Imaging Methods for the Design and Characterization of Tissue Engineering Constructs
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Introduction
Imaging is ubiquitous throughout tissue engineering. The voxel dataset inherent to imaging provides an integrated means to describe anatomic geometry, design scaffold architecture, and characterize scaffold quality, in vivo performance and regenerate tissue growth and morphology. Integrating and registering image datasets from multiple modalities may provide a means to track tissue engineering therapies from design to post-implantation. Here we review components of what could be such an integrated system from our own research.

Materials and Methods
Hierarchical image-based methods are used to design scaffolds that can fill any complex 3D anatomic defect, while having designed surgical fixation and a porous architecture to fill mechanical and mass transport requirements. The external scaffold geometry is designed using commercial image-processing programs like Mimics™ and Analyze™. We use custom written software to design porous architecture that generates desired elastic, permeability and diffusivity properties. Combined designs are then created though boolean operations with the anatomic and porous architecture datasets1,2. Scaffolds are fabricated using rapid manufacturing technology. Once fabricated, scaffold quality, in vitro and in vivo performance are characterized using non-invasive imaging methods. These include ultrasound elasticity imaging to characterize time dependent degradation of scaffold elastic modulus3 and Scanning Acoustic Microscopy (SAM) to non-invasively characterize the surface morphology of Ex Vivo Produce Oral Mucosa Equivalent (EVPOME)4,5.

Results
Tissue and scaffold morphology are determined by specific voxel characteristics that can be grouped by characteristics like density and density gradients. Using these properties, it is possible to group voxels into masks, and generate surface data that can be repositioned in MIMICS for anatomic scaffold design and surgical planning (Fig. 1a). Such data can then be used to directly fabricate biomaterial scaffolds (Fig. 1b). In addition, porous architectures can be designed to achieve specific elastic and mass transport properties, again with image datasets (Fig 1c). Masks in the anatomic scale are used to position designed architecture. Once implanted, we have used ultrasound to characterize in vivo scaffold degradation. (Fig. 2) and to non-destructively characterize in vitro tissue engineered constructs (EVPOME), information that could previously be determined only using histology (Fig. 3).

Fig 1. (a) Image-based design of craniofacial reconstruction using fibular grafts. (b) Resulting model fabricated from FDA approved biomaterial polycaprolactone. (c) Designed porous architecture in voxel dataset.

Fig. 2. Ultrasound characterization of scaffold degradation in mouse subq model (light = stiff, dark = compliant

Fig. 3. SAM (a) and histology (b) characterization of EVPOME constructs

References

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