Integrating Domain Dependent Tools in Artificial Bone Scaffolds Design

Yanen Wang[1,2], Shengmin Wei[1], Xiutian Yan[2], and Qingfeng Zeng[2,3]

[1] Mechatronic Engineering School, Northwestern Polytechnical University, Xi'an, China, 710072
[2] Department of Design, Manufacture and Engineering Management, The University of Strathclyde, Glasgow, UK, G1 1XJ
[3] Material School, Northwestern Polytechnical University, Xi'an, China, 710072
yanen.wang@strath.ac.uk

Abstract. This paper proposes a systematic approach to integrate domain-dependent design tools in artificial bone scaffolds process. Integrated solution of CAD modelling and properly analysis of biomedicine knowledge are utilized to design complicated bone scaffolds. FEA and CFD are comprehensively analyzed for the mechanical and internal micro circulation properties. A case study of a successful artificial bone scaffolds model demonstrates that the cooperative design methodology can facilitate the design in the multi-physics domain substantially.

Keywords: Integration, domain dependent tools, artificial bone scaffolds.

1 Introduction

Advances in biomaterials science, computer aided engineering techniques, applied mechanics, physics, and biomedicine offered new opportunities for bone tissue engineering. Bone scaffolds design has been developed separately by Computer Aided Design (CAD), Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD) and Material Computation (MC). Such a separation makes it cumbersome and complex for designers to exchange the necessary information in the design process. CAD tools provide bone scaffolds conceptual models with special internal microstructure. Most researchers who want to know biocompatible, mechanical properties of those models must go through the FEA and CFD tools[1].

In 1892, Wolff first demonstrated that relationship between bone cells growth ratio and the mechanical strength. Since then, many biological and physical scientists illustrate that interstitial fluid flow stimulates bone cells diffusion from piezoelectricity, and investigated the steaming potential, mechanical strain and fluid shear stress[2-4]. Researchers also indicated that complex and interconnected microstructure in natural bone can maintain the blood circulation, metabolism, nutrition transfer and bone's growth and reconstruction[5]. Based on these studies, the diameter of micro holes in current artificial bone scaffolds is set to be between 200 μm to 800 μm and micro holes of these sizes facilitate the micro circulation of bone nutrients in artificial bone scaffolds. These mechanical properties have guided the

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design of artificial bone structures, enable the construction of biomimetic internal structure of any artificial bones and facilitate the flow of the nutrient fluid and the growth of natural bones.

Due to continuing development of new bioactive material, new biodegradable three-dimensional porous scaffolds have now been fabricated to cure bone disease and they have gained great success in recent years. Present study revealed the potential of biomimetic constructs play critical role in osteoinduction. Researchers have also found that Bone Morphogenetic Protein (BMP) and Growth Factors (GF) can induce osteoblast-like cells to adhere to scaffolds.

Dawn of a new era of bioactive bone scaffolds is approaching. This is due to the fact that biodegrade bioactive artificial bone scaffolds can now be possibly developed by using advanced techniques such as CAD, FEA, CFD and MC. In the past, MC design, CAD modelling, FEA and CFD of artificial bone scaffolds are generally regarded as separate domains of interest and speciality in CAD, Computer Aided Engineering (CAE) and biomaterial communities. Such a separation of CAD, FEA, CFD and MC of bone scaffolds design makes it cumbersome and complex for designers to exchange the necessary information in the entire design process. Therefore, applications in all domains are impeded and consequently the numbers of biocompatible artificial bone scaffolds are limited.

This paper describes a systematic approach to integrate these domain-dependent design tools in supporting the design and evolution of artificial bone scaffolds in research at the University of Strathclyde and the Northwestern Polytechnical University (NPU). The complex and bio-oriented geometries of bone scaffolds and internal microstructures are modelled in CAD tools Pro/E and UG and relevant data from MC and CAD tools is transferred to FEA software system ANSYS and CFD system Fluent for design evaluation and validation of mechanical and fluid dynamic prosperities. A successful artificial bone scaffold model case study demonstrated that this collaborative design method involved multidisciplinary can facilitate the design of multi-physics domain in a systematic plan.

2 Motivation and Integration Model

Developing a good biocompatible artificial bone scaffolds should abide by the strict requirements and rules from clinicians and material scientists. The conflicting requirements for strong, yet porous bio-material structures always pose challenges for researchers. The important characteristics of these structure lies in the material selection, determination of pore sizes and suitable manufacturing methods and techniques for a designed structure. Research work is in fluid dynamics as well. These work[6, 7] showed partially satisfactory results in their work, but it is clear that a holistic design approach is needed to design scaffolds from system points of view. The deficiency of current design approach and opportunity to integrate the design tools available from multi-disciplines motivated this research to develop a holistic design and research approach. The research aims to investigate and generate a framework to support the collaboration of multidisciplinary design team members in their design and development of a suitable artificial bone scaffold structures.