Probabilistic Finite Element Analysis of the Lumbar Spine After Total Disc Replacement

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Background

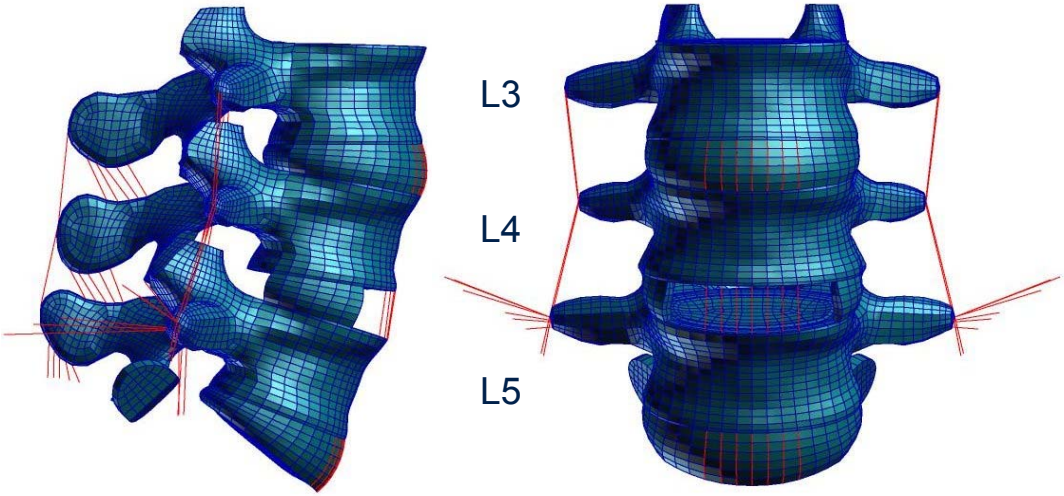
The mechanical behaviour of the lumbar spine after total disc replacement is affected by several factors including implant position in the sagittal and frontal plane, radius of the implant inlay, gap size in the facet joints and presence or absence of anterior scar tissue.

Purpose of the Study

To determine in a probabilistic finite element study the effects of 5 factors on intervertebral rotations, intradiscal pressures and forces in the facet joints.

Finite Element Model

A validated nonlinear osseoligamentous finite element model of the lumbar spine ranging from L3 to the disc L5/S1 was used. The L3 vertebra was loaded in the sagittal plane with pure moments of 7.5 Nm to simulate flexion and extension. An artificial disc with a fixed centre of rotation was inserted at level L4/L5.

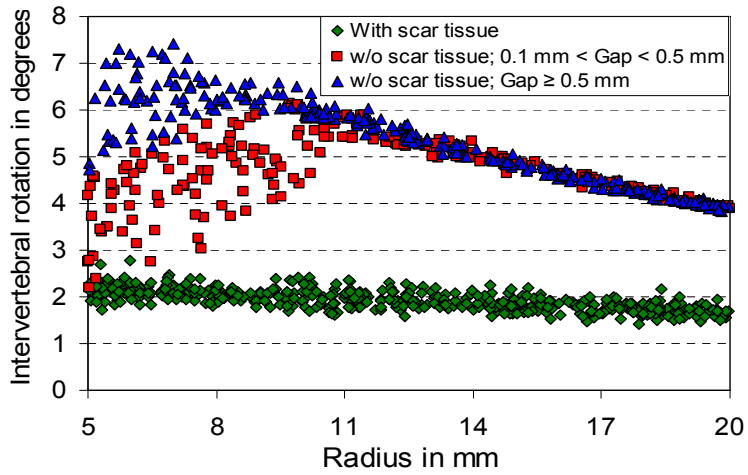


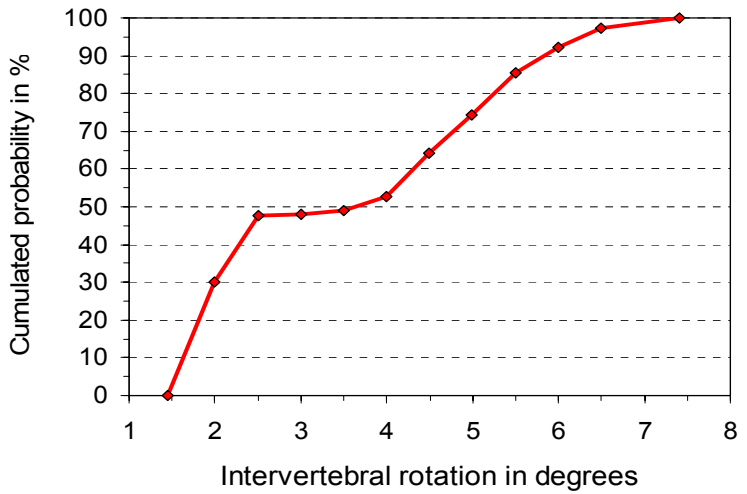
Parameters Varied

The implant position was varied in the sagittal and frontal plane by ± 3 mm from the central position and the gap size in the facet joints between 0.1 and 1.5 mm with a median value of 0.5 mm. For these factors a Gaussian distribution was assumed. The inlay radius varied between 5 and 20 mm and anterior scar tissue was either present or absent. These two parameters had a uniform distribution.

The probabilistic study was performed using the program NESSUS and the Monte Carlo method (1000 calculations).

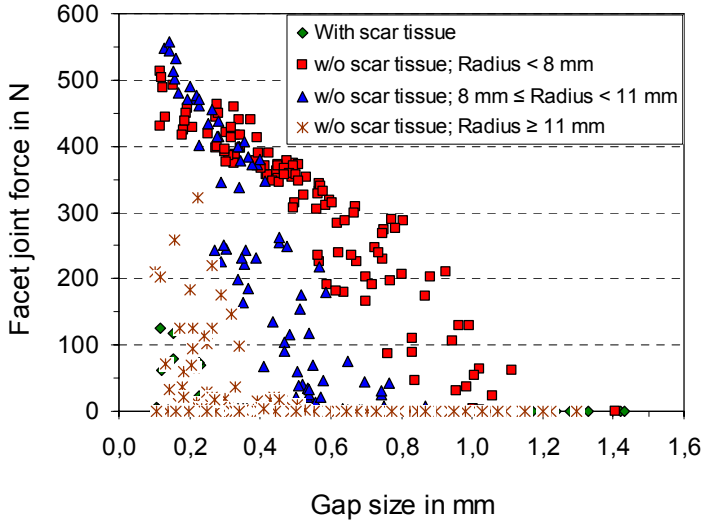
Intervertebral Rotations During Extension

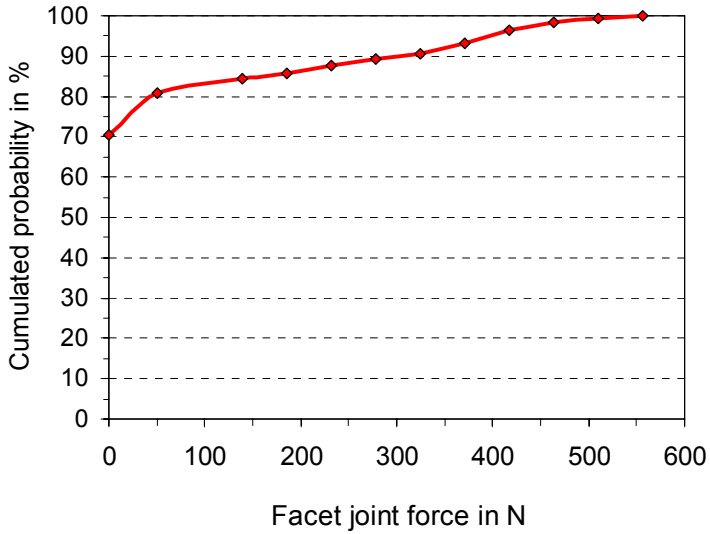




Intervertebral rotation at implant level varies between 1.4° and 7.4°. Scar tissue has the strongest effect. A median value of 1.9° is predicted when scar tissue is present and a value of 5.0° when it is absent.

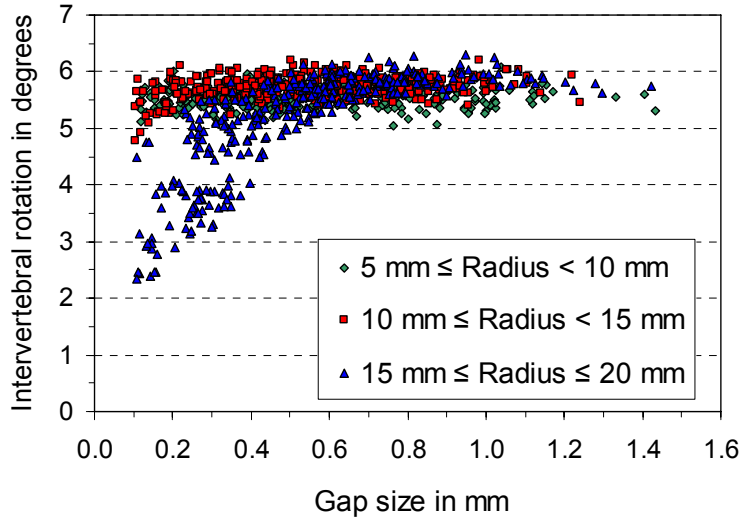
Contact Facet Joint Forces During Extension

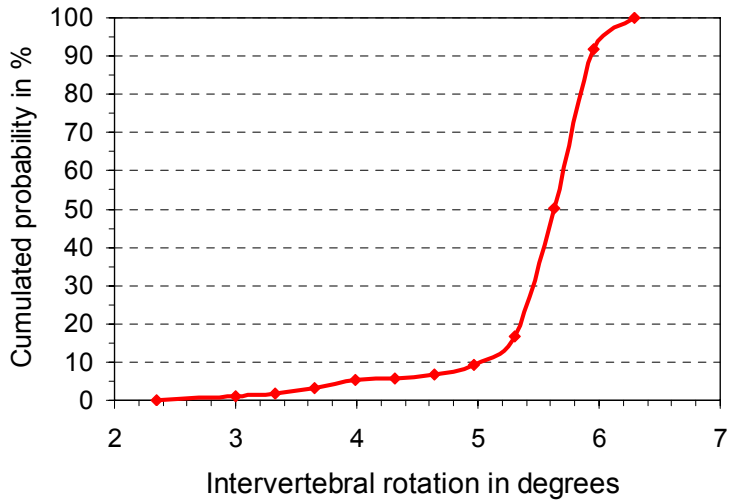




The forces in the facet joints vary between 0 and 559 N. In 70% of the cases the contact force is zero. High forces are predicted for a small gap size in the facet joints and a small radius of the inlay.

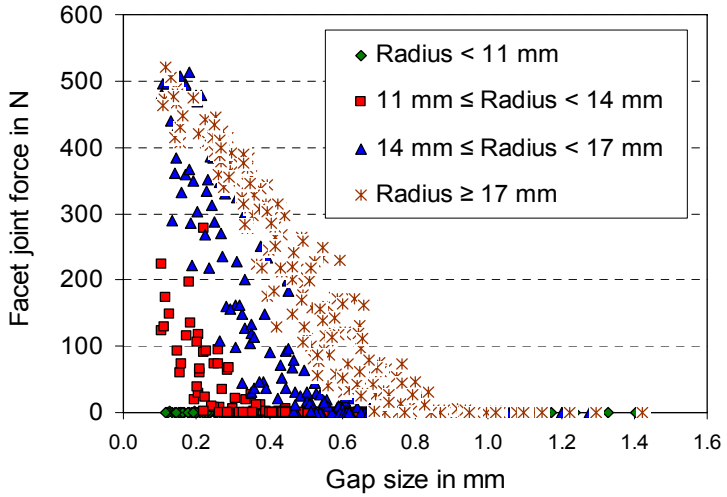
Intervertebral Rotations During Flexion

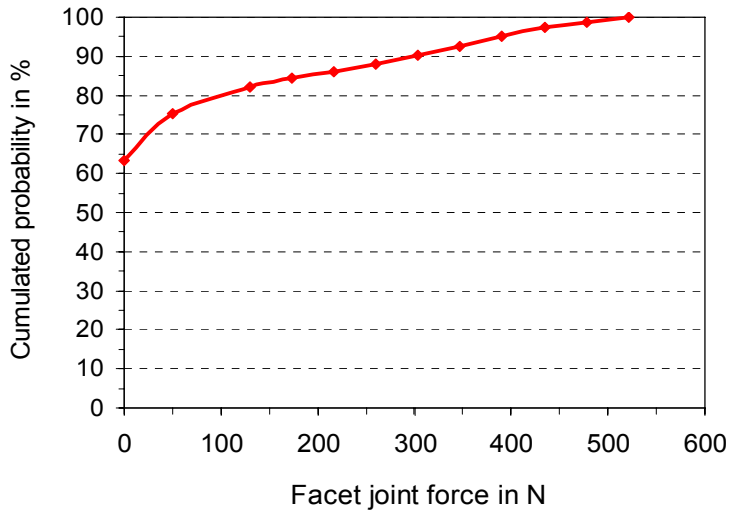




Intervertebral rotation varies between 2.4° and 6.3°. The gap size in the facet joints, the radius of the inlay and the implant position in the sagittal plane have the strongest effects. Small intervertebral rotation is predicted for the combination of a large inlay radius and a small gap size.

Contact Facet Joint Forces During Flexion





The forces in the facet joints vary between 0 and 533 N. In 63% of the cases the contact force is zero. High forces are predicted for a small gap size in the facet joints and a large radius of the inlay.

Intradiscal Pressure

The studied parameters have only a minor effect on intradiscal pressure and intervertebral rotation at the adjacent levels.

Discussion

Intervertebral rotation at implant level and facet joint forces can vary widely depending on inlay radius, gap size of facet joint and presence of scar tissue.

They may become unfavourable for some adverse combinations of the influencing parameters. These may be the cases which lead to unsatisfactory clinical results.

Acknowledgements

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