INTRODUCTION: Cervical disc degeneration can be debilitating, significantly reducing a patient’s range of motion and their ability to perform normal neck motions. Cervical arthrodesis, by definition, decreases neck motion and disc degeneration adjacent to fused levels is well recognized clinically. Previous kinematic studies on the human spine have been conducted under in vitro conditions, but recently, fluoroscopy has been used on other joints to determine in vivo kinematics. This study focuses on the determination of the in vivo kinematics during active flexion and extension of normal, degenerated, and fused cervical spines.

METHODS: Fifteen adult subjects (five normal, five degenerative, and five 2-level fused) were analyzed under fluoroscopic surveillance. The subjects having a fused spine were fused at the C5-C6 and C6-C7 levels (deemed clinically successful). Fluoroscopic images were downloaded directly to a workstation computer and were analyzed at ten various increments of spinal flexion/extension. During the computer analysis, constant points on each of the seven cervical spine vertebrae were tracked throughout the range of motion (Figure 1).

Fig. 1: Schematic of digitization process used to analyze the in vivo fluoroscopy images.
The points were analyzed to determine the rotation angle of each individual vertebra. The rotation of each vertebra relative to the subsequent vertebra was plotted with respect to time and the data was curve-fit to obtain a temporal function that represented the motion pattern. Using a mathematical model, the relative velocities were obtained and used to determine the partial angular and linear velocities. Kinematic comparisons were then made for each subject within each group and with subjects from the other two groups.

RESULTS The kinematic patterns for the three groups varied considerably. Normal cervical spines showed a smooth, arc like motion, whereas, the degenerative spines demonstrated inconsistent motion patterns especially at the C5, C6, and C7 vertebrae (location of the degeneration) (Figures 2 & 3). The two-level fusion patients demonstrated no motion at the fused C5-C6 and C6-C7 levels and marked abnormalities in the motion pattern at the C4-C5 level (level above fusion) (Figure 4). There was also a distinct difference in the relative angular velocities for the three groups. The subjects having a fused spine experienced a significant change in the relative angular velocities above the fused joint.

Fig. 2: Kinematic patterns for a normal cervical spine throughout the full range-of-motion cycle.
Fig. 3: Kinematic patterns for a degenerative cervical spine throughout the full range-of-motion cycle.

Fig. 4: Kinematic patterns for a fused cervical spine throughout the full range-of-motion cycle.
DISCUSSIONS: This is the first study to document the in vivo motions of the cervical spine. This analysis determined that there is a significant difference in the in vivo kinematics of the normal cervical spine compared to a degenerative or fused cervical spine. The abrupt change in motion detected above the fused levels may lead to further complications, possibly including accelerated disc degeneration due to the abnormal loading conditions adjacent to the fused cervical segments.

• If noted, the author indicates something of value received. The codes are identified as: a - research or institutional support, b - miscellaneous funding, c - royalties, d - stock options, e - consultant or employee. For full information, refer to inside back cover.