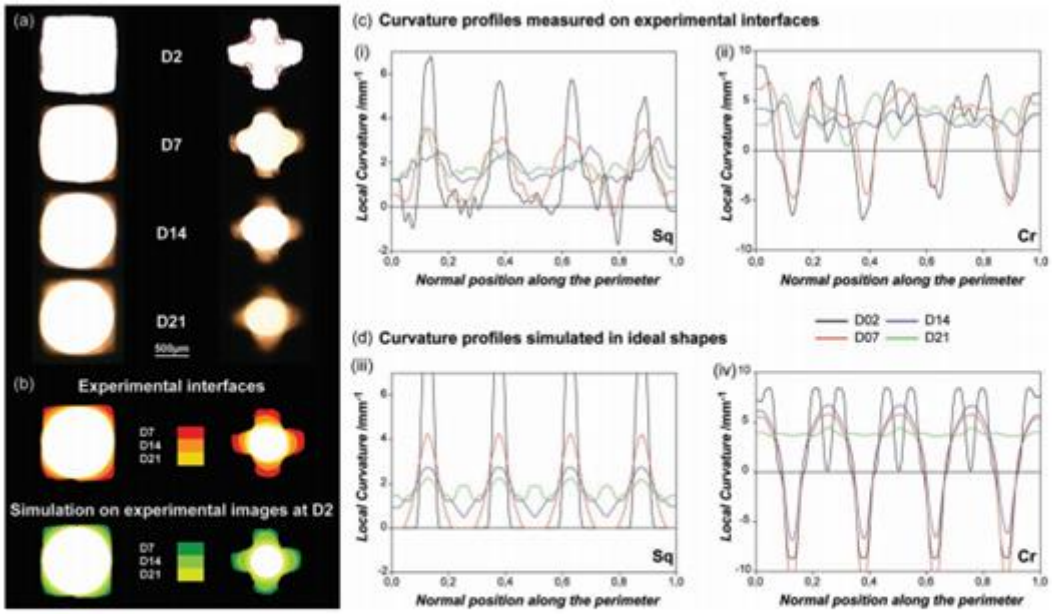

Figure 2. Tissue growth in square- and cross-shaped pores. a) Phase contrast images of the pore taken 2, 7, 14, and 21 days after seeding the MC3T3-E1 on the scaffolds. b) The superposition of the interfaces obtained experimentally is compared with the predictions of the curvature-driven growth simulation applied to the actual geometry of the experimental pore at D2. 7, 14 and 21 days of experiments are obtained with 36, 120, and 204 steps of simulation with $r = 8.5pxl$, $\alpha = 12steps$, $t_0 = 4$ d. c) Curvature profiles of the tissue–medium interface measured at D2, D7, D14, and D21 in a square- (i) and a cross-shaped pore (ii). d) Curvature profiles are measured on the interfaces predicted by the curvature-driven growth model after 7, 14, and 21 days of culture in ideal square- (iii) and cross-shaped pores (iv). The curvature measurements were smoothed using a mask size of $r = 14.5pxl$.