IN VITRO EFFECTS OF SURFACE ROUGHNESS AND CONTROLLED SURFACE MICROGEOMETRY ON FIBROUS TISSUE CELL COLONIZATION

J. L. RICCI, J. CHARVET, R. SEALEY, I. BITON, W. S. GREEN, S. A. STUCHIN, AND H. ALEXANDER

Departments of Bioengineering and Orthopaedic Surgery,
Hospital for Joint Diseases Orthopaedic Institute, New York

Introduction Soft tissue encapsulation of an implant has been found to correlate with the composition, surface chemistry, and surface microgeometry of the implant material. Surface microgeometry (or surface texture) of metal implants in bone has been shown to influence fibrous capsule formation. For example, smooth surfaces induce thicker fibrous capsule formation than roughened surfaces, suggesting that surface microgeometry influences fibrous tissue proliferation.

We evaluated the in vitro response of rat tendon fibroblast (RTF) cell colonies, and human implant capsule fibroblast (HICF) cell colonies, from fibrous capsule tissue from around total hip replacement components, to surfaces roughened by blasting techniques, and to controlled surface microgeometries consisting of small square post projections with features from 3 to12 µm in size.

Materials and Methods RTF cells were grown from hind-foot extensor tendons of 14-day-old Sprague Dawley rats. HICF cells were grown from fibrous capsule tissue samples obtained from patients undergoing total hip revision, including removal of an uncemented hip prosthesis. The tissues, obtained from an area near the proximal stem, were grown as explants under sterile conditions to produce stock cell cultures. All cells were grown as stock cultures, mixed with solubilized collagen, and dispensed and polymerized to initiate "dot" cultures, consisting of 2-µL dots each containing 20,000 cells, on all experimental surfaces. These cell-collagen dots acted as sources of cell outgrowth to form growing cell colonies. At 4 and 8 days cell colonies were fixed, stained, and measured for area of growth using a videocamera-equipped stereomicroscope connected to a computer image processing/image analysis system. Growth of the cell colonies was measured as area or diameter increase between 4 and 8 days.

Roughened surfaces were produced by grit-blasting or bead-blasting of polystyrene culture plates. A masked area was used as a smooth control surface. These surfaces consisted of a range of feature sizes depending on blast medium. The media were similar to those used to texture metal orthopaedic implants and produced similar sized features.

Controlled microgeometry substrates were molded in solvent-cast polystyrene from templates precision-fabricated using optical lithography methods at the National Nanofabrication Facility at Cornell University. All surfaces were sputter-coated with a 600-Å layer of TiO_2 to simulate an orthopaedic titanium alloy implant surface. The controlled microgeometry surfaces consisted of well-characterized, cross-hatched or checkerboard surface patterns consisting of square posts in 3-, 6-, 10-, and 12-µm feature sizes.

Results All cell colonies showed consistent growth by day 4, with cell outgrowth observed at the periphery of the dot. Randomly oriented cells formed circular colonies on the control surfaces, and the roughened surfaces. The controlled microgeometry surfaces produced colonies with unusual shapes because of surface restriction of direction of growth. On an individual cell level, the cells were observed to orient along surface structures and in grooves between surface structures. On the smallest controlled microgeometries each cell was observed to attach to the surfaces of several of the square posts.

All of the experimental surfaces significantly inhibited cell colony growth in both types of cells. Significant cell growth inhibition was observed on the grit-blasted Ti-coated surface (GB-Ti) compared to the control Ti-coated surface (C-Ti) and the control untreated culture plate (C-p) as shown in Fig. 1 which represents RTF cell growth. The most efficient cell growth inhibition was observed on the 3-µm cross-hatched surface (Fig. 2), although all of the cross-hatched surfaces caused significant inhibition of colony growth. Figure 2 also shows RTF cell colony data.

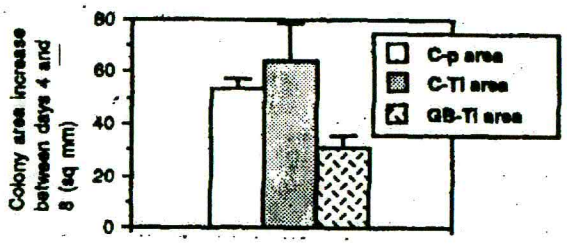

Fig. 1. RTF cell colony growth on roughened (GB-Ti) and smooth (C-p and C-Ti) surfaces.

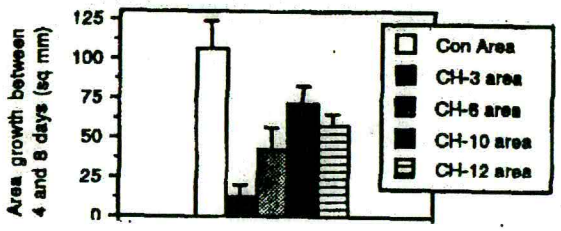

Fig. 2. RTF cell colony growth on cross-hatched surfaces from 3 µm (CH-3) to 12 µm (CH-12) in feature size, and on smooth surface controls (Con).

Conclusions RTF and HICF cell colonies grown on roughened surfaces and on a series of controlled microgeometries exhibited pronounced inhibition of growth. The surfaces did not increase cell density in the colonies and the effect was not based on increased substrate surface area. The observed results represent the effects of cellular contact guidance—the ability of substrate microgeometry to influence cell orientation and migration—on overall growth of cell colonies. The observed effects of roughened surfaces and surface microgeometries on fibrous tissue cell growth, in vitro, may be related to the observation that roughened surfaces cause less fibrous encapsulation in vivo. If so, controlled microgeometry surfaces may be used to effectively suppress fibrous encapsulation.

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Address correspondence to: Dr. John L. Ricci, Department of Bioengineering, Hospital for Joint Diseases Orthopaedic Institute, 301 East 17th Street, New York, NY

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