OPTIMIZATION OF SCAFFOLDS DESIGN FOR BONE TISSUE ENGINEERING: FROM DESIGN TO MANUFACTURE

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Introduction

One of the main concerns on Bone Tissue Engineering is to find a scaffold whose design best promotes bone growth. In this study a topology optimization algorithm is proposed to design scaffolds to meet mechanical and mass transport requirements. An optimized micro-structure is presented and a solid free form technique was used to build the scaffolds. The actual properties were measured experimentally and compared to the designed values.

Methods

The optimization problem was defined as the maximization of permeability (F_{perm}), subject to constraints on elastic energy (F_{elast}) and volume fraction (VF).

$$Min \quad \frac{1}{F_{perm}}$$

$$\text{subject to} \quad F_{elast} \leq F^{*}_{elast}, VF \leq VF^{*}$$

$$x \geq 0, x \leq 1$$

The permeability and elasticity functions are based on the homogenized properties [Dias et al 2012, Guedes et al 1990]. The aim was to get three different scaffolds with the same geometry, volume fraction and consequently the same mechanical properties, but with different permeability values. After obtaining the optimized microstructure (Figure 1 left), the size of the unit cell was scaled to 2mm, 3mm and 4mm, as permeability is scale dependent. Cylindrical scaffolds were built on PCL-4%HA, using a Selective Laser Sintering system. The scaffolds were scanned with a high-resolution micro-CT scanner in order to measure their manufactured features. The scaffolds were also mechanically tested in unconfined compression and tested in a flow chamber for permeability (Kemppainen, 2010)

Results

The actual features (struts and throats) were slightly different from the designed ones, not only in shape but also on the overall area. Also, porosity was slightly higher on the manufactured scaffolds.

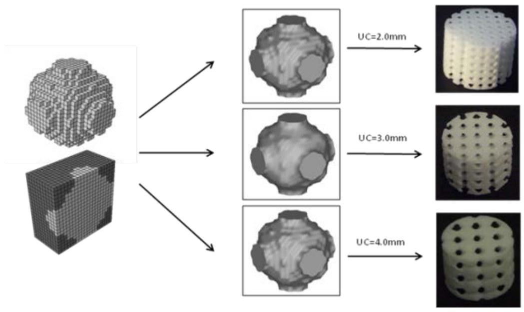

Figure 1: Optimized micro-structure (left), STL files (centre) and manufactured scaffolds (right).

The experimental and computational properties were well correlated with respect to both the mechanical and permeability values. However, differences existed between the experimental and computational data, likely due to the influence of the manufacturing process on the actual feature geometry.

Discussion

With this approach it is possible to obtain scaffolds for a wide range of situations (depending on the maximized function and the imposed constrains), which in the future, may be translated to a broad range of clinical cases. This method can also be used to study the influence of several parameters on bone growth. However, it is important to underline that there were some discrepancies between the actual and the prescribed properties of the scaffolds. Nevertheless, with the progress on the feasibility of solid free form techniques, it is believed that these discrepancies will become more and more negligible.

References

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