Cervical Spine Facet Joint Motion in Single-Level Anterior Fusion Patients and Age-Matched Asymptomatic Controls

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Introduction
Clinical, behavioral and physiologic evidence indicates mechanical injury to the cervical facet joint is a source of pain1-3. Although increased laxity in the capsular ligament may perpetuate chronic pain and clinical instability in whiplash patients4, no normative data exists describing in vivo kinematics of the cervical facet joint, as previous reports have been limited to facet joint motion in cadavers5,6. Additionally, restoring normal cervical facet kinematics is imperative to the long-term health of patients who undergo cervical fusion or disc replacement, as computational modeling indicates these surgical procedures may alter facet joint forces7.

The aims of this study were first, to establish normative data for in vivo cervical facet joint kinematics during dynamic flexion-extension in an asymptomatic control group and second, to compare facet joint motion between controls and single-level anterior fusion patients. It was hypothesized that facet joint motion adjacent to the fused motion segment would be significantly increased when compared to corresponding levels in asymptomatic controls.

Methods
15 single-level anterior fusion patients (10 C56 and 5 C67 fusions; 45±9 yrs; 4 M, 11 F; 7±1 mo. post surgery; 8 allograft, 7 autograft) and 15 age-matched asymptomatic controls (45±6 yrs; 7 M, 8 F) consented to participate in this IRB-approved protocol. Subjects performed continuous, full ROM flexion-extension at a rate of one complete cycle every 3 seconds. Biplane x-rays were collected at 30 images per second for 3 seconds each dynamic trial. Two to 3 trials were collected per subject, providing 80 dynamic movement trials for analysis. An additional static trial was collected, with the head in the neutral position. Subject-specific bone models of C2-C7 were created from CT scans. A previously validated tracking process determined three-dimensional vertebral position with sub-millimeter accuracy by matching bone models from the CT scan to the biplane X-rays8. Intervertebral flexion-extension rotation was calculated each frame using bone-specific anatomic coordinate systems.

Four markers were placed on each superior facet of the 3D bone model (Figure 1a). These markers defined facet-specific planes parallel and perpendicular to the facet surface. Partner points on the surface of the adjacent bone closest to the cranial and caudal facet markers were identified using the 3D data from the static neutral trial (Figure 1b).

The distance between facet and partner markers was automatically calculated each frame of continuous flexion-extension and expressed relative to the static neutral trial. Relative motion between markers represented facet joint shear deformation (parallel to facet surface) and tension/compression deformation (perpendicular to facet joint surface) during the dynamic flexion-extension trials. A best-fit line through the deformation versus flexion angle plot was determined for each subject for statistical analysis. Left and right facet deformations were averaged on each bone for each subject. Repeated measures analysis of variance was used to identify differences in facet shear and compression/tension deformation among vertebral levels (C2-C7) in control subjects. Analysis of variance was used to test for differences between control subjects and C56 and C67 fusion subjects (p < .05 in all cases). Fused motion segments were not included in the statistical analysis.

Results
Facet joint motion was characterized by a combination of translation and rotation between adjacent joint surfaces (Figure 2). Facet shear and tension/compression deformation was linear throughout flexion-extension, indicating facet motion was constant and did not increase or decrease near the end of the motion range.

![Figure 2: Facet joint near full extension (A) and near full flexion (B)](image)

The rates of facet shear and tension/compression deformation were not significantly different among vertebral levels in control subjects (Figure 3). The average rates of shear and compression/tension deformation across all levels (0.24 mm/deg. and 0.068 mm/deg., respectively) indicate that during a 15° intervertebral range of motion in control subjects, facet joint sliding covers a range of 3.6±0.6 mm, while the range of facet opening and closing is 1.9±0.3 mm.

Facet shear and compression/tension deformation was not significantly different between controls and C56 or C67 fusion subjects at any non-fused level (Figure 3).

Discussion
The normative data for in vivo cervical facet joint kinematics during dynamic flexion-extension establishes reference data that can potentially be used to identify abnormal facet motion in whiplash patients who experience chronic neck pain. Facet motion expressed per degree of rotation enables comparisons even in patients with limited neck movement. The data failed to support the hypothesis that facet joint motion adjacent to the fused motion segment would be significantly increased when compared to corresponding levels in asymptomatic controls. Increased sample size and long-term follow-up tests are necessary to confirm this result.

Significance
This is the first study to characterize cervical facet motion during in vivo dynamic, functional motion in asymptomatic controls and fusion patients. Single-level anterior cervical fusion does not appear to affect facet kinematics 7 months post-surgery.

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