Finite Element Study: Locus of Axis of Rotation of $T_{11}$-$T_{12}$ and $T_{12}$-$L_{1}$ Segments under Flexion/Extension and Axial Rotation Configurations

EC Teo1*, TX Qiu1, S Haiblikova2, L Vignard3

1School of Mechanical & Aerospace Engineering, Nanyang Technological University, Singapore
2Department Biomechanics and Medical Instruments, Czech Technical University in Prague, Czech Republic
3Department of Biomedical Engineering, Polytech Marseille (Aix-Marseille University), France

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*Corresponding author: Ee Chon Teo, School of Mechanical & Aerospace Engineering, Nanyang Technological University, College of Engineering, 50 Nanyang Avenue, Singapore 639798, E-mail: mecteo@ntu.edu.sg

Abstract

In human, the thoracolumbar junction (TLJ) is a transitional region where the normal kyphotic thoracic region shifts to the normal lordotic lumbar region; the coronally oriented facet joints of the thoracic region transform to the sagitally oriented facet joints of the lumbar; and the relatively immobile thoracic region changes to the relatively mobile lumbar region. The different anatomical characteristics at the functional spinal units (FSUs) of $T_{11}$-$T_{12}$ and $T_{12}$-$L_{1}$ provide an opportunity to study the associations between pathoanatomical changes in these two levels. Hence, it is of interest to investigate the biomechanical responses of the spinal motion segments $T_{11}$-$T_{12}$ and $T_{12}$-$L_{1}$, which possess the transitional vertebra $T_{12}$, to determine whether the biomechanical kinematic properties reflect these anatomical changes between these FSUs. The movement of a FSU is dependent upon several parameters, namely its complex geometry, facet articulations and material characteristics of the ligamentous tissues, intervertebral discs, and upon the applied load vectors.

Accordingly, this study aimed to use a validated FE models of thoracolumbar junctional $T_{11}$-$T_{12}$ and $T_{12}$-$L_{1}$ functional spinal units (FSUs) validated under physiological loading modes: flexion, extension, lateral bending and axial rotation, and to compare the kinematics in terms of the locations and loci of instantaneous axes of rotation (IARs).

Keywords: Thoracolumbar Junction; Finite Element; Axis of Rotation; Functional Spinal Unit

Abbreviations: TLJ: Thoraco Lumbar Junction; FSU: Functional Spinal Units; IAR: Instantaneous Axes of Rotation

Results and Discussion

The locations and loci of $T_{12}$-$L_{1}$ differ greatly from those of $T_{11}$-$T_{12}$. In sagittal plane, the locations and loci of the IARs were located below the intervertebral disc for $T_{11}$-$T_{12}$, situated in the intervertebral disc for $T_{12}$-$L_{1}$. In transverse plane, they fell in the medio-anterior region of the movable vertebra $T_{11}$ for the $T_{11}$-$T_{12}$, and located near the cortical shell of the upper vertebra $T_{12}$ for $T_{12}$-$L_{1}$, (Figures 1 & 2).

It is known that the anatomical geometrical structure of a FSU defines its motion and related biomechanical responses. Hence, some differences in anatomical features of these two FSUs may account for the variation in loci [2]. At level $T_{11}$-$T_{12}$, the facet articulation is essentially oriented in the coronal plane; while in the $T_{12}$-$L_{1}$ segment, the facet joint surfaces are sagitally aligned. For the intervertebral disc, at $T_{11}$-$T_{12}$, the anterior height is slightly larger than the posterior height; whereas, at $T_{12}$-$L_{1}$, the anterior height is greater than the posterior height, which results a lordotic angle. These different orientations of the facets and the geometry of intervertebral discs demonstrate the difference in loci at the two levels, (Figures 3 & 4).

Significance

These findings offer an insight to better understanding the kinematics of the human thoracolumbar spine; provide clinically relevant information for the evaluation of spinal stability and implant devices functionality, and the biomechanical load effect on spinal deformity.
Figures 1 & 2: below show T12-L1 FE model and a validation study on the biomechanical responses of T11-T12 and T12-L1 under flexion/extensions, respectively.

Figure 3: T11-T12 Locus of axis of rotation under F/E and A Rotation.
Figure 4: T12-L1 Locus of axis of rotation under F/E and A Rotation.

Figures 3 & 4: shows the locus of axis of rotation of T11-T12 and T12-L1 models under two loading configurations of flexion/extension and axial rotation, respectively.

References