THE FACET JOINT LOADING PROFILE OF A CERVICAL INTERVERTEBRAL DISC REPLACEMENT INCORPORATING A NOVEL SADDLE-SHAPE ARTICULATION

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Introduction: The design of an effective intervertebral disc replacement requires an improved biomechanical understanding, if not a precise profile, of facet joint loading in the intact cervical spine and the effects of device implantation on the native joint articulation. Both the magnitude and distribution of facet joint loading is relevant to the predisposition or exacerbation of facet arthropathy. An improved understanding of cervical facet loading may permit advances in cervical arthroplasty design and may inform clinical decision-making regarding patient selection for total disc replacement.

Cervical range of motion in situ is determined by a combination of soft tissue balance, the bilateral facet joint articulations, and the bilateral uncovertebral joints. In the subaxial cervical spine, from C3-4 to C6-7, the maximum physiologic range of motion is 10 degrees of flexion-extension, 11 degrees of lateral bending, and 7 degrees of axial rotation.

A cervical disc replacement design that adequately replicates the normal motion of the functional spinal unit should also function to protect the facet joints from abnormal or supra-physiologic loading that might contribute to or result in facet arthropathy and/or a painful articulation. The purpose of this investigation was to evaluate the cervical facet loading profile of an intervertebral cervical disc prosthesis incorporating a novel articulation mechanism. In doing so, we hoped to determine the effect of implanting this cervical intervertebral disc replacement, on both the loading curve and area distribution of facet loading when compared with that of an intact specimen. Acquiring a complete load profile necessitated multiple recordings. To accomplish this, two commercial pressure-measuring technologies were distinctively joined, or mated, through a specially constructed “pocket” to form a unique, single pressure sensor mechanism that would accommodate repeat measuring without damaging either the film or further violating the capsule.

Materials and Methods: Construction of the Facet Transducer

The novel pressure sensor was constructed by combining Fuji pressure-sensitive film and a resistive ink pressure load sensor.

The novel sensor permitted the continuous recording of incremental load throughout the loading cycle while simultaneously providing a graphical representation of the contact area and pressure distribution. Both the Fuji film and the resistive ink thin film sensors were calibrated prior to unilaterally inserting them in the cervical facet joint. The Fuji film was calibrated according to the protocol described by Kuroda et al., while the thin film sensors were preconditioned and calibrated as per the method described by Valdevit et al.³

Specimen Preparation

Fresh-frozen cervical ovine spine specimens were harvested in bloc and utilized for this investigation. They were then disarticulated to yield six functional spinal units (C3-C4) and (C5-C6) and secured into 4-inch square aluminum sleeves using Cerrobend (Cerrometals, Bellefonte, Pennsylvania). The facet transducer was introduced into the facet joint via a small arthrotomy on the superior aspect of the facet joint. The Fuji film was calibrated according to the protocol described by Kuroda et al., while the thin film sensors were preconditioned and calibrated as per the method described by Valdevit et al.³

Biomechanical Testing

The specimens were mounted in a custom fixture on a material-testing apparatus (Mini-Bionix, MTS Systems, Eden Prairie, Minnesota). The fixture permitted flexion, extension, and lateral bending through a preset moment arm without disruption of the specimen alignment. A displacement was applied through the moment arm so as to generate moments of 0.5Nm, 1Nm, and 2Nm in each of the loading modes. The specimens also were tested in axial rotation in a non-destructive fashion at a rate of 0.25Nm/s for a total torque of 1Nm, 2Nm and 3Nm. At the end of each loading cycle, the final load was held for 30 seconds to expose the Fuji film.

A correlation analysis was conducted to verify the output of the Fuji film reader, and the thin film sensor yielded statistically similar results with respect to peak (static) loading data. With respect to the in vitro tests, a paired Student’s t-test was performed to determine any differences between the intact and CerviCore®-implanted conditions under each loading condition.

Results: There were no statistically significant differences in mean or maximum pressures between the intact specimen and the CerviCore®-implanted specimen in all loading configurations. Similarly, there was no significant difference in the total measured force between the groups in all loading configurations. There were no significant differences in contact areas between the groups in flexion, lateral bending, or axial rotation. When evaluated in extension, the intact specimen had a mean contact area of 0.8 cm², compared with 0.5 cm² for the CerviCore®-implanted specimen (p < 0.02).

Discussion: The current study suggests that metal-on-metal saddle-shaped bearing surfaces of the CerviCore® disc effect an articulation of the facet joints, in a CerviCore®-implanted segment, that is sufficiently similar to the articulation of the facet joints in a native intact segment. The approximation of a natural facet joint loading profile by the CerviCore® disc may prove useful in preventing late degenerative changes. Continued study of facet loading in different models may lead to improvements in patient selection for total disc replacement and help to better define indications. While the ovine model has been well validated, further testing in a human cadaveric model is warranted, and long-term clinical results also would be informative.