Auricular Reconstruction with a Novel Nanocomposite Scaffold

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Statement of Purpose: The use of alloplastic materials has greatly increased the options available for auricular reconstruction resulting from congenital microtia, trauma and cancer. Current treatment involves a hand-carved autologous costal cartilage framework, but drawbacks are associated with donor site morbidity, length of operation and the need for skilled surgeons. Synthetic materials offer an alternative solution, with Medpor® (high-density porous polyethylene [HDPE]: Porex Surgical, Newnan, GA) as the current market leader[1], but complications associated with infection and extrusion occur in about 14.8% of cases. Here, we discuss the development of a new auricular nanocomposite (NC) material, designed to overcome these high extrusion rates by matching the elastic modulus of the native tissue, and encouraging cell attachment/growth. Different fabrications of this material have already been implanted in humans for lacrimal duct conduits, vascular grafts and tracheal reconstruction[2]. Our previous studies have shown that auricle-shaped POSS-PCU constructs can be created which have an elastic modulus similar ear native cartilage (Fig. 1). Here, we report on fibroblast interactions with this construct including, cellular adhesion, proliferation, and ECM production compared to Medpor®.

Material and Methods: The non-biodegradable NC polymer was synthesized by incorporating polyhedral oligomeric silsesquioxane (POSS) nanocages into polycarbonate based urea-urethane (PCU) as previously described[3]. Porosity was induced by incorporating salt leaching sodium bicarbonate ($NaHCO_3$) using a solvent evaporation technique (Fig. 1). NC sheets were manufactured into sheets (700-800µm in thickness). Surface morphology, topography and chemical properties of these NCs & Medpor® were assessed by scanning electron microscopy (SEM), atomic force microscopy (AFM) and contact angle measurements via the captive air bubble method. The 16 mm polymer discs were autoclaved and placed in 24 well plates. Each polymer sample (n=4) was seeded with human foreskin fibroblasts (HFF) at a density of 2 x 10^4 cells/cm^2 in 1 ml of DMEM supplemented with 10% FBS. Wells containing TCP with no polymer were used as positive controls. HFF cell adhesion, proliferation and metabolic activity was performed on NC scaffold with total DNA and Alamar Blue® assays, and compared with Medpor®. Cell adhesion was assessed in both static and dynamic environments (orbital plate shaker, 50rpm) over 24 h. On day 2, 6 and 10 collagen was also determined by quantitative picro-sirius red to assess ECM production.

Results: Significantly increased cell adhesion was found on POSS PCU compared to Medpor® after 24 h (Fig 2). Dynamic conditions reduced cell attachment on both scaffolds but POSS-PCU maintained higher cell adhesion than Medpor®. There was no significant difference in the rate of proliferation or metabolism/unit DNA between the materials, but a significant increase in collagen was observed on the nanocomposite POSS-PCU compared to Medpor®. Increased cell adhesion and collagen secretion may be explained due to the differences in surface topography of the NC surface, which may influence protein adsorption and cellular behavior. The nanocomposite had a nanoscale topography (Rq=82.2±11.8) compared to the microtopography of Medpor® (Rq=119.0±13.8).

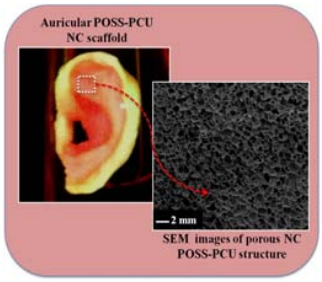

Figure 1. Porous auricular POSS-PCU NC scaffold fabricated by solvent evaporation/salt leaching method using glass mold.

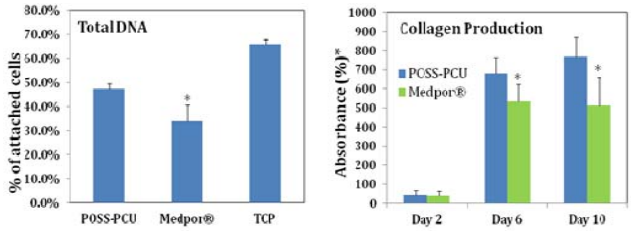

Figure 2. Fibroblast adhesion (24 h cell culture) and collagen production was significantly decreased on Medpor® compared to POSS-PCU and TCP (*P< 0.05). *Relative to day 2 TCP.

Conclusions: Increased cell adhesion and collagen production was observed on the POSS-PCU NC compared to Medpor®, this may indicate enhanced biological interactions and possibly reduced extrusion. Further studies on cellular infiltration and the angiogenic/inflammatory response to the scaffolds are underway. Such studies with matched elastic modulus of the native ear indicate that this is a promising scaffold for auricular surgical reconstruction.

References:

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