Pre-clinical Testing of 3D Printed, Nanostructured Osteochondral Implant for Knee Repair in a Small Animal Model

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Introduction: Osteochondral lesions of the knee are difficult injuries to treat. Despite improvements in the diagnosis of these lesions, optimal treatment remains elusive, likely as a result of the complex interactions between host factors and lesions specific factors. Lesions with disrupted cartilage that are unstable are especially difficult to treat in skeletally immature patients with current treatment methods leading to mixed results overtime. We investigated the feasibility of using three-dimensional biologically inspired implants, manufactured using novel 3D printing techniques and synthetic bio-nanomaterials for treatment of osteochondral defects in a rodent model.

Materials and Methods: An osteochondral defect was created in the trochlear groove of the left knee of 6-week old female Sprague-Dawley rats. 2 mm defects were created. Four experimental groups included a blank control, a solid hydrogel implant and two experimental implants were implanted. Two different experimental implants were designed mimicking the complex micro-structure of the osteochondral transition zone and fabricated using a 3-d bioplotter: 1) a polycaprolactone and polyethylene glycol blended resin which is photocured via UV light and a nonporous thermoplastic polyurethane (TPU) based material. At 1 and 3 months samples were stained for hematoxylin and eosin (Figure 1).

Results and Discussion: The surgical procedure was successful in all animals and all subjects survived to end point. Histologic analysis (Figure 1) demonstrated some bone remodeling and mostly formation of trabecular bone and marrow in the control, and in the PEG group. The PCL based experimental implant showed the formation of extensive fibrosis and scar tissue. TPU showed the formation of fully remodeled bone around the implant, and some bone invading the implant microstructure. As periosteum like membrane also formed over the articulate surface of the implant. At 3 months this yielded the formation of new fibrocartilage over the implant surface, and fusing the implant to existing articulate cartilage. Additional in vitro study was performed to evaluate vascularized bone formation.

Translational Impact: Experimental highly nanoporous TPU material can effectively be 3D printed into a complex microstructure implant for the repair of osteochondral lesions, accelerating bone growth with no fibrosis, as compared to controls and other experimental designs. The implant also showed signs of encouraging vascular and cartilage formation. There is great potential for a scaled up implant which could quickly graft to bone and fuse to the healthy cartilage in a human patient’s defect, for fast and effective recovery from joint damage/disease.

Disclosure Statement: Work presented in this study may directly impact the value of intellectual property and holdings in Nanochon LLC, which would directly benefit some of the authors.

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