Kinematics of a Two-level Selectively Constrained Cervical Disc Replacement: Comparisons to Hybrid and Fusion Constructs

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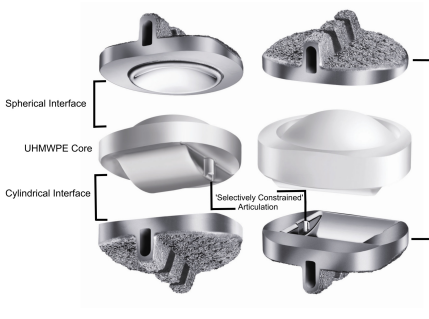
Introduction

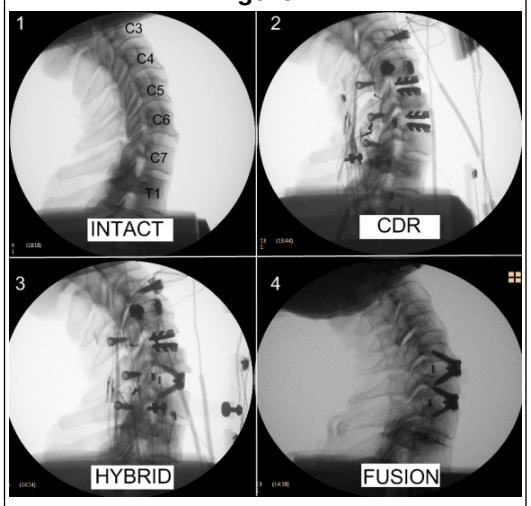
Single-level fusion does not seem to significantly alter the overall motion of the cervical spine, but motion is adversely affected when multilevel fusion is performed [1]. Because fusing multilevel causes more loss of motion, the concept of motion preservation by cervical disc replacement (CDR) (Figure 1) seems more appealing in multilevel degenerative disc disease than in one-level. But there are very few biomechanical studies evaluating the kinematics of two-level CDR and hybrid constructs. The aim of the present study was to evaluate the multidirectional kinematics of a two-level CDR and hybrid construct with CDR adjacent to integrated plate spacer (IPS), compared to two-level fusion using a selectively constrained CDR.

Figure 1



Selectively Constrained Cervical Disc Replacement. The design allows rotation in all three planes and sagittal plane translation. This is achieved through a three-piece design with a superior sphere and inferior cylinder as articulating surfaces.

Figure 2



Test Constructs

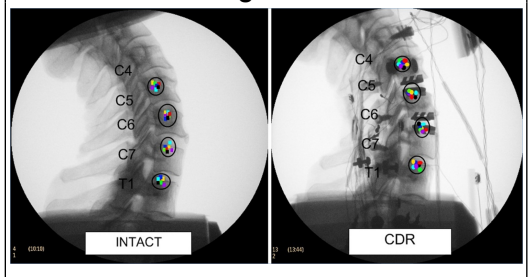
Methods

Seven cadaveric cervical spines (C3-T1) were tested in the following sequence (Figure 2): 1) INTACT; 2) Two-level CDR (CDR C5-C7); 3) HYBRID (CDR C5-C6 + IPS C6-C7); and 4) Two-level FUSION (IPS C5-C7). A load control protocol with 2 Nm moments applied at a rate of 1°/sec was used in flexion-extension (FE), lateral bending (LB) and axial rotation (AR) to establish intact values. Flexibility testing using displacement control was employed for the remaining constructs. Range of motion at both implanted and adjacent levels was calculated. Center of rotation at operative and adjacent levels was calculated according to the method of perpendicular bisectors using full flexion-extension radiographs. Data was normalized to intact (Intact =100%) with significance set at $p<0.05$.

Results

At the level of implantation, motion was preserved in flexion-extension (102%) and axial rotation (96%), and tended to decrease in lateral bending (79%), with two-level CDR. The findings also revealed that two-level CDR and hybrid construct did not significantly change adjacent level kinematics compared to the intact condition, whereas the two-level fusion construct demonstrated a significant increase in flexibility at the adjacent level. The location of center of rotation in the sagittal plane at C5-C6 and C6-C7 for the two-level CDR construct was similar to that of the intact condition (Figure 3).

Figure 3



Center of Rotation for Intact and CDR at implanted and adjacent levels

Table 1. Range of motion values (degrees) of various surgical constructs at implanted and adjacent levels in all loading modes expressed as mean (standard deviation).

Flexion-Extension	Intact	CDR	Hybrid	Fusion
C34	10.42 ± 4.99	10.76 ± 5.36	11.27 ± 6.02	11.91 ± 6.3
C45	6.06 ± 4.28	6.3 ± 4.37	6.35 ± 4.45	7.63 ± 4.46*,#,^
C56	5.57 ± 2.75	5.99 ± 4.2	5.52 ± 4.07	2.9 ± 1.34*,#,^
C67	4.14 ± 2.31	3.97 ± 2.45	2.2 ± 1.21*	1.82 ± 1.23*,#
C7T1	2.49 ± 1.39	2.71 ± 1.62	3.73 ± 1.24	4.23 ± 1.9*
Lateral Bending	Intact	CDR	Hybrid	Fusion
C34	12.69 ± 5.07	13.53 ± 5.78	13.75 ± 5.82	14.49 ± 5.85*
C45	6.14 ± 4.34	6.62 ± 4.03	6.8 ± 4.57	7.93 ± 4.24*
C56	4.24 ± 2.51	3.27 ± 2.93	3.62 ± 3.33	1.87 ± 0.51
C67	3.02 ± 1.26	2.44 ± 1.06	1.57 ± 1.09*	1.66 ± 0.96*
C7T1	1.89 ± 1.4	2.25 ± 2.04	2.87 ± 1.7*	3.29 ± 1.44*,#
Axial Rotation	Intact	CDR	Hybrid	Fusion
C34	7.55 ± 3.83	8.29 ± 3.52	8.21 ± 3.44	8.67 ± 3.43
C45	7.06 ± 2.95	7.46 ± 3.11	8.34 ± 3.5	9.02 ± 3.35*
C56	9.36 ± 3.81	8.88 ± 3.15	8.04 ± 4.09	5.73 ± 2.58
C67	5.95 ± 1.05	5.81 ± 2.76	4.43 ± 2.27	3.56 ± 1.44*,#
C7T1	6.92 ± 4.23	7.2 ± 4.55	7.78 ± 4.95	9.42 ± 4.37*,#,^

** means significant with respect to intact*
 # means significant with respect to CDR (CDR C5-C7)
*^ means significant with respect to hybrid (*CDR C5-C6 + IPS C6-C7*)*

Conclusions

The two-level cervical replacement construct tended to mimic motion profile similar to the intact condition in flexion-extension and axial rotation but tended to reduce in lateral bending. The results of this study for the flexion-extension range of motion and location of center of rotation support the unconstrained sagittal plane kinematics of the selectively constrained cervical disc design. In addition, the axial rotation motion results support the unconstrained kinematics in the transverse plane. The hybrid construct incorporating cervical replacement immediately superior to rigid instrumentation did not significantly change adjacent level kinematics compared to the intact condition. Two-level fusion demonstrated a significant increase in motion at the adjacent levels. Clinically, hybrid constructs may alleviate abnormal motion at adjacent levels compared to two-level fusion and hence may be an effective alternative for the treatment of two-level disease.

References

1. Lopez-Espina, C.G., F. Amirouche, and V. Havalad, Multilevel cervical fusion and its effect on disc degeneration and osteophyte formation. Spine (Phila Pa 1976), 2006. 31(9): p. 972-8.

Disclosure

The device, SECURE®-C (Globus Medical Inc., Audubon, PA) is not FDA-approved for this indication and is not commercially available in US.