Controlled Motion with the XL-TDR Lateral-approach Lumbar Total Disc Replacement: In vitro Kinematic Investigation

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Purpose: While anterior-approach lumbar disc replacement devices are thought to retain close to “normal” range-of-motion (ROM), they are also inherently unstable due to resection of the anterior longitudinal ligament and annulus. This instability/laxity is manifested as increased neutral zone motion. The XL-TDR device (Nuvasive, Inc., San Diego, CA) is implanted through a lateral approach that preserves the anterior ligamentous and annular structures. This potentially makes the XL-TDR device significantly more stable than those delivered anteriorly. This study investigates the kinematics of XL-TDR in a cadaveric model, and also investigates the contribution of the anterior ligament/annulus to stability.

Methods: Six fresh-frozen cadaveric specimens (L2-S1) were subjected to non-destructive multi-directional testing using the hybrid protocol described by Panjabi, where the total L2-S1 intact ROM at ±8 N·m is applied to the reconstructed conditions. Motion segment kinematics were obtained using an optoelectronic system. Test conditions were: (1) intact spine, (2) XL-TDR at L4-5, and (3) XL-TDR at L4-5 with anterior annulus/ligament resected. Total ROM (ROM = NZ + EZ; NZ = neutral zone, EZ = elastic zone) and NZ were calculated for each condition in each loading direction (flexion-extension total, flexion alone, extension alone, lateral bending and axial rotation).

Results: Insertion of the XL-TDR device led to decreased ROM with respect to intact in all directions. This achieved statistical significance for flexion-extension, extension, and axial rotation (p < 0.006). NZ in all directions was not statistically different from intact (p < 0.05; Figure 1), although there was a trend towards decreased NZ in flexion (p = 0.078). Removing the anterior ligament/annulus increased ROM significantly with respect to the XL-TDR condition in all directions (p < 0.003). NZ also increased, with the most significant changes in extension, lateral bending and axial rotation (p < 0.002).

Neutral Zone (NZ) Motion
* p < 0.05 vs. Intact and vs. XL-TDR

![Figure 1](image-url)
Conclusion: This is the first study to investigate the kinematics of XL-TDR. Retention of the anterior ligament/annulus had a significant stabilizing effect. Device insertion leads to tensioning of the anterior and posterior longitudinal ligaments and remaining annulus. While less ROM than intact was observed, the motion was found to be more controlled (more natural NZ). The XL-TDR NZ motion compares favorably with commercial anterior TDR devices which typically exhibit higher NZ motion, particularly in axial rotation (approx 3x intact; Cunningham, Cappuccino et al., SAS9, 2009). Removing the anterior ligament/annulus illustrated its stabilizing role, with ROM and NZ increasing. Future studies will investigate the potential benefit of controlled XL-TDR motion on facet kinematics, which may have clinical implications related to limiting facet degeneration.