SPINE

Biomechanical Analysis of Disc Pressure and Facet Contact Force After Simulated Two-Level Cervical Surgeries (Fusion and Arthroplasty) and Hybrid Surgery

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Key words
- Adjacent-segment degeneration
- Cervical arthroplasty
- Facet contact force
- Hybrid surgery
- Intradiscal pressure

Abbreviations and Acronyms
ACDF: Anterior cervical discectomy and fusion
ASD: Adjacent-segment degeneration
FCF: Facet contact force
IDP: Intradiscal pressure
ROM: Range of motion

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OBJECTIVE: **The objective of this study was designed to compare 2-level cervical disc surgery (2-level anterior cervical discectomy and fusion [ACDF] or disc arthroplasty) and hybrid surgery (ACDF/arthroplasty) in terms of postoperative adjacent-level intradiscal pressure (IDP) and facet contact force (FCF).**

METHODS: **Twenty-four cadaveric cervical spines (C3-T2) were tested in various modes, including extension, flexion, and bilateral axial rotation, to compare adjacent-level IDP and FCF after specified treatments as follows: 1) C5–C6 arthroplasty using ProDisc-C (Synthes Spine, West Chester, Pennsylvania, USA) and C6–C7 ACDF, 2) C5–C6 ACDF and C6–C7 arthroplasty using ProDisc-C, 3) 2-level C5–C6/C6–C7 disc arthroplasties, and 4) 2-level C5–C6/C6–C7 ACDF. IDPs were recorded at anterior, central, and posterior disc portions.**

RESULTS: **After 2-level cervical arthrodesis (ACDF), IDP increased significantly at the anterior annulus of distal adjacent-level disc during flexion and axial rotation and at the center of proximal adjacent-level disc during flexion. In contrast, after cervical specified treatments, including disc arthroplasty (2-level disc arthroplasties and hybrid surgery), IDP decreased significantly at the anterior annulus of distal adjacent-level disc during flexion and extension and was unchanged at the center of proximal adjacent-level disc during flexion. Two-level cervical arthrodesis also tended to adversely impact facet loads, increasing distal rather than proximal adjacent-level FCF.**

CONCLUSION: **Both hybrid surgery and 2-level arthroplasties seem to offer significant advantages over 2-level arthrodesis by reducing IDP at adjacent levels and approximating FCF of an intact spine. These findings suggest that cervical arthroplasties and hybrid surgery are an alternative to reduce IDP and facet loads at adjacent levels.**

INTRODUCTION

Adjacent-segment degeneration (ASD) is a long-term complication of cervical fusion procedures that requires additional surgical intervention with time (8, 9). Great effort has been devoted to preventing this type of progressive deterioration, including the development of artificial cervical discs and the introduction of hybrid surgical techniques involving single-level treatments (anterior cervical discectomy and fusion [ACDF] plus arthroplasty) as opposed to 2-level ACDF. A number of biomechanical studies, including our preliminary reports (2-4), also have documented the changes that range of motion (ROM) spinal movements exact at the adjacent vertebral level after spinal fusion, hybrid surgery, or cervical arthroplasty. Unfortunately, these investigations do not fully explain the degenerative disc changes that ensue.

According to recent speculation, altered spinal biomechanics may create pressure changes within adjacent discs after surgery. Although Nachemson (13) was first to use intradiscal pressure (IDP) for estimating in vivo load, others have examined the effects of spinal fusion on IDP in various postures (5, 6), and some have suggested that assessing the load transmitted by facet joints (facet contact force [FCF]) is another critical component in biomechanical evaluation of the spine (11, 15).

We subsequently sought to stratify adjacent-level IDP and FCF in vivo according to type of surgery performed: 2-level cervical fusion, 2-level disc arthroplasty, or single-level hybrids thereof. Using cadaveric simulations of these procedures, we sought to gauge the potential for later development of ASD.

MATERIALS AND METHODS

In Vitro Cadaveric Testing

Twenty-four cadaveric human cervical spines (C3-T2) were selected for study, excluding those with bony deformity by fluoroscopic radiographs (anteroposterior and lateral views) and low bone mineral density by dual-energy X-ray absorptiometry scan (Discovery QDR Series; Hologic, Inc, Bedford, Massachusetts, USA), equating osteoporosis with a T score < -2.5.

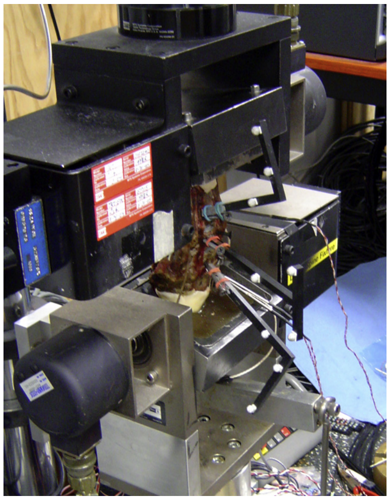

Figure 1. Oblique view of the testing setup shows the cadaveric human cervical spine (C3–T2) specimen potted in the potting fixture and attached to the spine biomechanical loading frame.

The specimens were thawed overnight at room temperature and were meticulously stripped of muscles, with careful preservation of spinal ligaments and facet joints. Each specimen was immobilized by inserting screws at C3 and T2 terminals, and screws were mounted in the potting fixtures of a material testing machine (MTS 858, Mini Bionix II Test System; Eden Prairie, Minnesota, USA) using poly(methyl methacrylate) and polyester resins (Figure 1). The cadaveric spines were then separately hoisted onto the mechanical loading frame for simulation testing in extension, flexion, and bilateral axial rotation.

Discectomy, Fusion, and Artificial Disc Implantation

Anterior discectomies at C5–C6 and C6–C7 were performed using the Smith-Robinson technique. Most of the human cadaveric spines available showed significant degenerative loss of disc height. Only specimens with adequate disc height were acceptable for study. Cervical fusion was done by inserting a 7-mm anterior cervical fusion plastic spacer, in conjunction with an anterior cervical plate and screw system (Cervical Locking Spine Plates; Synthes Spine, West Chester, Pennsylvania, USA). A 7-mm thick artificial cervical disc (Pro-Disc-C; Synthes Spine) was used for arthroplasty. Each step complied with the recommended surgical technique. Fluoroscopy was used to correctly position the cervical fusion plate/screws and disc prosthetics. Therapeutic arms (Figure 2) were grouped as follows: 1) 2-level C5-C6/C6-C7 ACDF (FF), 2) C5-C6 disc arthroplasty with ProDisc-C plus C6-C7 ACDF (PF), 3) C5-C6 ACDF plus C6-C7 disc arthroplasty with ProDisc-C (FP), and 4) 2-level C5-C6/C6-C7 disc arthroplasty with ProDisc-C (PP).

Biomechanical Testing

Specimen kinetics were tested in 3 modes (extension, flexion, and bilateral axial rotations) via the use of a load control protocol, whereby up to 2 Nm was applied for each mode at a rate of 0.2 Nm/second. During each test phase, a constant compression preload of 100 N was applied via 2 loading cables passed through the center of rotation in the sagittal planes at left and right sides of the spine. To minimize the viscoelastic variation, the specimen was loaded 3 times, and only the third attempt was recorded. IDP and FCF values were obtained above (C4–C5) and below (C7–T1) operative level. Pressure transducer needles (Model 6376; Robert A Denton, Inc, Rochester Hills, Michigan, USA) inserted into targeted discs had 3 sensors to record pressures simultaneously at posterior, central, and anterior disc locations. Needle tips were inserted ~2 cm into the disc, positioning transducer #2 at the center, with transducers #1 and #3 at posterior and anterior locations, respectively. Pressures were thus recorded at posterior annulus fibrosus (#1), center of disc nucleus (#2), and anterior annulus fibrosus (#3). Strain gauges (Model CEA-06-062UW-350; Vishay Micro-Measurements, Wendell, North Carolina, USA) also were mounted on C4–C5 and C7–T1 facet joint surfaces, allowing evaluation of FCF above and below operative level. Pressure transducer and strain gauge signals were amplified by a signal conditioner (System 2100; Vishay Micro-Measurements) and recorded by the mechanical test system.

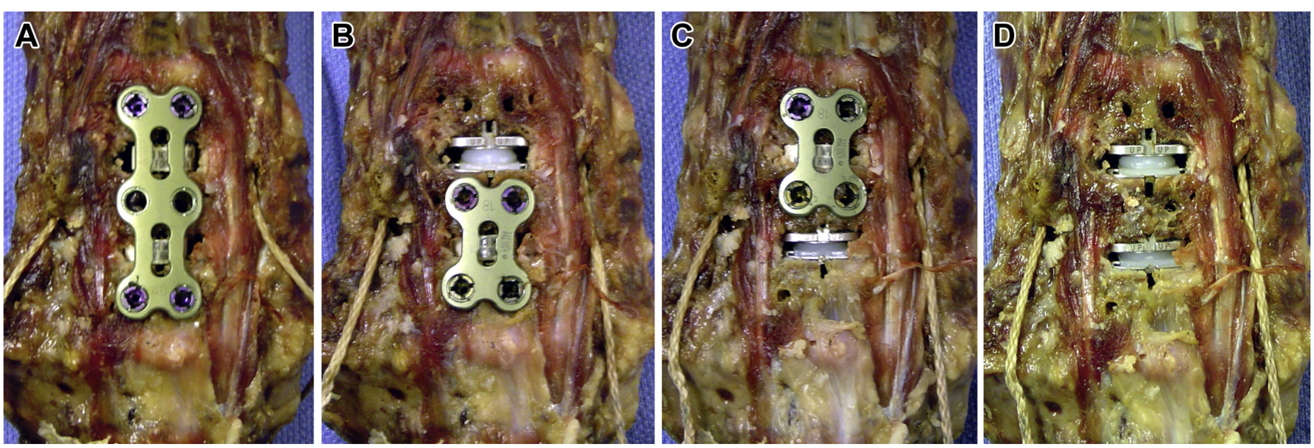

Figure 2. Anterior view of test specimens, grouped by implantation by method. (**A**) FF: 2-level C5–C6/C6–C7 anterior cervical discectomy and fusion, (**B**) PF hybrid: C5–C6 ProDisc-C arthroplasty plus C6–C7 ACDF, (**C**) FP hybrid: C5–C6 ACDF plus C6–C7 ProDisc-C arthroplasty, and (**D**) PP: 2-level C5–C6/C6–C7 ProDisc-C arthroplasty.