High Fidelity Tissue Engineering of Patient Specific Auricles for Reconstruction of Pediatric Microtia

Karina A. Hernandez DO, Alyssa J. Reiffel MD, Bryan Brown PhD, Justin L. Perez BS, Rachel Campbell MD, Jeremiah Joyce BA, Sherry Zhou, Lawrence J. Bonassar PhD, Jason A. Spector MD FACS

Abstract

Background: Autologous techniques for reconstruction of pediatric microtia are plagued by suboptimal aesthetic outcomes and morbidity at the costal cartilage donor site. In previous work, we reported success in combining digital photogrammetry with computer-assisted design/computer-assisted manufacturing (CAD/CAM) techniques to develop biocompatible tissue-engineered auricular reconstructions. We now wish to report our results after long-term in vivo implantation.

Methods: Three-dimensional structures of normal pediatric ears were digitized using the Cyberware® 3D Digitizer. These images were then converted to virtual solids using Geomagic Studio® and translated into volume models for mold design. Image-based synthetic reconstructions of the normal pediatric external ear were fabricated from collagen type I hydrogels cast from these three-dimensional computer-generated molds. Half were seeded with 2.5x10^8 bovine auricular chondrocytes. Cellular and acellular constructs were implanted subcutaneously in the dorsa of nude rats and harvested after 1 and 3 months.

Results: Gross inspection of in vivo implants after 1 month revealed that acellular implants had significantly decreased in size. In contrast, cellular constructs retained their general contour and projection from the animal’s dorsal surface. These findings were even more pronounced at 3 months. Post-harvest weight of cellular constructs was significantly greater than that of acellular constructs after 4w (4.17±0.17g v. 0.80±0.07g, p<1x10^-4) and 12w (4.48±1.63g v. 0.69±0.03, p=0.046). Safranin O-staining revealed that only cellular constructs demonstrated evidence of a self-assembled perichondrial layer and cartilage deposition by lacunar chondrocytes. Verhoeff staining of cellular constructs revealed elastin fibers interspersed among the chondrocytes. The confined compression modulus of cellular constructs increased significantly from 9.2±1.4kPa pre-implantation to 31±14kPa at 4w (p<0.05). Conversely, at 3 months there was no significant difference in the biomechanical properties of our bioengineered ear and those of native auricular cartilage.

Conclusions: Digital photogrammetry was successfully combined with CAD/CAM techniques to create high-fidelity, biocompatible, patient-specific tissue-engineered constructs for auricular reconstruction. We believe that our cellular constructs’ appropriate biomechanical properties and maintenance of volume, shape and topographical characteristics over time can be attributed in part to their type I collagen hydrogel composition, which allows for the optimal rates of chondrocyte growth, matrix resorption, and the in vivo deposition of elastic cartilage. This strategy holds immense potential for tissue-engineered auricular reconstructions, and we are currently studying construct evolution over a longer implantation interval prior to translation of this technology to the clinical realm.

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