ONLINE ONLY

Supplemental material

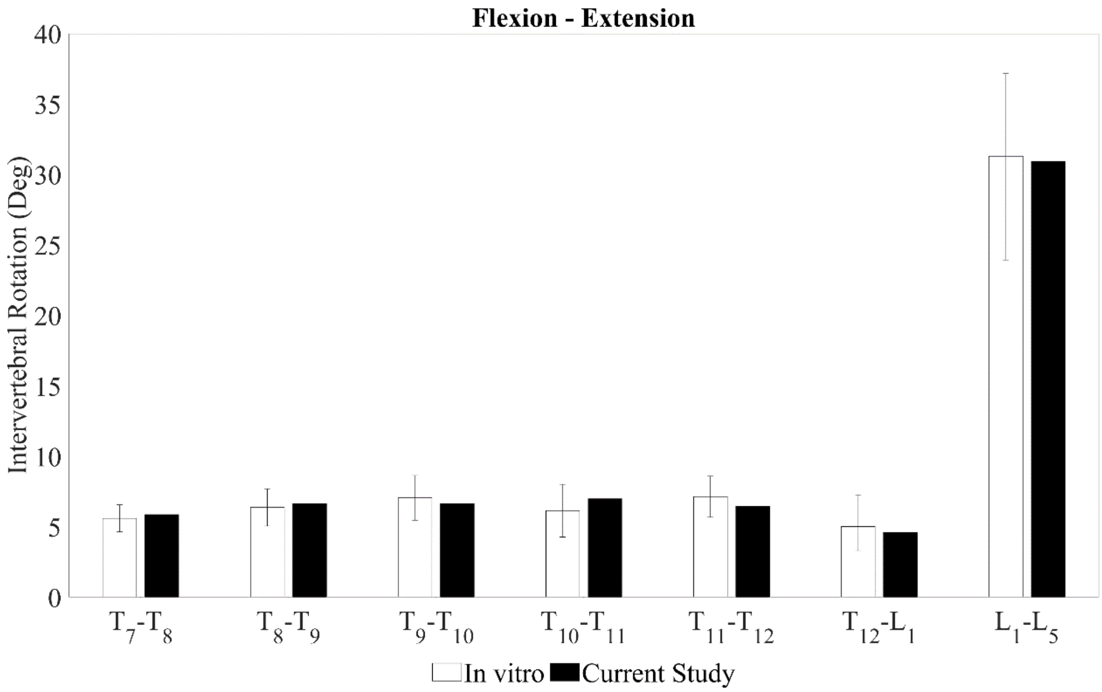
Can semirigid fixation of the rostral instrumented segments prevent proximal junctional kyphosis in the case of long thoracolumbar fusions? A finite element study

Turbucz et al.

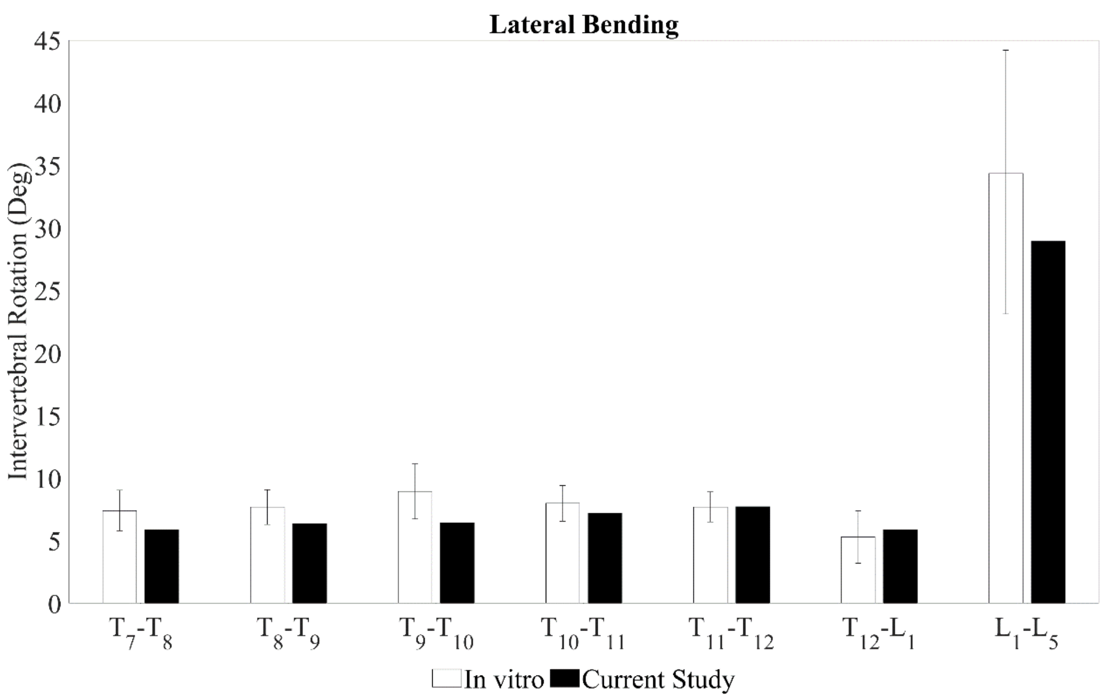
https://thejns.org/doi/abs/10.3171/2023.1.SPINE22931

DISCLAIMER The *Journal of Neurosurgery* acknowledges that the following section is published verbatim as submitted by the authors and did not go through either the *Journal's* peer-review or editing process.

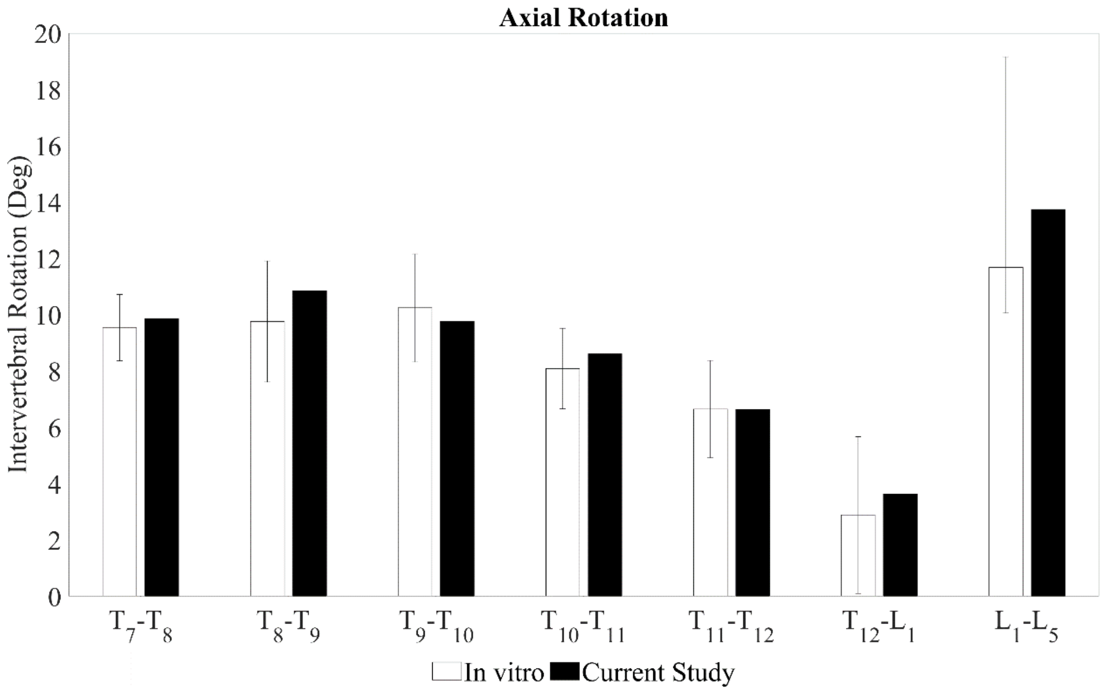
Supplementary Materials



Supplementary Fig. 1: Obtained intervertebral rotation angle values in flexion-extension compared to the available in vitro measurements[1–3].



Supplementary Fig. 2: Obtained intervertebral rotation angle values in lateral bending compared to the available in vitro measurements[1–3].



Supplementary Fig. 3: Obtained intervertebral rotation angle values in axial rotation compared to the available in vitro measurements[1–3].

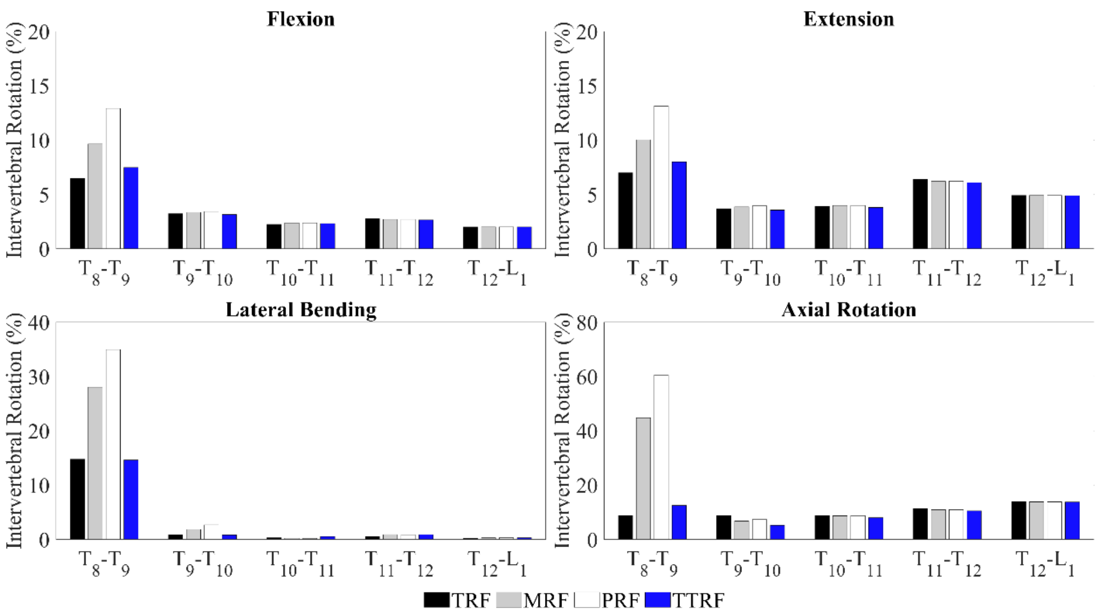
Supplementary Table 1: Weighting factors obtained from the calibration process.

Spinal level	λ_{GS}	λ_{fiber}
T7 - T8	0.32	0.47
T8 - T9	0.28	0.4
T9 - T10	0.3	0.42
T10 - T11	0.5	0.45
T11 - T12	0.5	0.45
T12 – L1	0.5	0.5

λ_{GS} = Calibration factor for the annulus ground substance, λ_{fiber} = Calibration factor for the annulus fibers

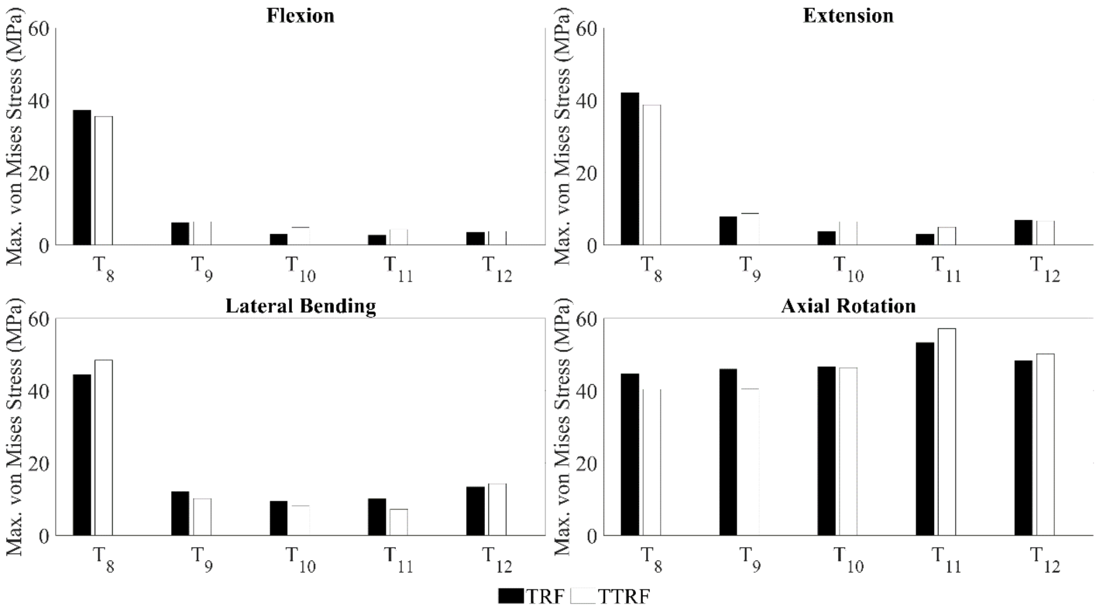
Supplementary Study 1 – The biomechanical effect of the connector device

The semirigid fixation techniques (SFT) analyzed in this study use a connector device to join the conventional titanium rod to a less rigid peek rod or multiple thin titanium rods. A theoretical titanium rod fixation (TTRF) technique connecting titanium rod with titanium rod was modeled and compared with the TRF model to evaluate the biomechanical effect of the connector device. Identical boundary and loading conditions were applied: the inferior surface of L5 was fixed, while the load was applied at the superior endplate of the T7 vertebra. Two sets of loading were used to test the fixation techniques. First, a pure bending moment of 5 Nm was applied to measure the intervertebral rotation (IVR) values. Second, the displacement of the TRF model was applied to the TTRF to allow the comparison of the stress values under identical motion.



Supplementary Fig. 4: Obtained IVR values of the TRF, MRF, PRF and TTRF models in A) flexion, B) extension, C) lateral bending, and D) axial rotation.

In the load-controlled step, the IVR values normalized by the intact spine results were measured for TTRF in addition to the SFTs. At the T8-T9 level, the TTRF model gave 0.99%, 0.99%, and 3.68% larger IVR values than TRF in flexion, extension, and axial rotation, respectively (Supplementary Fig. 4 A, B, D). Meanwhile, in lateral bending, the TTRF's IVR was reduced by 0.2% (Supplementary Fig. 4C).



Supplementary Fig. 5: Obtained maximum pedicle screw values of the TRF and TTRF models in A) flexion, B) extension, C) lateral bending, and D) axial rotation.

In addition to the IVR predictions, the maximum stress values in the pedicle screws were measured and compared in the displacement-controlled load step (Supplementary Fig. 5 A-D). At the uppermost instrumented vertebra (UIV), the TTRF model reduced the maximum stress by 1.67 MPa, 3.37 MPa, and 4.18 MPa in flexion, extension, and axial rotation, respectively (Supplementary Fig. 5 A, B, D). In lateral bending, the maximum stress value was larger in the case of TTRF by 4.05 MPa compared to the TRF model (Supplementary Fig. 5 C).

The results of this current supplementary study allow us to separate the biomechanical effects of the presence of the connector device from the mechanical properties of SFTs. The results indicate that connecting two titanium rods via a connector device increases mobility and reduces screw stress for flexion, extension, and axial rotation. However, the opposite is observed for lateral bending, i.e., mobility decreases and pedicle stress increases. This phenomenon is not observed in the case of connector devices combined with SFTs, such as the MRF and PRF, as they gave higher mobility and lower stresses in all load directions than the TRF technique. Furthermore, compared to the TTRF, the SFTs increase mobility substantially more, which is well visualized in Supplementary Fig. 4A-D.

In conclusion, although the connector device somewhat increases the upper instrumented segment's mobility, but it is much less compared to the mobility of the different SFTs. This highlights that the connector device alone does not significantly influence the mobility and the SFTs are responsible for most mobility increase and load reduction.

Supplementary References

1. Rohlmann A, Neller S, Claes L, Bergmann G, Wilke H joachim. Influence of a follower load on intradiscal pressure and intersegmental rotation of the lumbar spine. *Spine (Phila Pa 1976)*. 2001;26(24):557-561.
2. Couvertier M, Germaneau A, Saget M, et al. Biomechanical analysis of the thoracolumbar spine under physiological loadings: Experimental motion data corridors for validation of finite element models. *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine*. 2017;231(10):975-981. doi:10.1177/0954411917719740
3. Wilke HJ, Herkommer A, Werner K, Liebsch C. In vitro analysis of the segmental flexibility of the thoracic spine. *PLoS One*. 2017;12(5). doi:10.1371/JOURNAL.PONE.0177823