The Effect of Wicking Fibers on Transport Properties of Tissue Engineered Scaffolds

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Statement of Purpose: A major challenge for bone tissue engineering is the design of large volume constructs that allow vascularity as well as transport of essential factors and cells throughout the entire scaffold[1]. Vasculature provides the mass transport of oxygen and nutrients, and a mode of delivery for cells and growth factors that contribute to bone formation[1,2,3]. In general large bone defects require large volume scaffolds that promote the transport of oxygen and nutrients through vascularization[1]. Osteoprogenitor cells in a large tissue construct will not proliferate, differentiate, and form bone without transport of oxygen, nutrients, and vital growth factors[11]. Non-unions and pseudarthrosis may occur without sufficient transport[3].

Conventional mechanisms to improve transport involve biological approaches incorporating angiogenic factors to develop vascular networks. Biological approaches have had limited success[4,5]. Our novel approach involves using synthetic engineered "wicking" fibers, i.e. fibers of non-circular cross section, to provide transport in large bone scaffolds. In this study, we characterized the effects of incorporated wicking fibers on the transport of proteins through a three-dimensional (3D) scaffold and the vertical movement of osteoprogenitor cells. Our preliminary data demonstrates that wicking fibers improve the rate of protein movement in a 3D system and enhance the displacement and movement of progenitor cells.

Methods: The effect of incorporated wicking fibers on the protein movement in a 3D system was evaluated by analyzing the unimolecular diffusion of fluorescein isothiocyanate (FITC)-conjugated bovine albumin (Sigma). A solution of FITC-albumin and serum-free medium (100µg/mL) was added into a well containing collagen-agarose composite hydrogel with either round fibers or wicking fibers. A 50:50 collagen-agarose gel was formed using 1mg/mL PurCol, Bovine Collagen Solution, Type 1 (Advance Biomatrix) and 2% agarose (Sigma). The rate of FITC-albumin movement through the different gel systems was evaluated using fluorescent confocal microscopy (Nikon Eclipse TI) and NIS-Elements Imaging software. To evaluate the vertical movement of progenitor cells along the fibers, CellTracker green probe (Invitrogen) was used to label D1 mouse mesenchymal stromal cells from ATCC. Cells were seeded in a low attachment 12-well plate at a density of 1 million per mL. Custom-made lids were used to keep the 3cm fibers vertical. After 6, 12 and 24 hours, the fibers were transferred to microscope slides and the vertical displacement was evaluated using fluorescent microscopy and imaging software. ImageJ was used to evaluate the cellular density on each fiber type.

Results: The rate of movement of FITC-conjugated albumin was determined at various distances from the hydrogel and FITC-albumin solution interface. FITC-albumin diffused at a much faster rate in hydrogels containing wicking fibers compared to those containing round fibers. Vertical displacement and cell densities of D1 cells moving lengthwise along the wicking fibers were much greater than those in round fibers systems.

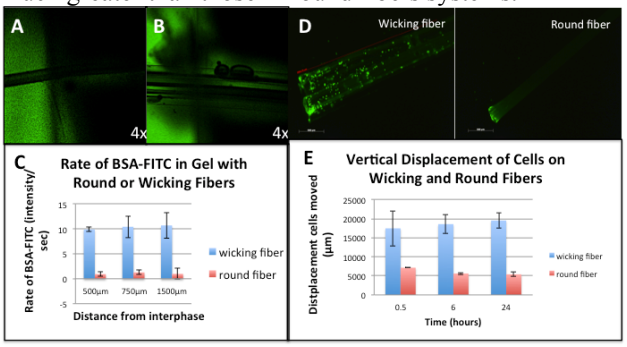

Figure 1. (A)/(B) Frame of fluorescent confocal image in z-stack illustrating the interface between the FITC-albumin solution on left, collagen-agarose hydrogel on right and round fiber (image A) and wicking fiber (image B) between the interfaces. (C) Bar graph illustrates the rate of FITC-albumin moving in hydrogel is significantly greater within gel containing wicking fiber. (D) Illustrates the much greater displacement and cell density of D1 cells on the wicking fiber. (E) The displacement of D1s along the wicking fibers is greater than that on the round fibers.

Conclusions: Our preliminary results indicate the wicking fibers can play a major role in recruiting and moving progenitor cells. Preliminary results also imply the wicking fibers enhance the rate of movement and density of protein into a 3D system. This work suggests the wicking fibers can play a role in bone tissue engineered scaffolds to improve recruitment and movement of osteoprogenitor cells and enhance the transport of proteins such as growth factors. Future work involves optimizing wicking fiber design to enhance transport of various cell types and growth factors involved in bone healing.

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References:

1. Amini AR, et al. *Tissue Eng*. 2012; 18:1-13
2. Reid JJ, et al. *J Biomech*. 2011; 44:213-220
3. Santos MI, et al. *Biomater*. 2007; 28:240-248
4. Stahl A, et al. *BBRC*. 2004; 684-692
5. Lienau J, et al. *JOR*. 2005; 23:639-45