TOPOLOGICALLY OPTIMIZED GRADED GYROID BONE SCAFFOLDS

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Abstract

Healing of large bone defects are still a challenge for clinicians and patients mainly due to limited availability of autologous bone grafts. Therefore, use of scaffolds as a carrier structure is current common practice. Among other functionalities, the scaffold should provide sufficient mechanical properties to endure the physiological loading while providing enough porosity and surface area for nutrition and oxygen delivery, waste disposal, cell attachments and bone growth. A proper design can be sought for by optimizing the geometry for sufficient strength, porosity, and the choice of material while ensuring manufacturability.

Topology optimization (TO) is an effective design method that iteratively distributes a given amount of material within a given design space under constraints[1]. It is used to design scaffold topologies with optimal properties[2]. However, very few TO studies exist that take into account fluid-flow based analysis and requirements while delivering a manufacturable graded gyroid structure. To address this need, here we propose an initial design framework (Figure 1) that integrates fluid flow-based FEA analysis in COMSOL software to a modified SIMP permeability model and reconstructs the final design in the form of a graded gyroid topology for bone scaffolds with enhanced regeneration properties.

Method

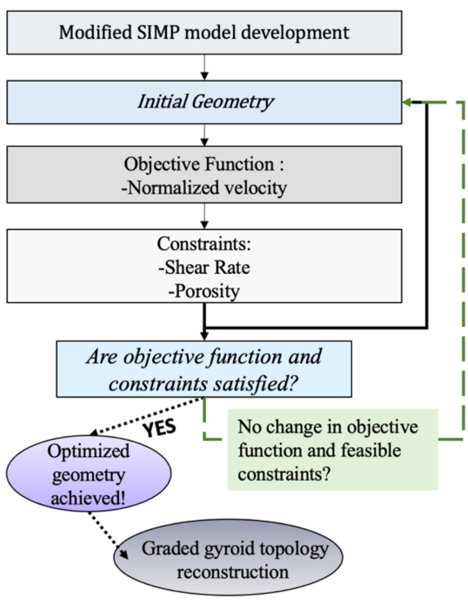

Figure 1: Topology optimization framework including physiological metrics.

Laminar flow conditions with inlet fluid velocity of 1.2 mm/s and free outflow were assumed[3]. The density distribution was obtained via modified SIMP material model after TO, which was then transformed into a graded gyroid design via earlier developed methods[4].

Results

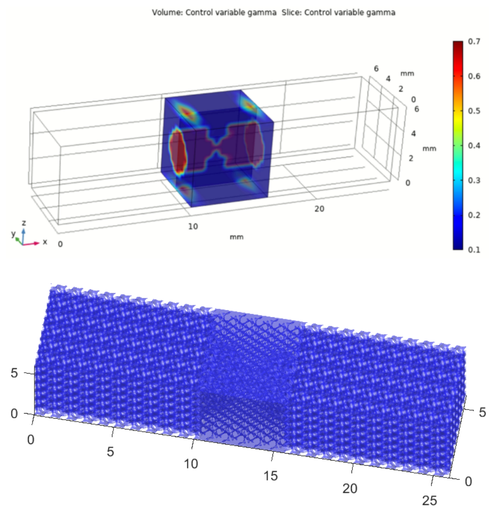

Figure 2: Optimal density distribution (top) and reconstructed graded gyroid structure (bottom).

The design results presented here aimed to design scaffolds under certain fluid velocity, shear rate and porosity requirements (*Figure 2*). Results show that the framework has potential to incorporate comprehensive metrics that are likely to result in further performance enhancements.

References

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