INTRODUCTION: The goals of total disc replacement (TDR) are to relieve pain of presumed discogenic origin, and restore near-normal spinal segment kinematics, thereby preventing adjacent levels from further degeneration. The three-piece Charité TDR, with two cobalt-chrome endplates and an unconstrained sliding polyethylene (PE) core, was designed to allow the replication of near-normal lumbar segment kinematics under physiologic loads.

While previous studies have demonstrated preserved segmental motions after Charité TDR, little is known about the effects of physiologic loads on the behavior of the implanted segment. In addition, to our knowledge, there have been no reports in the literature on the effects of mal-positioning of the prosthesis on spinal kinematics. It is recommended that the Charité TDR be centered exactly in the midline of the vertebral body in the coronal plane, and that it be centered 2 mm dorsal to the mid-vertebral line in the sagittal plane.

We investigated the effect of implant placement on: (1) the ability of Charité TDR to restore normal segmental motion under physiologic loads, and (2) the motion of prosthesis components in each position.

METHODS: Seven human lumbar cadaveric spines (L1-sacrum; age 52±1.1 yrs) were tested. Prior to testing, each specimen was screened with X-rays, MRI, and a peripheral computed tomography bone-mineral densitometry instrument to ensure none were osteopenic, and none had facet joint arthrosis. Each specimen was mounted on a six-component load cell to measure applied compressive preload and moments. Range of motion of each segment was measured using an optoelectronic motion measurement system. Fluoroscopic imaging was used during implantation of the TDR to confirm placement in the sagittal and frontal planes. Sequential fluoroscopic imaging was used for the duration of flexion and extension testing to monitor motions between prosthesis endplates and core, as well as movements between vertebral endplates and the prosthesis. Each specimen was tested in flexion moments to 8 Nm and extension moments to 6 Nm under a 400 N compressive follower preload. 1

A total of 14 TDRs were implanted, 7 at L5/S1 and 7 at L4/L5. The order of testing sequence was: (i) intact specimen (ii) Charité TDR at L5-S1 in three positions (anterior, middle, and posterior in relation to the mid-sagittal line of the vertebral body (iii) simulated healed fusion at L5-S1, with TDR at L4-L5 in two positions (middle, posterior). Anterior position (Fig. 1A) was defined as the prosthesis centered anterior to mid-vertebral line. Middle position was defined as the prosthesis centered in the mid-vertebral line. Posterior position (Fig. 1B) was defined as the prosthesis centered 2 mm dorsal to the mid-vertebral line. All implants were centered in the midline in the coronal plane.

The range of motion at each level before implantation and after implantation in the various positions was analyzed using repeated-measures analysis of variance. The level of significance was set at p<0.05. Prosthesis motions were analyzed by visual assessment of the sequential video-fluoroscopic images obtained during the flexion-extension range of motion tests. Five independent observers assessed whether there was angular motion at each of the two endplate-core joints and whether or not there was visible core translation. In addition, any separation of the core from prosthesis endplates was noted. In order to assess whether the frequency distribution of these motion patterns depended on the segmental level (L5-S1 vs. L4-L5) or on the compressive preload (0 N vs. 400 N), statistical analysis for contingency tables was performed.

RESULTS: Charité TDR, when placed posterior to the midline, increased the segmental range of motion from intact values of 7.1±3.7 to 9.9±2.0 degrees at L5-S1 and from 7.3±2.2 to 10.5±2.4 degrees at L4-L5 (p<0.05) under a 400 N compressive follower preload (Fig. 2A-B). Implant placement anterior to the midline reduced the range of motion to 3.1±2.6 degrees at L5-S1 (p<0.05). The reduction in motion at L4/L5 between posterior and middle TDR positions was also statistically significant (p<0.05). Of note, the anterior position resulted in less ROM than intact, non-implanted segments at L5-S1 (p<0.05).

DISCUSSION: The goal of disc arthroplasty is to allow restoration of near-normal intervertebral kinematics. We have demonstrated that, in the sagittal plane, positioning of the Charité TDR anterior to or centered on the mid-sagittal line of the vertebral body results in significantly decreased range of motion compared to the posterior positioned TDRs and the intact segments. It may be necessary to release posterior tethers, i.e. the posterior longitudinal ligament, or osteotomize endplates that may be ‘lipped’ in order to obtain optimal position of the implant.

The other findings of our study indicate that even with an optimally positioned implant, the implant intra-prosthesis motion in this unconstrained device occurs between the superior endplate and the polyethylene core. We observed few ‘obvious’ cases of core translation, although there were subtle hints of angular movement between both endplates and the core in 8 of 14 TDRs. Further studies are needed to determine the effects of such motion patterns on posterior element loads, adjacent segment biomechanics, and polyethylene core wear.

The cadaveric nature of this study is an obvious limitation. Clinical correlation with live fluoroscopic images in patients with implanted TDRs will assist with understanding the nature of movements within the prosthesis itself and segmental range of motion at the implanted segment. To our knowledge, this is the first study to demonstrate that mal-positioning of this device may result in statistically significant motion loss at the implanted segment.