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Biomechanical comparison of adjacent segmental motion after ventral cervical fixation with varying angles of lordosis

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Abstract

BACKGROUND CONTEXT: Complications, such as graft subsidence and adjacent segment degeneration, are not uncommon after ventral cervical fusion. It has been theorized, but not proven, that sagittal alignment may affect this process. It is therefore hypothesized that increasing lordosis during anterior cervical fusion decreases adjacent segment motion (ASM) and thus decreases the rate of adjacent disc degeneration. A study was designed to test the first portion of this hypothesis; ie, that increasing lordosis during anterior cervical fusion decreases ASM.

PURPOSE: To determine the effect on the adjacent segment motion (ASM) after ventral cervical spine fusion obtained by varying the angle of lordosis using interbody spacers with different heights (small: 6-mm interbody spacer; large: 9-mm interbody spacer).

STUDY DESIGN: A biomechanical study comparing the segmental motion at adjacent disc levels after cervical fusion with varying angles of lordosis. Sample and outcome measures: six human cadaveric spines C2–C7, range of motion (ROM).

METHODS: Six fresh human cadaveric cervical spines (C2–C7) were embedded at C2 and C7 and biomechanically tested to 0.7 Nm flexion and 0.5 Nm extension. Lordosis was measured at C4–C5 from radiographs; range of motion (ROM) at C3–C4, C4–C5, and C5–C6 was measured using markers during flexion and extension in the intact state, after ventral cervical fixation at C4–C5 with a small (6-mm) and with a large (9-mm) interbody spacer. A repeated measures analysis of variance was used to compare lordosis and the ROM for the different states.

RESULTS: Six cervical spines with a mean age of 55.3$\pm$1.6 years were studied. The mean sagittal angles of the specimens measured at C4–C5 using the Cobb angle method were $-6.4\pm1.3°$ intact, $-8.8\pm1.4°$ with small interbody spacer (intact vs. small spacer $p=.02$), and $-12.4\pm0.9°$ with large interbody spacer fixation (intact vs. large spacer $p=.005$). The lordotic angle of the specimens was lowest in the intact state, higher with the small spacer, and highest with the large spacer. The greatest ROM in the intact state testing was at C4–C5 ($10.6\pm1.3°$), followed by at C5–C6 ($7.2\pm1.5°$), and then at C3–C4 ($7.1\pm0.9°$). After C4–C5 fusion, the ROM at C3–C4 and C5–C6 was significantly increased with the small spacer only. No significant change in ROM was observed with the large spacer. The greatest overall ROM (all three motion segments) was observed in the intact state ($24.9\pm1.8°$), followed by the small spacer ($21.4\pm2.0°$) and the large spacer ($15.1\pm1.7°$).

CONCLUSIONS: Under the conditions of this study, there is a significant increase in ASM with the achievement of a modest increase in lordosis (small spacer) that is not observed with a greater increase in lordosis (large spacer).

Keywords: Biomechanical study; Adjacent disc level; Segmental motion; Different interbody spacer heights; Anterior cervical fusion; Lordosis; Degeneration

FDA device/drug status: approved for this indication (Orion cervical plate and screws).

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Introduction

Anterior cervical discectomy and fusion was originally popularized in the 1950s by Bailey and Badgley [1], with subsequent modifications made by Smith and Robinson [2]. This is a well-established technique that is associated with a high fusion rate (approximately 95%) that achieves good to excellent clinical results in nonsmoking patients. However, it is reported that approximately 25% of these patients will develop further degenerative changes at levels adjacent to the fusion within 10 years of the initial surgery. Eck et al. [3] demonstrated increased adjacent level intradiscal pressure and range of motion (ROM) in the cervical spine after plate fixation, whereas Akamaru et al. [4] demonstrated increased rostral adjacent level ROM with hypolordotic lumbar alignment and increased caudal adjacent level ROM with hyperlordotic lumbar alignment. Cunningham et al. [5] showed increased adjacent level ROM and intradiscal pressure after lumbar fusion. Oda et al. [6] fused in vivo sheep lumbar spines in kyphosis and identified degenerative changes in the adjacent rostral levels.

Graft size is an important factor in cervical fusion, playing a major role in determining the lordotic posture of the cervical spine. Smaller grafts may not optimally restore lordosis and may be associated with high extrusion risk [7]. Smith and Robinson recommended the use of 10–15-mm grafts [2]. More recent studies have recommended smaller grafts (4–7 mm) [8,9]. This may lead to kyphosis. Kyphosis of the fused cervical spine involves the loss of vertical height and is a component of subsidence. Pistoning of the strut into the vertebral bodies, collapse of the graft, and poor carpentry contribute to this process [10].

No studies have directly characterized the effect of alteration of cervical lordosis, with different interbody spacers, on adjacent level segmental motion (ASM). Therefore, a study was designed to test the hypothesis that sagittal alignment indeed affects ASM after ventral cervical fusion. The objective of this study was to determine the effect of alteration of cervical lordosis by varying interbody spacer height on ASM in the cadaveric cervical spine.

Materials and methods

Specimen preparation

Eight human cadaveric cervical spine specimens, 4 male and 4 female, were studied (45–57 years) (Table 1). Each specimen underwent radiography to ensure that no major structural abnormalities were present. The specimens were stored at −20° Celsius and were thawed for 24 hours at room temperature the day before testing. The surrounding musculature was removed from each spine, leaving all ligaments, joint capsules, and discs intact. Wood screws (1'') were placed into the rostral portion of the C2 vertebra and the caudal portion of the C7 vertebra in each specimen in a multiplanar fashion to improve purchase in the polyester resin material used for embedding C2 and C7 (Bondo Mar-Hyde, Atlanta, GA). The specimens were wrapped with gauze and kept moist with normal saline during the biomechanical testing.

Table 1
Specimen histories

Specimen	Age	Sex	Cause of death
43863	57	Male	Unknown
43866	54	Male	Cardiac arrest
43911	56	Female	Cardiac failure
43935	57	Male	Subdural hematoma
43944	53	Male	Hypertensive stroke
45023	55	Female	Cardiac failure

Before each specimen was tested, lateral radiographs were taken for baseline measurements of sagittal angle by the Cobb angle method. Then sagittal angle marking pins with polyethylene spheres were carefully inserted into the ventral aspect of each vertebral body (C3, C4, C5, and C6) that acted as sagittal angle markers during subsequent motion measurements in flexion and extension. The ROM was measured by digital photographs taken in full extension and full flexion, with the ROM taken as the difference between the baseline and fully flexed/extended measurements taken at each of the levels C3–C4, C4–C5, and C5–C6 between the individual markers (Fig. 1).

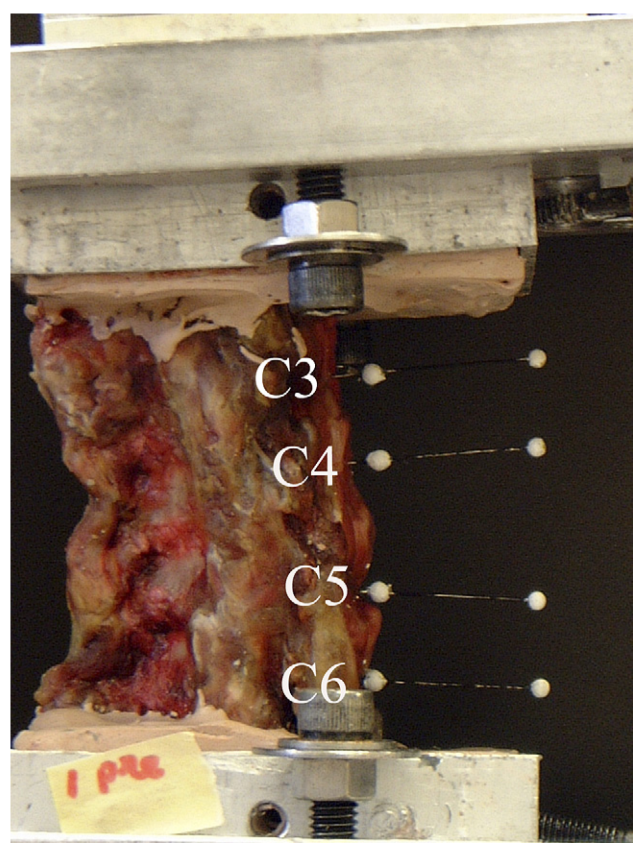

Fig. 1. Lateral photographic view of C2–C7 segment, C2 and C7 embedded in polyester resin, with markers in C3, C4, C5, and C6.