Influence of One-Level and Two-Level Cervical Total Disc Replacement on Motion of the Target and Adjacent Segments

Morten Vogt[1], Christoph Mehren[2], Hans-Joachim Wilke[1]
[1]Institute of Orthopaedic Research and Biomechanics, University of Ulm, Germany [2]Spine Center, Schoen Clinic Munich-Harlaching, Munich, Germany
morten.vogt@uni-ulm.de

Disclosures: Morten Vogt (N), Christoph Mehren (3B-Centinel Spine LLC), Hans-Joachim Wilke (5-Centinel Spine LLC).

INTRODUCTION: In contrast to anterior cervical discectomy and fusion cervical total disc replacement (TDR) aims at motion preservation at the treated vertebral level, thereby sparing the adjacent segments. The inclined facet joints of the cervical spine lead to lateral bending (LB) and axial rotation (AR) always occurring in conjunction. Despite this motion coupling being a well-known feature of the cervical spine, biomechanical studies mostly focus on primary motions and only rarely report coupled motions. Therefore, in this in-vitro study the aim was to combine both and to investigate the primary and coupled range of motion (ROM) after one-level and two-level cervical TDR in the treated and also in the adjacent segments.

METHODS: Seven fresh frozen human cervical spine specimens (C4-T1, mean age 40 ± 17 years, four female) were included in this study. Specimens were tested in the intact condition first, followed by one-level TDR at C5-6 which was subsequently extended one level further caudal (C5-7). Each specimen was quasistatically loaded with pure moments up to 1.5 Nm in flexion/extension (FE), lateral bending (LB) and axial rotation (AR) in a universal spine tester for 3.5 cycles at 1 °/s. During the tests three dimensional motion tracking was performed for each vertebral body individually. From that the primary and coupled ROM of each spinal level during the third full cycle of motion was evaluated. Non-parametric statistical analysis was performed using a Friedman-test and post-hoc correction with Dunn-Bonferroni-tests ($p < 0.05$). Ethics approval was obtained in advance.

RESULTS: In FE, one-level TDR (C5-6) moderately increased primary FE in all four segments, but only significantly at the cranial adjacent level C4-5 (Fig. 1 left). Additional TDR at C6-7 further increased the ROM at the target segment without much influence on the other levels. Coupled motions were minimal in all test conditions at all levels.
In LB, coupled AR was observed in all test conditions at all levels (Fig. 1 middle). One-level TDR decreased primary LB at the target segment C5-6 significantly, without much influence on the other levels. Extending TDR to C6-7 decreased ROM in the target segment again (without gaining statistical significance) but notably decreased coupled AR at the cranial adjacent level C4-5.
In AR, coupled LB was observed in all test conditions at the levels C4-5, C5-6 and C6-7, while the transition level to the thoracic spine C7-T1 showed only little coupled LB (Fig. 1 right). After one-level TDR at C5-6 both primary AR and coupled LB at the caudal adjacent level C6-7 were significantly increased. Extending TDR to C6-7 significantly increased coupled LB at the cranial adjacent level C5-6. Compared to the intact condition multiple statistically significant differences were found at the levels C4-5 and C7-T1 in primary AR as well as coupled motions.

DISCUSSION: The general motion preservation capabilities of cervical TDR have already been described in the literature, however the influence on the adjacent segments is not regularly reported and motion coupling is often neglected. In this study, even one-level TDR resulted in small but significant increased motion during FE not only in the target segment but also the adjacent segments. A possible explanation is the surgical procedure. During the ventral approach and the decompression of the spinal canal the anterior longitudinal ligament, major parts of the ventral annulus and the posterior longitudinal ligament at the target level are dissected. This seems to have a motion increasing effect spanning several segments.
While the change in kinematics after one-level TDR was more subtle, two-level TDR affected primary as well as coupled motions at multiple levels simultaneously. Balancing this more pronounced change of kinematics after two-level TDR might require additional muscle control of the patient, but since in this test setup muscle forces were not simulated, this remains speculative. Patient selection for two-level TDR should take increased demand for motor control into consideration.

SIGNIFICANCE/CLINICAL RELEVANCE: The prevention of unphysiological strains due to altered kinematics after cervical fusion, which could possibly explain adjacent segment degeneration, were a driving factor in the development of TDR. Based on the thorough evaluation of cervical motion, these experimental findings suggest a more extensive change of cervical kinematics also at the adjacent segments after two-level than after one-level TDR.

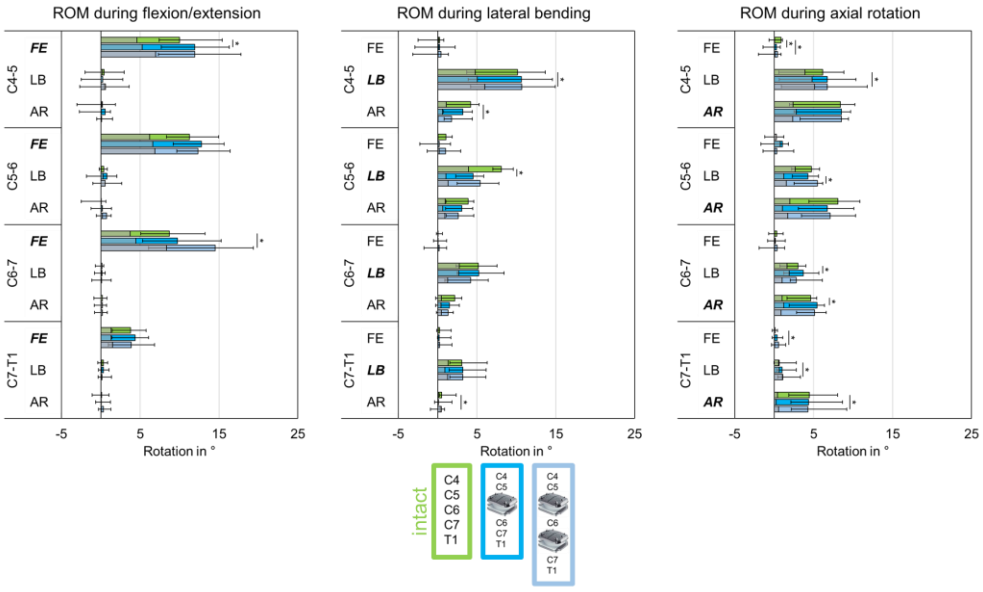

Fig. 1: Median primary and coupled ROM and neutral zone of each motion segment during FE (left), LB (middle) and AR (right). Error bars represent range of ROM. Significant differences ($p<0.05$) in ROM are denoted with an asterisk.