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Basic Science

The importance of the posterior osteoligamentous complex to subaxial cervical spine stability in relation to a unilateral facet injury

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Abstract

BACKGROUND CONTEXT: Unilateral facet disruptions are relatively common in the cervical spine; however, the spectrum of injury is large, and little is known regarding the magnitude of instability expected to be present in an isolated posterior osteoligamentous injury.

PURPOSE: To quantify the contribution of the posterior osteoligamentous structures to cervical spine stability during simulated flexion-extension (FE), lateral bend (LB), and axial rotation (AR).

STUDY DESIGN: An in vitro biomechanical study.

METHODS: Eight cadaveric C2–C5 spines were used in this study. A custom-developed spinal loading simulator applied independent FE, LB, and AR to the specimens at 3°/s up to ±1.5 Nm. Using an optical tracking system, data were collected for the intact specimen and after sequential surgical interventions of posterior ligamentous complex (PLC) disruption, unilateral capsular disruption, progressive resection of the inferior articular process of C3 by one-half, and finally complete resection of the inferior articular process of C3. The magnitude of segmental and overall range of motion (ROM) for each simulated movement along with the overall neutral zone (NZ) was analyzed using two-way repeated-measures analyses of variance and post hoc Student-Newman-Keuls tests (α=.05).

RESULTS: An increase in ROM was evident for all movements ($p<.001$). Within FE, ROM increased after cutting only the PLC ($p<.05$). For AR, sectioning of the PLC and complete bony facet fracture increased ROM ($p<.05$). Lateral bend ROM increased after facet capsular injury and complete articular facet removal ($p<.05$). There was an overall effect of injury pattern on the magnitude of the NZ for both FE ($p<.001$) and AR ($p<.001$) but not for LB ($p=.6$); however, the maximum increase in NZ generated was only 30%.

CONCLUSIONS: The PLC and facet complex are dominant stabilizers for FE and AR, respectively. The overall changes in both ROM and NZ were relatively small but consistent with an isolated posterior osteoligamentous complex injury of the Stage I flexion-distraction injury.

Keywords: Spine biomechanics; Cervical spine; Instability; Range of motion; Posterior osteoligamentous complex

FDA device/drug status: Not applicable.

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Introduction

Unilateral facet disruptions are relatively common injury patterns of the subaxial cervical spine [1]. However, little consensus exists among experts as to the best form of treatment [2,3]. The poor agreement stems from a combination of factors but likely includes the classification of the exact injury [2]. A number of classification systems have been reported [4]. The most well accepted and widely used is the Allen and Ferguson classification [5,6].

The development of these classification systems is largely based on mechanism of injury, devised from radiographic reviews, with little supporting biomechanical evidence. For the distractive-flexion mechanism, Allen et al. [5] classified these injuries into four stages of increasing injury severity, where a Stage I injury was defined as failure of the posterior ligamentous complex (PLC). Clinically, these isolated posterior soft-tissue injuries may also include unilateral articular process fractures. However, for specific injuries such as these, biomechanical investigations can help add depth to these classifications or treatment algorithms by providing an understanding of the instability present for specific injuries.

Previous biomechanical studies have examined the stability provided by the posterior structures in the subaxial spine in the context of sectioning studies to the soft tissues, posterior laminectomy, and in advanced stages of distractive-flexion injury [7–13]. Although these studies begin to address the stabilizing role of the posterior elements, they are, for the most part, not applicable to the stability present after a traumatic Stage I distractive-flexion injury. In fact, there is a specific lack of biomechanical understanding of the stability of these injuries under the normal motions of the cervical spine and, as such, has most likely led to the controversy surrounding the most appropriate course of treatment [2].

Thus, the purpose of this biomechanical study was to quantify the increase in motion produced after sequential disruption of the posterior osteoligamentous structures (ie, Stage I injury) based on applying simulated flexion-extension (FE), axial rotation (AR), and lateral bend (LB). It was hypothesized that sequential sacrifice of the posterior stabilizing structures of the unilateral facet complex would result in progressive increase in range of motion (ROM) and neutral zone (NZ) for all simulated motions.

Materials and methods

Eight fresh-frozen cadaveric C2–C5 cervical spines (mean age, 68±9 years) were cleaned of musculature without disruption of ligaments, bones, and disc tissue. A previously described technique was used to pot the specimens at the cranial and caudal ends [14–16]. To achieve adequate fixation, screws were inserted into both C2 and C5 with the protruding ends of the screws potted within cement (Denstone; Heraeus Kulzer Inc., South Bend, IN, USA) of 1-in thickness in 4-in diameter polyvinyl chloride piping. Proper specimen alignment was achieved with the use of laser levels to maintain C3–C4 horizontal. Fluoroscopy was used to ensure specimen integrity and appropriate screw placement. Because of the length of time required for preparation and potting, the specimens were refrozen and thawed again for testing. Repeated freezing and thawing has been shown to have little effect on the biomechanical properties of the spine [17].

The spinal loading simulator, a custom-designed modification to an existing materials testing machine (Instron 8874; Instron Corp., Canton, MA, USA), was used to independently apply dynamic nondestructive bending moments to the spine. Loading was applied to the cranial end (C2), whereas the caudal end (C5) was fixed to the base platform of the simulator (Fig. 1). Specimens were loaded at 3°/s up to the target of 1.5 Nm to simulate movements of FE, AR, and LB [12,14]. Design of the simulator allowed for the cranial end of the spine to be free in all directions except for the movement of interest, allowing five degrees of freedom. To account for the viscoelastic effects, each movement was repeated for three complete cycles (ie, FE), with the data from the final cycle used for analysis [18].

An Optotrak Certus optical tracking system (NDI, Waterloo, ON, Canada) was used to capture three-dimensional kinematics at 60 Hz. Markers were attached

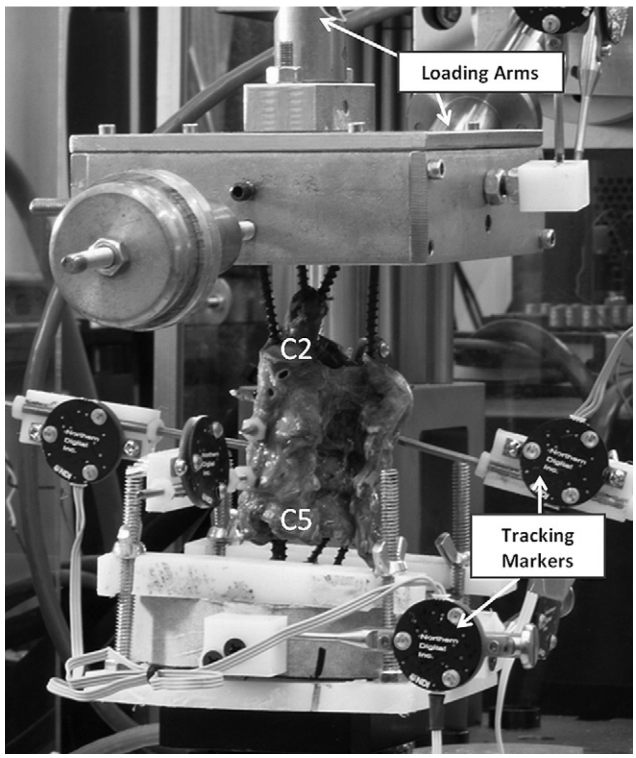

Fig. 1. Experimental setup. Motion was applied to cervical spine specimens (C2–C5) by means of loading arms attached to the cranial potting fixture. The caudal end of the spine was fixed to the testing platform. Axial rotation (AR) and flexion-extension (FE) could be applied in the same simulator orientation; however, lateral bend (LB) required a 90° rotation of the specimen. To capture this motion, optical tracking markers were attached in two planes (sagittal and frontal) to track FE, LB, and AR.