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Investigation of the Effects of Bone Material Modelling Strategies on the Biomechanics of the Thoracolumbar Spine Using Finite Element Method

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ABSTRACT

Decompression surgery is one of the useful methods to relieve the pressure on the spinal cord and nerves [1]. In computational simulation, various bone material modelling strategies have been used to model cortical bone and cancellous bone of spinal vertebrae [2,3]. However, the effects of the bone material modelling strategies on the biomechanics of the thoracolumbar spine are unclear. Thus, this study aimed to investigate the biomechanics of the thoracolumbar spine with various bone modelling strategies using a patient-specific finite element modelling technique.

Three-dimensional finite element models of the human thoracolumbar spine were developed from the computed tomographic (CT) scan images of the Visible Human Project of the US National Library of Medicine using Amira-Avizo (Thermo Fisher Scientific, Waltham, MA, USA). Three types of bone material modelling strategies were considered to model the cortical and cancellous bones of the thoracolumbar spine. In the first modelling strategy, which is named as the UVSHELL, the cortical bone was modelled using shell elements with unvaried bone material properties. In the second modelling strategy, which is named as the UVSOLID, the cortical bone was modelled using solid elements with unvaried bone material properties. The cancellous bone for both the UVSHELL and UVSOLID was modelled using solid elements with unvaried bone material properties. In the third modelling strategy, which is named as the VSOLID, both the cortical bone and cancellous bone were modelled using solid elements with varied bone material properties. For the loading and boundary conditions, the end surfaces of the sacrum were fully constrained. Additionally, a follower load of 400 N and six types of spinal movements were applied to the thoracolumbar spines. All the finite element models were developed using ANSYS Workbench (ANSYS, Inc., Canonsburg, PA, USA).

The results revealed that the range of motion (ROM) predicted by the present study could be verified by the past studies [4,5]. Comparing three bone material modelling strategies, the UVSOLID could provide closer ROM results to the VSOLID than the UVSHELL. Both the intersegmental rotation and disc stress of the UVSOLID showed closer results to the VSOLID. The VSOLID, which was developed by a bone material mapping technique, was suggested for developing the finite element model of the thoracolumbar spine.

KEYWORDS

Patient-specific modelling; material mapping; range of motion; disc stress; intersegmental rotation

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