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Basic Science

Influence of graft size on spinal instability with anterior cervical plate fixation following in vitro flexion-distraction injuries

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Abstract

BACKGROUND CONTEXT: Anterior cervical discectomy and fusion with plating (ACDFP) is commonly used for the treatment of distractive-flexion cervical spine injuries. Despite the prevalence of ACDFP, there is little biomechanical evidence for graft height selection in the unstable trauma scenario.

PURPOSE: This study aimed to investigate whether changes in graft height affect the kinematics of instrumented ACDFP C5–C6 motion segments in the context of varying degrees of simulated facet injuries.

STUDY DESIGN: In vitro cadaveric biomechanical study was used as study design.

METHODS: Seven C5–C6 motion segments were mounted in a custom spine simulator and taken through flexibility testing in axial rotation, lateral flexion, and flexion-extension. Specimens were first tested intact, followed by a standardized injury model (SIM) for a unilateral facet perch at C5–C6. The stability of the ACDFP approach was then examined with three graft heights (computed tomography-measured disc space height, disc space height undersized by 2.5 mm, and disc space height oversized by 2.5 mm) within three increasing unstable injuries (SIM, an added unilateral facet fracture, and a simulated bilateral facet dislocation injury).

RESULTS: In all motions, regardless of graft size, ACDFP reduced range of motion (ROM) from the SIM state. For flexion-extension, the oversized graft had a larger decrease in ROM compared with the other graft sizes ($p<.05$). Between graft sizes and injury states, there were a number of interactions in axial rotation and lateral flexion, where specifically in the most severe injury, the undersized graft had a larger decrease in ROM than the other two sizes ($p<.05$).

CONCLUSIONS: This study found that graft size did affect the kinematic stability of ACDFP in a series of distractive-flexion injuries; the undersized graft resulted in both facet overlap and locking of the uncovertebral joints leading to decreased ROM in lateral bending and axial rotation, whereas an oversized graft provided larger ROM decreases in flexion-extension. As such, a graft that engages the uncovertebral joint may be more advantageous in providing a rigid environment for fusion with ACDFP.

Keywords: Anterior instrumentation; Cervical spine biomechanics; Facet injury; Graft height

FDA device/drug status: Not applicable.

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Introduction

Traumatic facet joint subluxation, a precursor to facet fracture-dislocation, is an injury pattern common to distractive-flexion injuries in the subaxial cervical spine [1,2]. Specific to unilateral facet injuries, in vivo imaging studies and in vitro biomechanical models have identified large increases in range of motion (ROM) and significant soft tissue damage, including the facet capsules, ligamentum flavum, annulus fibrosis, and nucleus pulposus as the most commonly injured structures [3–6]. Compounding damage, such as the addition of a facet fracture or complete posterior ligamentous disruption, further destabilizes the affected motion segments, removing important restraints to pathologic rotation and translation [7,8]. Clinical and biomechanical evidence supports the use of anterior cervical discectomy and fusion with plating (ACDFP) for effective stabilization of traumatic distractive-flexion injuries [9–12], although biomechanical testing has found ACDFP less stable than some posterior approaches, particularly in axial rotation [12,13]. However, there are a number of biomechanically relevant factors to the ACDFP approach that may improve the time-zero stability of the instrumented construct, including the surgeon's selection of an appropriately sized bone graft to fit within the exposed disc space.

The purpose of the graft, in addition to promoting bone-on-bone fusion, is to restore disc space height, soft tissue tensioning, and normal spine curvature. Selecting a larger graft may increase stability as a result of restored tension in the ligaments, yet too much distraction decreases the load carried by the facet joint. Olsewski et al. noted that a distraction of 3 mm or greater over the baseline height significantly reduced the ratio of posterior element to graft loading [14]. This would also decrease the buttress effect of the facet joint during rotation or translation. On the other hand, too small a graft can result in pathologic changes to spinal alignment, poor soft tissue tensioning, and the potential for graft prolapse [15]. Most of the evidence to date has come from cadaveric imaging studies or retrospective clinical reviews [15–17]. Although graft size is clearly an important surgical factor, it has not been thoroughly investigated from a biomechanical perspective in the context of subaxial cervical trauma.

The objectives of this study were (1) to determine if graft height significantly alters the kinematic stability (ie, changes in ROM) of ACDFP for a simulated unilateral facet subluxation injury and (2) to examine further changes in ACDFP stability following additional simulated unilateral facet fracture and bilateral facet dislocation injuries. It was hypothesized that, in comparison to a graft size equivalent to the height of the disc space, ACDFP with an undersized graft will lead to poor soft tissue tensioning and therefore reduced stability in all motions, whereas an ACDFP with an oversized graft will be more stable as a result of the increased soft tissue tension.

Methods

Seven fresh-frozen cadaveric cervical spine segments were used (mean age 76±5 years). Specimens were imaged with computed tomography (CT) scanning to rule out any abnormal degeneration (such as autofusion) or other pathology. They were thawed at room temperature and cleaned of musculature without disruption of ligaments, discs, or joint capsules. With an interest in testing instrumentation in the C5–C6 motion segment, C4–C7 spine segments were isolated for each specimen. Screws were placed through C4 into the superior end plate of C5 and through C7 into the inferior end plate of C6 to immobilize the C4–C5 and C6–C7 motion segments and thereby isolate motion to the C5–C6 functional unit. Each specimen was potted in 2.5- cm thick, 10-cm diameter PVC piping using Denstone cement (Heraeus Kulzer Inc, South Bend, IN).

Flexibility testing was performed on each specimen using a previously developed spinal loading simulator modified from an existing materials testing machine (Instron 8874, Instron Corp., Canton, MA) (Fig. 1) [7]. Sequential loading was applied to the cranial end of each specimen to induce simulated flexion-extension, axial rotation, and lateral flexion. Transmission of an applied bending moment from the torque actuator to induce the desired motion to the cranial end of the specimen was achieved via a telescoping loading arm with

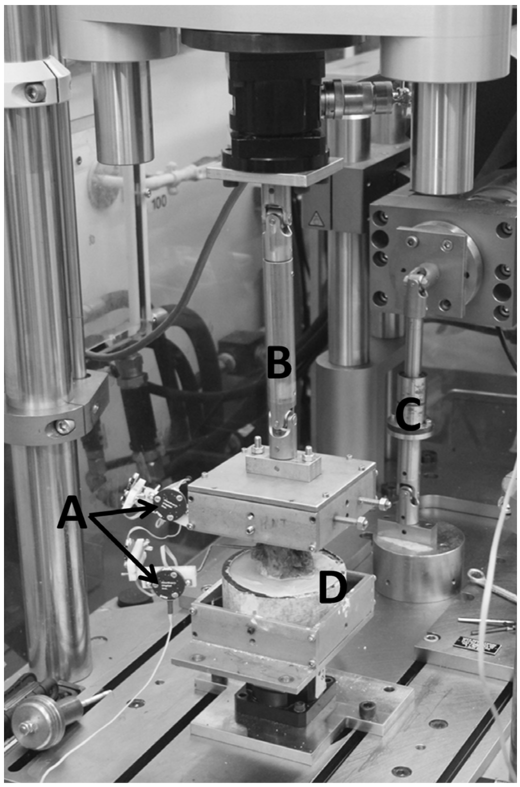

Fig. 1. Experimental setup of the custom spinal loading simulator. Spinal motion was tracked using Optotrak Smart markers (A). Two telescoping loading arms (B,C) with universal joints at each end were connected to torque actuators of the Instron and to the cranial end of the specimen (D) to apply bending loads.