Zero-profile hybrid fusion construct versus 2-level plate fixation to treat adjacent-level disease in the cervical spine

Laboratory investigation

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Object. Single-level anterior cervical discectomy and fusion (ACDF) is an established surgical treatment for cervical myelopathy. Within 10 years of undergoing ACDF, 19.2% of patients develop symptomatic adjacent-level degeneration. Performing ACDF adjacent to prior fusion requires exposure and removal of previously placed hardware, which may increase the risk of adverse outcomes. Zero-profile cervical implants combine an interbody spacer with an anterior plate into a single device that does not extend beyond the intervertebral disc space, potentially obviating the need to remove prior hardware. This study compared the biomechanical stability and adjacent-level range of motion (ROM) following placement of a zero-profile device (ZPD) adjacent to a single-level ACDF against a standard 2-level ACDF.

Methods. In this in vitro biomechanical cadaveric study, multidirectional flexibility testing was performed by a robotic spine system that simulates flexion-extension, lateral bending, and axial rotation by applying a continuous pure moment load. Testing conditions were as follows: 1) intact, 2) C5–6 ACDF, 3) C4–5 ZPD supraadjacent to simulated fusion at C5–6, and 4) 2-level ACDF (C4–6). The sequence of the latter 2 test conditions was randomized. An unconstrained pure moment of 1.5 Nm with a 40-N simulated head weight load was applied to the intact condition first in all 3 planes of motion and then using the hybrid test protocol, overall intact kinematics were replicated subsequently for each surgical test condition. Intersegmental rotations were measured optoelectronically. Mean segmental ROM for operated levels and adjacent levels was recorded and normalized to the intact condition and expressed as a percent change from intact. A repeated-measures ANOVA was used to analyze the ROM between test conditions with a 95% level of significance.

Results. No statistically significant differences in immediate construct stability were found between construct Patterns 3 and 4, in all planes of motion (p > 0.05). At the operated level, C4–5, the zero-profile construct showed greater decreases in axial rotation (–45% vs –36%) and lateral bending (–55% vs –38%), whereas the 2-level ACDF showed greater decreases in flexion-extension (–40% vs –34%). These differences were marginal and not statistically significant. Adjacent-level motion was nearly equivalent, with minor differences in flexion-extension.

Conclusions. When treating degeneration adjacent to a single-level ACDF, a zero-profile implant showed stabilizing potential at the operated level statistically similar to that of the standard revision with a 2-level plate. Revision for adjacent-level disease is common, and using a ZPD in this setting should be investigated clinically because it may be a faster, safer alternative.

Key words • anterior cervical discectomy and fusion • biomechanics • zero-profile fusion device • adjacent-level disease

Abbreviations used in this paper: ACDF = anterior cervical discectomy and fusion; ACP = anterior cervical plate; AR = axial rotation; FE = flexion-extension; LB = lateral bending; PMMA = polymethylmethacrylate; ROM = range of motion; ZPD = zero-profile device.

Anterior cervical plate (ACP) fixation is routinely used in conjunction with ACDF, because it has been shown to significantly improve fusion rates for single- and multilevel procedures and it reduces the risk of pseudarthrosis and graft extrusion.15,18,27 Although ACDF is an established treatment, with fusion rates up to 95% for single-level surgeries,15,18 19.2% of patients will develop...
symptomatic adjacent-level disease in the 10 years after initial surgery. Overall, 7%–15% of ACDF cases will need revision surgery, which is associated with greater complications and risk and is technically more challenging. The extent to which alterations of adjacent-level biomechanics and intradiscal pressures accelerate the normal degenerative process remains unclear at this time.

Fusing a level adjacent to a prior ACDF often calls for exposing and removing the previously placed plate and screws. This additional step has the potential to prolong operating time and exposure magnitude, which may correlate with outcomes and infection rates. Alternative treatments for adjacent-level disease include total disc arthroplasty at the adjacent level; however, arthroplasty is an option only in select patient groups. A recent consideration since the advent of the zero-profile device (ZPD) is the placement of such implants adjacent to previously fused segments.

Zero-profile implants combine an interbody cage, which provides stability necessary for bony fusion to occur and restores disc height, with an anterior plate, which further stabilizes the spine during extension, into a single device that does not extend beyond the intervertebral disc space. Such implants minimize contact between instrumentation and local anatomical structures, including adjacent levels, and can potentially avoid complications of unnecessary soft-tissue injury seen with revision ACDF. Scholz et al. evaluated the biomechanical stability of the Zero-P implant (Synthes, Inc.) and showed that it provided similar stability, with slightly greater motion in extension, compared with an anterior plate plus cage for a single level. Clavenna et al. demonstrated that using zero-profile implants for 2- and 3-level ACDFs had biomechanical stability comparable to that of traditional anterior plate and interbody cage systems. Some clinical studies with ZPDs have shown a decreased incidence of dysphagia-related symptoms compared with traditional ACDF and no implant-related complications.

In this study, we sought to evaluate the kinematic changes in operated and adjacent segmental levels following the placement of a ZPD at the level adjacent to prior ACDF and to compare these results with those after a standard 2-level ACDF. We hypothesized that a ZPD placed supraadjacent to a single-level ACDF would less effectively stabilize the operative segment than a standard 2-level ACDF.

Methods

Specimen Preparation

Nine fresh-frozen cadaveric human spines (C-2 to T-1; 5 males, 4 females; mean age 54.1 years, range 30–68 years) were used. These specimens were assessed for any significant structural defects or anatomical abnormalities through visual inspection and anterior-posterior and lateral radiographs prior to testing. Each specimen was carefully dissected to remove all nonligamentous soft tissue, including paraspinal musculature. The vertebral bodies, discs, facet joint capsules, anterior and posterior longitudinal ligaments, and interspinous and supraspinous ligaments were preserved. The spine was then frozen at −20°C until testing.

Experimental Procedure

In vitro multidirectional flexibility testing was implemented using a 6-axis robotic spine testing system (KUKA, KR-16 GmbH; Fig. 1). The cervical spine specimens were secured onto the testing system using custom-designed spinal fixtures. The mounting procedure and robotic test system have been described in detail in previous studies. For this study, the robot was programmed to apply 3 continuous loading and unloading cycles of applied moment along each primary axis of motion to simulate flexion-extension (FE), lateral bending (LB), and axial rotation (AR). The specimens were preconditioned to eliminate any viscoelastic effects. Range of motion (ROM) between vertebral segments was determined from the final loading cycle for each specimen. The relative vertebral motion was captured using an optoelectronic camera system (Optotrac, Northern Digital Inc.). An array of 3 noncollinear infrared light–emitting diodes were rigidly affixed to each vertebral body. The camera system was used to track and measure the motion of each array.

The spine was thawed to room temperature overnight prior to the test day and was kept moist throughout testing by lightly spraying exposed tissues with saline solution. On the day of testing, the specimen, rigidly affixed to the custom spinal fixtures, was mounted onto the robot.

Fig. 1. The robotic testing apparatus.
The spine’s posture was adjusted to its neutral posture, and this position was recorded by the test system. Each specimen was subjected to 3 cycles of FE, LB, and AR at an applied moment of ± 1.5 Nm with a constant vertical force of 40 N. Before the start of a new test condition, the spine was returned to its initial neutral position. After intact specimen testing, the hybrid test protocol originally developed by Panjabi was implemented to evaluate each surgical condition and determine operated-level and adjacent segment-level kinematics. This test protocol applies a continuous incremental load (under hybrid control) on the specimen after each surgical intervention and replicates the specimen’s intact kinematic motion obtained from the prior intact flexibility test.

**Surgical Conditions**

The flexibility tests were first performed on each intact specimen to determine intact kinematics, followed by the hybrid test protocol after the following surgical conditions: 1) single-level ACDF (C5–6) with ACP plus polymethylmethacrylate (PMMA) (Fig. 2A); 2) 2-level ACDF (C4–6) “hybrid ZPD-ACP construct” with ZPD device (Synthes) at C4–5 and ACP at C5–6 (Fig. 2B); and 3) 2-level ACDF (C4–6) with 2-level ACP (Fig. 2C). The latter 2 surgical conditions were randomized to eliminate potential bias. Each procedure was supervised by a fellowship-trained staff neurosurgeon (T.B.F.) and performed by a neurosurgical resident (A.T.H.). The procedures were performed in clinically relevant fashion, sparing supra- and subadjacent ligamentous integrity. ACDF was performed while placing the specimen in adequate extension and distraction. An annulotomy was performed, after which intervertebral disc material was resected and scraped from the endplates with curette tools. The posterior longitudinal ligament was incised and resected with Kerrison rongeurs. The largest possible fibular ring allograft was secured into the disc space under distraction, after which the specimen was moved back to neutral position. After verification of secure graft placement, a single-level ACP was secured at C5–6. This was followed by injection of PMMA around the allograft to fill the disc space (C5–6), to reproduce the effects of a fusion at this level.

At C4–5, either the ZPD (with 2 up-going and 2 down-going screws) was placed or a fibular allograft was placed with removal of the subadjacent single-level plate and placement of a 2-level ACP spanning C4–6. In a clinically relevant fashion, any screw replacement required upsizing screw diameter and length.

**Data and Statistical Analysis**

Mean segmental ROM for operated levels C4–5 and C5–6, as well as adjacent levels C2–3, C3–4, C6–7, and C7–T1, was determined from the final loading cycle of each condition. Intact ROM was measured in this study as the angular motion between the segments at peak applied moment, ± 1.5 Nm. After each surgical procedure, the moment required to reach intact ROM during the hybrid test protocol was also reported. All results were normalized to intact conditions and expressed as a percent change from intact condition. Statistical analysis was performed using Minitab 16 (Minitab Inc.). A repeated-measures ANOVA was used to analyze the ROM between test conditions with a 95% level of significance. Post hoc Tukey-Kramer analysis (p < 0.05 considered statistically significant) was used for multiple comparisons of the ROM between conditions.

**Results**

Table 1 shows the mean ± SD ROM values for the intact, single-level ACDF, 2-level ACDF, and zero-profile constructs. The graphs in Fig. 3 show the percent change in ROM with respect to intact condition for the different surgical conditions in FE, LB, and AR.
TABLE 1: Range of motion values for intact and instrumented spines*

<table>
<thead>
<tr>
<th>Construct</th>
<th>C2–3</th>
<th>C3–4</th>
<th>C4–5</th>
<th>C5–6</th>
<th>C6–7</th>
<th>C7–T1</th>
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<tr>
<td><strong>ROM (°)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td><strong>FE</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>intact</td>
<td>5.06 ± 1.41</td>
<td>9.47 ± 2.97</td>
<td>12.0 ± 2.20</td>
<td>13.9 ± 2.96</td>
<td>9.68 ± 5.38</td>
<td>5.45 ± 1.72</td>
</tr>
<tr>
<td>single-level ACDF</td>
<td>6.24 ± 1.41</td>
<td>10.7 ± 3.24</td>
<td>13.8 ± 2.35</td>
<td>7.84 ± 3.50</td>
<td>10.8 ± 5.74</td>
<td>6.38 ± 1.81</td>
</tr>
<tr>
<td>ZPD</td>
<td>6.90 ± 1.87</td>
<td>11.6 ± 3.84</td>
<td>7.95 ± 3.66</td>
<td>10.5 ± 3.83</td>
<td>11.7 ± 5.94</td>
<td>7.18 ± 2.72</td>
</tr>
<tr>
<td>2-level ACDF</td>
<td>7.92 ± 1.45</td>
<td>13.1 ± 3.79</td>
<td>7.23 ± 2.86</td>
<td>8.21 ± 3.17</td>
<td>11.9 ± 6.26</td>
<td>7.47 ± 2.81</td>
</tr>
<tr>
<td><strong>AR</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>intact</td>
<td>3.09 ± 2.58</td>
<td>9.22 ± 4.11</td>
<td>10.7 ± 3.43</td>
<td>7.05 ± 2.17</td>
<td>3.95 ± 2.18</td>
<td>3.39 ± 1.00</td>
</tr>
<tr>
<td>single-level ACDF</td>
<td>3.45 ± 2.76</td>
<td>9.73 ± 4.47</td>
<td>11.5 ± 3.68</td>
<td>3.64 ± 2.59</td>
<td>4.46 ± 1.80</td>
<td>3.96 ± 1.28</td>
</tr>
<tr>
<td>ZPD</td>
<td>3.98 ± 3.32</td>
<td>10.6 ± 4.64</td>
<td>5.88 ± 3.01</td>
<td>5.04 ± 2.18</td>
<td>5.39 ± 2.27</td>
<td>4.53 ± 1.55</td>
</tr>
<tr>
<td>2-level ACDF</td>
<td>4.09 ± 3.38</td>
<td>10.8 ± 5.37</td>
<td>6.91 ± 3.01</td>
<td>4.06 ± 1.94</td>
<td>5.28 ± 2.49</td>
<td>4.52 ± 1.69</td>
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<tr>
<td><strong>LB</strong></td>
<td></td>
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<td></td>
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<tr>
<td>intact</td>
<td>7.21 ± 3.85</td>
<td>10.6 ± 2.20</td>
<td>11.4 ± 4.18</td>
<td>9.07 ± 2.73</td>
<td>7.76 ± 4.19</td>
<td>4.01 ± 1.46</td>
</tr>
<tr>
<td>single-level ACDF</td>
<td>9.05 ± 3.50</td>
<td>11.9 ± 2.56</td>
<td>11.9 ± 3.44</td>
<td>4.10 ± 2.49</td>
<td>8.59 ± 4.32</td>
<td>4.51 ± 1.42</td>
</tr>
<tr>
<td>ZPD</td>
<td>11.6 ± 3.27</td>
<td>13.7 ± 3.16</td>
<td>5.14 ± 2.36</td>
<td>5.76 ± 2.24</td>
<td>9.76 ± 4.62</td>
<td>5.36 ± 1.60</td>
</tr>
<tr>
<td>2-level ACDF</td>
<td>10.8 ± 3.53</td>
<td>13.4 ± 3.56</td>
<td>7.17 ± 3.10</td>
<td>4.27 ± 2.36</td>
<td>9.59 ± 4.68</td>
<td>5.23 ± 1.54</td>
</tr>
</tbody>
</table>

* Values are expressed as the mean ± SD. Boldface type values indicate a significant difference from intact condition (p ≤ 0.05).

![Fig. 3. Percent change in ROM in FE (A), LB (B), and AR (C).](image-url)
Zero-profile fusion device versus 2-level plate fixation

Intact Condition

Range of motion was recorded in the native state for every subaxial cervical level. FE was found to be greatest at C5–6 (average 13.97°; range 7.1°–17.4°), followed by C4–5 (average 12.05°; range 9.2°–14.6°), and was least at the terminal ends of the specimen (C2–3, average 5.06°; C7–T1, average 5.45°). LB and AR exhibited similar trends except that C4–5 was more mobile than C5–6 in LB (average 11.48° vs 9.07°, respectively) and in AR (average 10.71° vs 7.05°).

Single-Level ACDF (C5–6)

Single-level ACDF showed a statistically significant decrease in ROM at the operated level, C5–6 in FE (–43.9%, \( p = 0.0029 \)), LB (–54.8%, \( p = 0.0009 \)), and AR (–48.4%, \( p = 0.014 \)) compared with the intact condition. This significant decrease in C5–6 ROM was associated with a trend toward increased motion at adjacent segments levels. However, increases at nonoperated levels were not statistically different from the intact condition. We found that adjacent-level motion increased by an average of 16.1%, 13.0%, and 11% during FE, LB, and AR, respectively (Fig. 3). The largest increase in adjacent-level motion occurred at C2–3 during FE (23.3%, \( p = 0.38 \)) and LB (25.5%, \( p = 0.69 \)), whereas the subadjacent level (C6–7) showed the largest increase in ROM during AR (16.8%, \( p = 0.82 \)).

Two-Level ACP Versus Hybrid ZPD-ACP Construct

We observed that operated-level ROM (C4–5) after 2-level ACP fixation showed a significant reduction in motion compared with the intact condition in FE (–40.0%, \( p = 0.0053 \)), LB (–37.5%, \( p = 0.04 \)), and AR (–35.5%, \( p = 0.04 \)). Similar results were observed with the ZPD at C4–5 in FE (–34.0%, \( p = 0.02 \)), LB (–52.2%, \( p = 0.002 \)), and AR (–45.1%, \( p = 0.02 \)). In terms of immediate cervical stability, both construct patterns showed a statistically similar reduction in motion at the operated level, C4–5.

When analyzing the effects on adjacent levels, in FE the 2-level ACP caused an average of 38.9% (range 23.7%–56.7%) increase in motion at the adjacent levels. The most pronounced increase in motion occurred at C2–3 (56.7%, \( p = 0.0023 \)). Other nonoperated cervical levels exhibited no significant change in motion compared with the intact condition. In contrast, the ZPD construct increased adjacent-level FE ROM by an average of 28% (range 20.9%–36.4%) in FE (\( p > 0.05 \)). Although C2–3 ROM was the most pronounced adjacent-level increase for the ZPD, the observed change was not significantly different from intact condition (36.4%, \( p = 0.08 \)). In LB, adjacent-level motion on average increased by 32.5% (range 23.6%–49.8%, C2–3 being the greatest) for 2-level ACP construct and 37.4% (range 25.8%–61.7%, C2–3 being the greatest) for the ZPD. Even though both constructs showed a trend toward increased adjacent-level motion, the resulting differences were not significant compared with the intact condition. In AR, the 2-level ACP construct showed no significant change in motion at all adjacent levels (mean 29.1%, range 17.2%–33.6%, C6–7 being the greatest). Similarly, for the ZPD, we found no significant increase in adjacent-level motion compared with the intact condition (mean 28.4%, range 15.2%–36.4%, C6–7 being the greatest).

Compared with intact loading condition (1.5 Nm), the average maximum moment required to reach intact ROM after 2-level ACP placement increased by 155%, 50%, and 86% for FE, LB, and AR, respectively. Similarly, the ZPD required an increase of 157%, 64%, and 78% for FE, LB, and AR, respectively. Both constructs showed statistically similar stiffness in all 3 planes of motion.

Discussion

We found that a ZPD had a stabilizing potential at the operated level that was statistically similar to that of the standard revision with a 2-level plate when treating degeneration adjacent to a single-level ACDF.

The biomechanical feasibility of the ZPD as an alternative to ACP has been addressed for single-level\textsuperscript{35} and multilevel\textsuperscript{6} constructs. Both prior studies have found equivalence with nonstatistically greater motion in FE with a ZPD.\textsuperscript{10,35} Anecdotally, we have found clinical utility of the ZPD when treating disease adjacent to a prior ACDF with ACP. Knowing that the level adjacent to an ACDF incurs greater pressures and shear forces,\textsuperscript{14,31} we hypothesized that a hybrid construct (with a cervical plate subadjacent to a ZPD) may impart greater forces and perhaps accentuate the previously described difference in FE stiffness afforded by the ZPD.

This common clinical scenario where the ZPD is placed adjacent to a previous ACP may offer a number of theoretical advantages, including minimal dissection of the prior surgical level, obviating the removal of previously placed plate and screws and reducing the additional retraction needed for 2-level plate exposure and placement. All the aforementioned possibilities have the potential to reduce operating time and dysphagia risk.\textsuperscript{24}

Observational clinical results have suggested lower rates of dysphagia at 6-month follow-up with a single- or multilevel ZPD compared with traditional ACDF, in addition to 100% fusion rates.\textsuperscript{86} Prospective, long-term clinical outcomes are not presently available but are currently under way.\textsuperscript{32}

Our study found that the hybrid ZPD-ACP construct showed biomechanical characteristics statistically similar to those of the 2-level ACP construct. Relative stiffness provided by either construct was nearly identical. Our results for the operated level, C4–5, were comparable to those of Scholz et al.,\textsuperscript{35} who found that the ZPD showed biomechanical stability similar to that of single-level ACDF. With regard to adjacent-level effects, both constructs showed comparable outcomes for all levels except the supraadjacent level C2–3, which exhibited a significant increase in FE ROM following the placement of a 2-level ACP. This difference in adjacent-level motion may highlight the differing adjacent-level effects of the 2 constructs. However, additional factors may contribute to this difference seen at C2–3. First, there were trends toward greater reductions in FE ROM with the ACP construct. This, coupled with the utilization of the hybrid model, may have also contributed to the statistical
increase in adjacent-level ROM. The hybrid protocol assumes that patients, in general, attempt to move the spine in a similar manner after instrumentation, compared with the presurgical scenario. However, the implementation of this protocol required loading of the spine to potentially nonphysiological magnitudes. In our study, loads peaked at an average of 3.85 Nm to achieve intact ROM for FE. Perhaps lower loads would not have created this statistically significant increase in motion at the nonfused segments. On the other hand, this difference may allude to different adjacent-level effects of the ZPD. The ability of both constructs to withstand these supraphysiological forces, however, is a testament to their stability.

We noted a couple of trends that did not reach clinical significance but are worth mentioning: 1) the 2-level ACP more effectively reduced FE, and 2) the hybrid ZPD-ACP construct more effectively reduced AR and LB. Mechanically, the greater limitation of FE by the 2-level ACP is expected. Both existing studies that examined the ZPD revealed trends toward decreased FE stiffness with the ZPD, whereas LB and AR were equal. We expect this difference intuitively: with a fixed moment arm cantilever such as in the 2-level ACP, the ACP will act as a tension band fixator in extension, effectively resisting motion in this direction, likely better than a construct with 2 separate components. In flexion, too, the plate bears this axial load and acts as a distracting force, limiting flexion more than would an internally situated ZPD. It is also possible that a rigid ACP will less effectively resist LB and AR compared with FE, as has been shown in other studies. The trend found that the ZPD may more effectively reduce motion in AR, and LB may be concordant with the kinematics of a rigid anterior device. The fixation point of the ZPD is closer to the operated segment’s native instantaneous axis of rotation, which may reduce the lever arm and, therefore, bending moment experienced by the dorsal elements with the 2-level ACP. These attributes of ACP fixation are more apparent in 2- and 3-column injuries and multilevel corpectomies; however, the same principles likely contribute to the non-statistically significant differences observed herein.

From a clinical standpoint, we feel the overall equivalence of the 2 constructs is sufficient to encourage the use of the ZPD adjacent to previous levels of fusion. Prospectively collected clinical data, of course, would be optimal and necessary to draw definitive conclusions regarding the equality and benefits of the ZPD in this specific scenario. Furthermore, biomechanical proof of efficacy would require a cyclical testing study. From a procedural standpoint, placement of the ZPD was more straightforward in this revision situation. Procedural time was not calculated, but determining appropriate plate size and position, in addition to using previous screw holes in the C-5 and C-6 vertebral bodies, accounted for anecdotally longer procedural times and difficulty. Even without the presence of the vital anterior cervical soft tissues and the need for retraction and scar tissue dissection, we favored the ZPD from a technical standpoint: The 2 screws placed into the C-5 vertebral body did not interfere with already existent screws from the C5–6 ACDF.

Our current testing system has been validated and supported by previous investigations in cervical, thoracic, and lumbar biomechanical studies. It is unique in its ability to efficiently combine both load control and displacement control for testing of multisegmental specimens. It also provides the flexibility to control both the loading and boundary conditions, desired for conducting biomechanical tests. The multiaxial motion system is capable of applying continuous primary loads while simultaneously minimizing all off-axis loads in an unconstrained, reliable, and reproducible manner. The versatility of the robotic testing system permitted serial testing of all 3 major axes without the need to reposition or reorient the specimens at any time. In this study, we used the hybrid control algorithm to determine both operated-level and adjacent-level kinematics for each surgical condition. A novel head weight loading protocol was also used in our study to simulate a constant head weight, in addition to the application of moments, which better simulates physiological loading conditions and thus provides better translation of in vitro simulations for in vivo applicability. The axial compressive load due to the head could play a significant role in affecting the biomechanical stability of the spine following the placement of each construct.

We recognize a number of limitations of our study. The limitations include the use of cadaveric specimens. Although specimen processing is intended to be uniform, there is still intrinsic variability between specimens. Whether this is accounted for entirely by natural anatomical and physiological differences between specimens is unclear, and of course, a larger number of specimens would be useful to better define this variability. Furthermore, the immediate stability of the experimental construct does not imply long-term stability or equivalent fusion rates. The ZPD utilizes a polyetheretherketone interbody spacer, which may or may not result in decreased fusion rates when translated to a clinical population. The use of morcellized autograft or other fusion substrates could also affect fusion rates but was not addressed in this study. Finally, we acknowledge an important finding in the analysis of our data of the C5–6 level. We intended this level to be a “fused segment.” We sought minimal motion at this level and used PMMA in the interbody space around the spacer. Unfortunately, this model was insufficient, with only modest motion reduction. Previous studies have found it to be a useful model in compression but did not test it in other directions. This is an important point that should be considered in future investigations. Likely, a better model would have been to replicate the “external fixator-styled” fusion model reported by Lee et al. On the other hand, motion detected at this “fused” level may be partially attributable to the use of the hybrid testing protocol, asserting average peak moments of up to 3.85 Nm. Despite this limitation, both constructs were able to withstand these supraphysiological loads to a similar extent. Both constructs were tested in all specimens, in a randomized fashion, and therefore both experienced the same conditions and were determined to be equivalent.

Conclusions

In terms of immediate biomechanical stability at an
operated level adjacent to a prior ACDF, we found no significant difference between a zero-profile construct and a standard 2-level plate ACDF construct. Adjacent-level effects were largely equivalent as well. Cyclical loading of zero-profile constructs such as these may be the next step to confirm or refute biomechanical equivalence. Clinical trials to compare fusion rates, operating time, and surgical complication rates would also help us understand the important clinical implications of utilizing zero-profile constructs adjacent to previous anterior cervical fusions.

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Author contributions to the study and manuscript preparation include the following. Conception and design: Healy, Cardenas, Mageswaran, Benzel. Acquisition of data: Healy, Mageswaran. Analysis and interpretation of data: Healy, Mageswaran, Benzel, Mroz. Drafting the article: Healy, Sundar, Mageswaran, Benzel, Mroz. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Healy. Statistical analysis: Healy, Sundar, Mageswaran, Mroz. Administrative/technical/material support: Sundar, Mageswaran. Study supervision: Healy, Benzel, Mroz.

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