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Data-driven based modulus prediction of cancellous bone and 3D printing for defect repair in clinic treatment

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Abstract:

Bone defect repair is always a challenge issue of clinic treatment and academic research in biomechanics. Based on clinical CT images, the data-driven method is used to establish a modulus prediction model of cancellous bone, which includes the microstructure characteristics and distribution of trabecular bone. The degradable metamaterial by 3D printing is implanted for defect repair in clinic treatment. This work is scheduled by a few parts: (1) the sections of cancellous bone sample of distal tibia with different sex, age and physiological state are prepared. The ratio of trabecular volume and total volume (BV/TV) in each section and corresponding trabecular modulus is determined by nano-micro-indentation tests. The distal tibia cancellous bone of Small Tail Han Sheep is taken as the test sample here. The representative volume element (RVE) of FEM model including clear trabecular structure is established based on the micro-CT images. (2) the prediction modulus based on three-dimensional convolutional neural network (CNN) is established to training and verifying the data by using the clinical CT images and the equivalent mechanical parameters of RVE. The model reveals the mapping relationship between the equivalent compression modulus and the clinical CT images. (3) the 3D inhomogeneous cancellous bone model is reconstructed by the prediction modulus, and its typical mechanical response is basically consistent with the high precision cancellous bone model with microstructures. This means that the equivalent compression modulus of different regions of distal tibia can be obtained directly only by clinical CT scanning. (4) the degradable metamaterial by 3D printing is implanted for defect repair in clinic treatment. After implantation of substitution material into tibia of the patient, it takes time for the osteocyte to grow inside tibia, which evidences that it grows if it has stress.

Keywords: data-driven, cancellous bone, defect repair, modulus prediction, clinical treatment, 3D printing

Short resume:

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Professor and former Dean, School of Aerospace Engineering, Tsinghua University, Beijing, China. Chief scientist of national fundamental scientific research of China. Ph.D, University College Dublin, Ireland, 1995; Honorary Doctorate Degree (EngD) of Swansea University, UK, 2017. EC member of IACM, EC member of APACM; President of Chinese Association for Computational Mechanics (CACM); President of Beijing Society of Mechanics; Committee Member of Beijing Association for Science and Technology, China. Published more than 300 papers, 10 books in Chinese and 2 books in English by Elsevier, named: (1) Extended Finite Element Method; (2) Dislocation Mechanism-Based Crystal Plasticity, Theory and Computation at the Micron and Submicron Scale. Given Plenary Lecture at Complas2015 and Complas2019 in Barcelona, Spain; Semi-Plenary Lecture at WCCM2016 in Seoul, Korea and WCCM2020 in Paris, France; Plenary Lecture at CM4P in Porto, Portugal, 2019; Semi-Plenary Lecture at Compsafe2020 in Kobe, Japan.