

Realistic Loading Conditions for Simulating Axial Rotation

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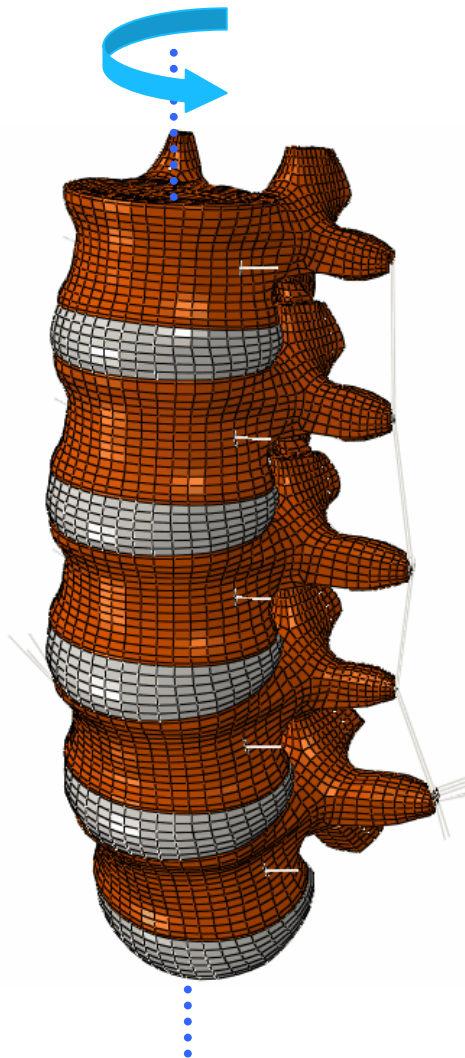
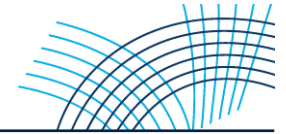


Fig. 1: Axial rotation of the lumbar spine

New spinal implants or surgical treatments should be pre-clinically tested to guarantee their function *in vivo*.

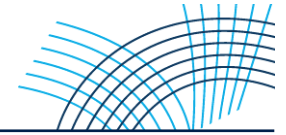
This requires realistic loading conditions, which mimic the *in vivo* situation.

However:

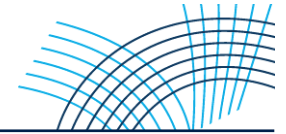
Loading conditions for the simulation of spinal axial rotation vary strongly in literature.

Thus:

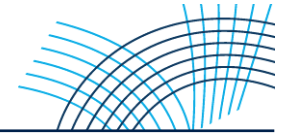
Current investigations are hardly comparable and the most realistic loading mode is still unknown.



The aim of the study was to determine the most realistic loading mode for axial rotation, in which the results coincide best with *in vivo* measured data.



- An extensive literature survey was performed to reveal the range of to date load assumptions for the simulation of axial rotation.
- A validated finite element model of the lumbar spine was employed (Rohlmann et al., 2005).
- Reference values for a realistic simulation of axial rotation were taken from *in vivo* measurements of segmental intervertebral rotations (e.g.: Steffen et al., 1997, Li et al., 2009) and intradiscal pressure (Wilke et al., 1999).
- The range of possible results (e.g.: intradiscal pressure, intersegmental rotation) due to these different load assumptions and potential experimental errors was quantified.



- In a sensitivity analysis, numerous parameters were investigated (Fig. 2) to identify the ones, which mostly affect the segmental intervertebral rotations, the intradiscal pressure and the facet joint forces during axial rotation.
- In a subsequent optimisation study, these most influencing parameters were optimised to find the most realistic load assumptions for axial rotation.

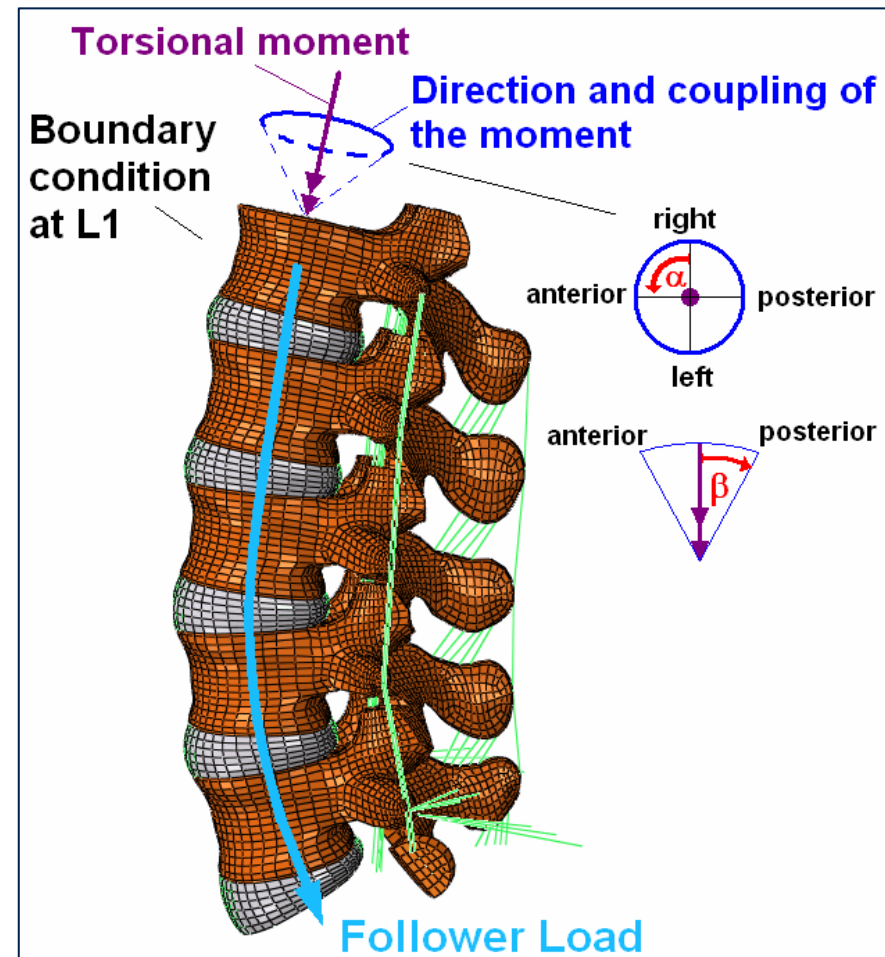
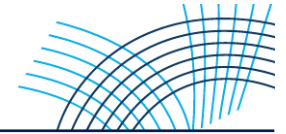


Fig. 2: Parameters investigated in the sensitivity analysis.

Results



- Different load assumptions in literature and potential experimental errors lead to widely varying results for the simulation of axial rotation (e.g. Fig. 3).
- The values of the applied follower load and the torsional moment dominate the results of the rotary motion, intradiscal pressure and facet joint forces during axial rotation.
- The boundary conditions at the first vertebra have a strong influence especially on the coupled motion of the whole lumbar spine.

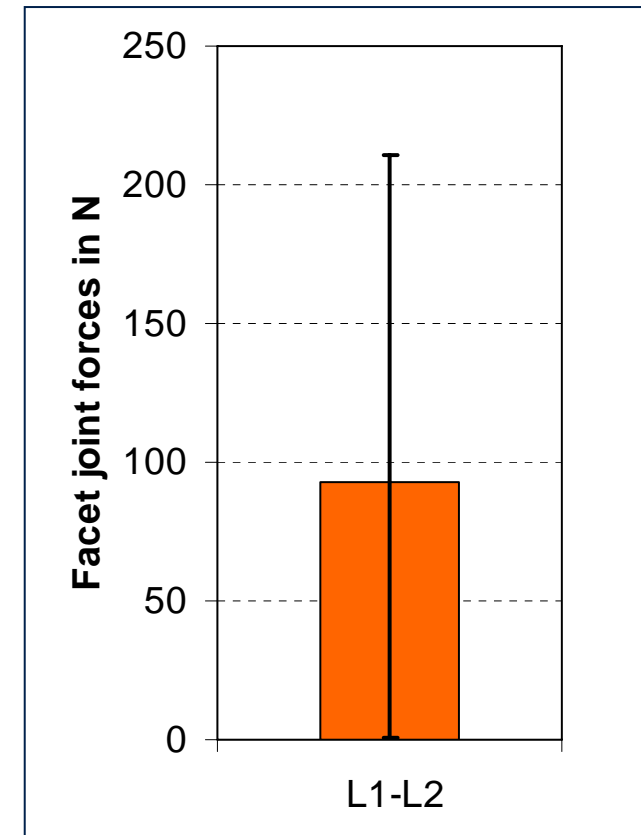
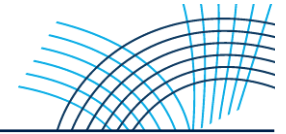


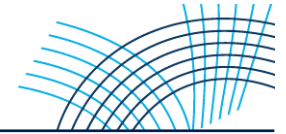
Fig. 3: Range of facet joint forces at level L1-L2 due to different load assumptions in literature and potential experimental errors.



The best agreement with measured *in vivo* data was found for the following loading mode:

Compressive follower load of 730 N
and
pure torsional moment of 6.3 Nm.
Boundary condition: L1 unconstrained

Results



Comparison of the averaged segmental intervertebral rotation measured *in vivo* with the calculated optimised values:

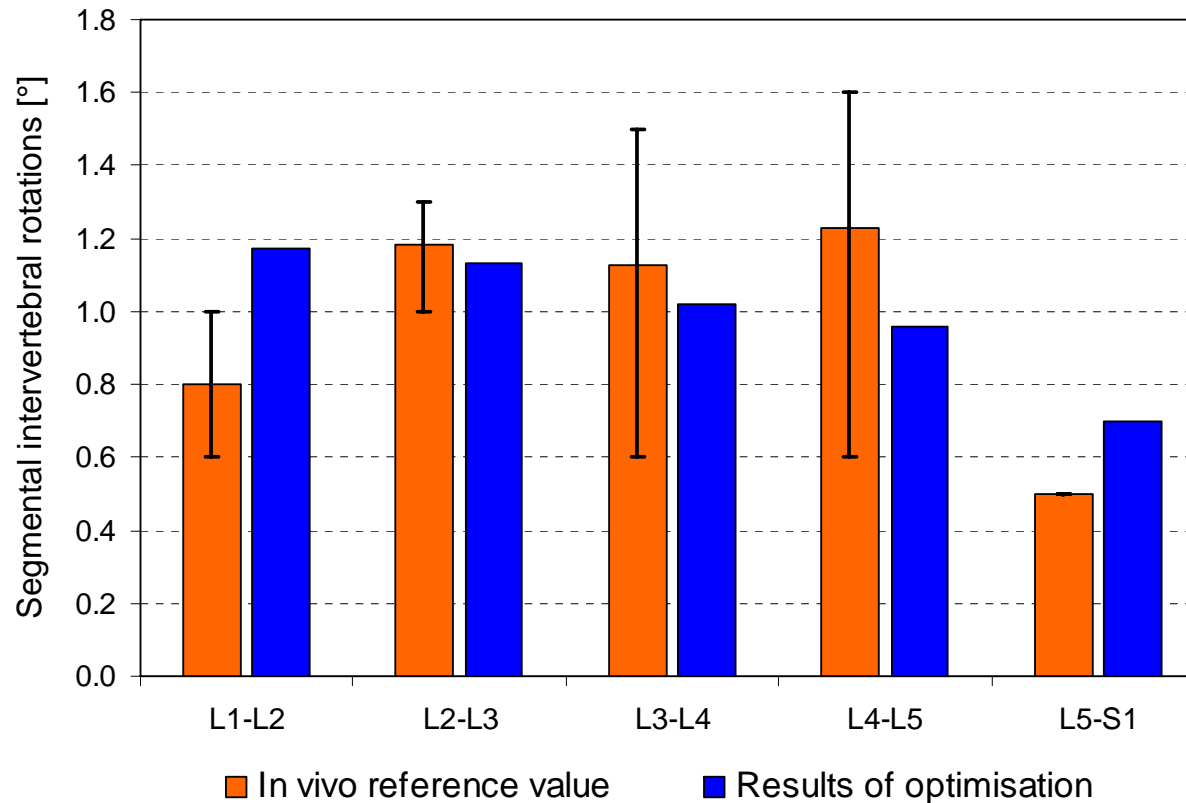
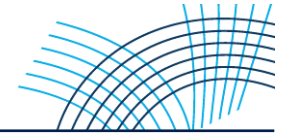


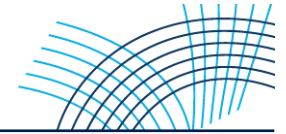
Fig. 4: Comparison of measured and calculated segmental intervertebral rotations.

- Except for L1-L2, the calculated optimised values are within the *in vivo* ranges of the segmental intervertebral rotations.
- The optimisation leads to a good agreement of the calculated intradiscal pressure (L4-L5) with the *in vivo* measured value of 0.65 MPa.



Although advanced methods (optimisation and sensitivity analysis) were used and several hundred single finite element calculations were performed, this study has some limitations:

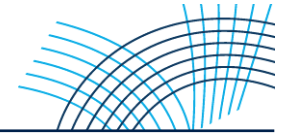
- Reference values for axial rotation were taken from *in vivo* measurements, which are very complex as well as seldom performed and only few volunteers took place in those investigations.
- The constant direction of the applied torsional moment at L1 leads in contrast to the *in vivo* situation to a decrease of the segmental intervertebral rotations from cranial to caudal. Thus, the applicability of pure moments is limited.
- Therefore, the findings of this study represent an average rotary motion of the lumbar spine and small deviations from the suggested loading conditions can lead also to results within the *in vivo* range.



However, the optimised findings obtained here deliver for the first time loading conditions that mimic the *in vivo* situation for which measured data exist.

An application of this load would additionally lead to a better comparability of investigations performed by different groups.

References

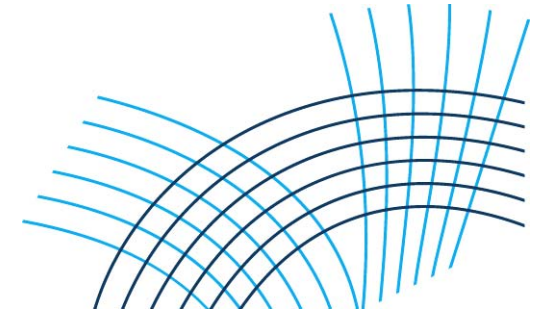


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Conflict of interest

No conflict of interest exists for each author participating in this study.

Thank you for your interest!



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