Biomechanical comparison of anterior Caspar plate and three-level posterior fixation techniques in a human cadaveric model

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Traumatic cervical spine injuries have been successfully stabilized with plates applied to the anterior vertebral bodies. Previous biomechanical studies suggest, however, that these devices may not provide adequate stability if the posterior ligaments are disrupted. To study this problem, the authors simulated a C-5 teardrop fracture with posterior ligamentous instability in human cadaveric spines. This model was used to compare the immediate biomechanical stability of anterior cervical plating, from C-4 to C-6, to that provided by a posterior wiring construct over the same levels. Stability was tested in six modes of motion: flexion, extension, right and left lateral bending, and right and left axial rotation. The injured/plate-stabilized spines were more stable than the intact specimens in all modes of testing. The injured/posterior-wired specimens were more stable than the intact spines in axial rotation and flexion. They were not as stable as the intact specimens in the lateral bending or extension testing modes. The data were normalized with respect to the motion of the uninjured spine and compared using repeated measures of analysis of variance, the results of which indicate that anterior plating provides significantly more stability in extension and lateral bending than does posterior wiring. The plate was more stable than the posterior construct in flexion loading; however, the difference was not statistically significant. The two constructs provide similar stability in axial rotation. This study provides biomechanical support for the continued use of bicortical anterior plate fixation in the setting of traumatic cervical spine instability.

KEY WORDS • biomechanics • cervical spine • spinal instrumentation • spinal fusion • spinal injury

Almost 80% of cervical spine trauma affects the lower cervical spine (C3–7). The most frequent site of cervical vertebral body fracture is C-5, and fracture/dislocation occurs most often at the C5–6 interspace. Flexion, with or without compression or distraction, is a common mechanism of injury. Flexion injuries resulting in fracture of the vertebral body are often associated with posterior ligamentous instability, and realignment may be difficult to achieve or maintain with conservative methods. Failure to realign the spine following a flexion injury increases the risk of developing a kyphotic deformity. Flexion injuries may result in anterior spinal cord compression secondary to the vertebral body fracture and/or traumatic disc herniation. Surgical management of teardrop fractures (a flexion/compression injury) is most efficaciously accomplished through an anterior route. Posterior bony and/or ligamentous injuries are frequently associated with these injuries; therefore, after anterior decompression, postoperative immobilization has been recommended.

Internal fixation with an anterior plate is an attractive method of providing postoperative stability in these patients because decompression, grafting, and stabilization may be performed through the same exposure. Previous biomechanical evaluations of anterior plate strength over a single motion segment, however, have suggested that this device may not provide adequate stability when the posterior ligamentous structures have been compromised. These previous studies examined plate strength over a single motion segment; however, anterior surgical treatment of cervical body fractures results in the fusion of two motion segments. We have developed a human cadaveric model that simulates an anterior teardrop fracture with posterior ligamentous instability to assess the immediate strength provided by an anterior cervical plate and a posterior construct over two motion segments.
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Materials and Methods

Specimen Preparation

Cervical spines (C2-T1) were obtained from donated human cadavers shortly after death. The specimens were sealed in doubled plastic bags and kept frozen at -20°C until testing. All specimens were screened with anteroposterior and lateral roentgenograms to exclude those with neoplasms, marked degenerative changes, and significant osteoporosis. After screening, 10 spines were determined to be of sufficient quality for study.

Prior to preparation and testing, the specimens were thawed to room temperature in a warm water bath for 2 hours. The integrity of the double-bag seal was maintained to limit any direct contact between the specimen and the water. When fully thawed, the paravertebral musculature was carefully dissected from each specimen to avoid disrupting the spinal ligaments. Two wood screws of nominal dimensions (⅛ x 20 x 2 in.) were placed in the T-1 body to provide extra purchase prior to mounting that vertebra in a plastic padding base.* The embedded spine was oriented in the neutral position with the C5-6 disc parallel to the testing base. After mounting, two threaded rods were drilled through the C-2 vertebra for attaching a loading frame. One of these rods was drilled through the base of the dens, parallel to the horizontal and sagittal planes, and the other was placed through the body of C-2 parallel to the horizontal and transverse planes. A loading frame (cut from polyvinyl chloride plumbing pipe 114 mm in diameter), with four holes corresponding to the ends of the rods drilled through the axis, was placed around the C-2 vertebra. Another set of four rods was secured to the loading frame by the use of specially constructed adapters. The combined mass of the frame and rods was about 70 gm.

Knowledge of the locations of three non-colinear points on a vertebra is sufficient to uniquely specify its position in space. This set of points was provided by rigidly attaching three infrared light-emitting diodes (LED’s) to each vertebra from C-3 to C-7. Two LED’s were secured to the ends of Steinmann pins drilled through the laminae of each vertebra and bent to face posteriorly. A third LED was wired to each spinous process from C-3 to C-7 (Fig. 1).

The three-dimensional (3-D) motion of the specimen was monitored with the Selspot II system;† which is a photoelectric system based on the principles of stereophotogrammetry. The LED’s, attached to the base and to each vertebra, are fired sequentially via an LED control unit. The emitted light is detected by two infrared cameras and expressed as X and Y voltages. The exact spatial position of each LED can be determined by processing the X and Y voltage data through a calibration matrix.

When viewing a 2-cu m volume, the Selspot I system is accurate to within 20 milliradians (1°) in rotation and 1 mm in translation. Accuracy improves markedly as the viewing volume is reduced. Calibration and verification studies undertaken by Goel, et al.,12,13 showed that the Selspot II system is accurate to within 0.5 mm in translation and 10 milliradians in rotation when used over a 0.25-cu m viewing volume. Accuracy of this order is more than adequate for in vitro 3-D spinal studies.

Testing of Intact Specimens

The prepared cadaveric spines were attached to the base of a testing cage. Experimental loads were applied in the form of moments exerted at C-2 through the use of a system of weights, pulleys, and nylon strings attached to the ends of the arms of the loading frames. This system enables one to approximate pure moments as closely as possible. To achieve this, the pulleys slide along movable suspension bars, directing the force so that the strings flex the spine in the desired plane for the desired load modality. For example, to produce axial rotation, the strings are arranged parallel to each other, in the transverse plane, pulling the loading arms in opposite directions.

The loads were applied in a graduated manner by progressive addition of 50-gm weights onto each string, thereby creating an incremental moment of 0.25 newton-meters (Nm). The maximum moment achieved was 1.00 Nm.

Every specimen was loaded in six modes of angular motion: flexion, extension, right and left lateral bending, and right and left axial rotation. Prior to and directly after every loading step within a mode of motion, the position of each LED was recorded by the Selspot II system. Before the start of loading in any direction, the spines were loaded and unloaded three times. The experimental preparations were sprayed with normal saline as deemed necessary during the course of testing.

Surgical Procedure and Stabilization

After the intact spine was tested, a teardrop fracture

† Selspot II system manufactured by Inovision Systems, Warren, Michigan.
of C-5 with associated posterior ligamentous disruption was simulated (Fig. 2). The posterior ligaments between C-5 and C-6 were almost totally disrupted surgically. The supraspinous and interspinous ligaments, ligamentum flavum, and facet capsules were incised. A cut passing caudally and dorsally from the anterior margin of the body of C-5 through the inferior end plate was made with an osteotome. This injury disrupted the anterior longitudinal ligament and damaged the disc. The majority of the posterior longitudinal ligament (PLL) was left intact in order to reproduce accurately the initial orientation. The injured spine was too unstable to test without fixation.

Stabilization was accomplished by first removing the C4–5 and C5–6 discs and the C-5 vertebral body. An appropriately sized iliac crest strut graft, obtained from a fresh cadaver, was placed in the surgical defect, and a Caspar plate was anchored to the C-4 and C-6 vertebral bodies (Fig. 3 upper). Care was taken to place the plate and screws exactly as recommended by the manufacturer, and bicortical screw purchase of C-4 and C-6 was achieved.* A unicortical anchoring screw secured the graft to the plate. The biomechanical testing sequence described previously was repeated.

The Caspar plate was removed after testing, and posterior stabilization was accomplished using a modification of the triple-wire construct described by Bohlman and Boada. Specifically, the spinous processes of C-4, C-5, and C-6 were wired together and then two iliac crest strut grafts were secured to these spinous processes with separate wires (Fig. 3 lower). All wires were made of No. 20 stainless steel. The entire sequence of tests was repeated.

Results

During the injury simulation of Specimen 10, it was discovered that the C-5 Steinmann pin, to which two LED’s were attached, passed through the C5–6 disc space. Although the rod was removed and replaced, the force-deformation characteristics of this spine differed markedly from the other specimens. Data from this specimen, therefore, were not used in the following analysis. Technical difficulties resulted in suboptimal detection of the LED signals in one posteriorly stabilized specimen during extension loading; therefore, extension data from only eight specimens were analyzed.

The spatial data recorded by the Selspot II system were described relative to a Cartesian system with coordinates defined by the three LED’s attached to the testing base (Fig. 4). In this system, the x-axis lies in the frontal plane with its positive direction toward the anatomical left of the spine, and the z-axis lies in the midsagittal plane with its positive direction anterior to the spine. The y-axis, a cross-product of the x- and z-axes, rises vertically. The spatial data were reduced to compute three Bryan/Eular angles as rotations between any two vertebrae after each increment of a load type. These rotational angles represent three distinct vertebral rotations: rotation in the sagittal plane, rotation in the transverse plane, and rotation in the frontal plane. Although rotation occurs in all three planes for any given load type, the rotation in one plane (major rotation) is an order of magnitude larger than the rotation in the other two planes (coupled rotations). For example, in flexion and extension, rotation in the sagittal

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* Caspar trapezial osteosynthetic plate manufactured by Aesculap, Inc., South San Francisco, California.
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**Fig. 4.** Illustration showing the Cartesian axis coordinates used in the data analysis in this study.

plane (± Rx) would represent the major rotation. Similarly, rotation in the transverse plane (± Ry) and in the frontal plane (± Rz) would represent the major rotations for axial rotation and lateral bending, respectively. Typical load-deformation curves for axial rotation of a single specimen are shown in Fig. 5. The ability of each construct to resist axial rotation can be appreciated by comparing the injured/stabilized curves to the load-deformation plots obtained from testing the intact specimen. For further details concerning data analyses, refer to previous publications.

The average major angular rotations across each of three motion segments (C4–5, C5–6, and C6–7) in the intact specimens are listed in Table 1. Tables 2 and 3 contain the corresponding average major angular rotations across these motion segments for the injured/stabilized specimens. The average major rotations presented in Tables 1, 2, and 3 are presented in Tables 1, 2, and 3 represent relative movement in the maximum loading condition only.

The relative rotations between injured/stabilized vertebral segments were normalized with respect to the intact specimen by the following relationship: \[ \text{NRj} = \frac{(Rj - Ro)}{Ro} \times 100 \], in which NRj represents the normalized relative rotational angle between two vertebrae about the j-axis (x, y, or z) for the injured/stabilized specimen at a specific load step (percentage).

**TABLE 1**

<table>
<thead>
<tr>
<th>Mode of Motion</th>
<th>C4/C5</th>
<th>C5/C6</th>
<th>C6/C7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lt axial rotation</td>
<td>3.00 ± 1.49</td>
<td>3.00 ± 0.80</td>
<td>2.10 ± 1.23</td>
</tr>
<tr>
<td>rt axial rotation</td>
<td>-2.58 ± 0.83</td>
<td>-2.82 ± 1.35</td>
<td>-1.66 ± 0.96</td>
</tr>
<tr>
<td>Lt lateral bending</td>
<td>-2.48 ± 1.76</td>
<td>-3.25 ± 1.06</td>
<td>-2.59 ± 1.54</td>
</tr>
<tr>
<td>rt lateral bending</td>
<td>2.53 ± 1.93</td>
<td>3.63 ± 2.60</td>
<td>3.07 ± 1.26</td>
</tr>
<tr>
<td>flexion</td>
<td>5.72 ± 2.68</td>
<td>6.18 ± 3.72</td>
<td>5.51 ± 1.92</td>
</tr>
<tr>
<td>extension</td>
<td>-2.06 ± 1.31</td>
<td>-1.91 ± 0.84</td>
<td>-2.61 ± 1.59</td>
</tr>
</tbody>
</table>

* Values presented are means ± standard deviations.

**TABLE 2**

<table>
<thead>
<tr>
<th>Mode of Motion</th>
<th>C4/C5</th>
<th>C5/C6</th>
<th>C6/C7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lt axial rotation</td>
<td>1.36 ± 0.91</td>
<td>2.22 ± 1.89</td>
<td>2.55 ± 1.65</td>
</tr>
<tr>
<td>rt axial rotation</td>
<td>-1.56 ± 0.78</td>
<td>-1.71 ± 2.27</td>
<td>-2.05 ± 1.34</td>
</tr>
<tr>
<td>Lt lateral bending</td>
<td>-1.60 ± 1.32</td>
<td>-2.02 ± 2.11</td>
<td>-2.89 ± 1.72</td>
</tr>
<tr>
<td>rt lateral bending</td>
<td>1.72 ± 1.12</td>
<td>2.57 ± 2.12</td>
<td>3.17 ± 1.59</td>
</tr>
<tr>
<td>flexion</td>
<td>1.19 ± 0.99</td>
<td>1.31 ± 0.93</td>
<td>5.31 ± 1.68</td>
</tr>
<tr>
<td>extension</td>
<td>-0.74 ± 1.36</td>
<td>-1.43 ± 1.36</td>
<td>-3.10 ± 1.83</td>
</tr>
</tbody>
</table>

* Values presented are means ± standard deviations.

**TABLE 3**

<table>
<thead>
<tr>
<th>Mode of Motion</th>
<th>C4/C5</th>
<th>C5/C6</th>
<th>C6/C7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lt axial rotation</td>
<td>1.83 ± 1.23</td>
<td>2.09 ± 0.91</td>
<td>2.67 ± 2.55</td>
</tr>
<tr>
<td>rt axial rotation</td>
<td>-1.71 ± 1.47</td>
<td>-2.35 ± 1.20</td>
<td>-2.17 ± 0.94</td>
</tr>
<tr>
<td>Lt lateral bending</td>
<td>-2.64 ± 0.83</td>
<td>-3.25 ± 1.82</td>
<td>-2.48 ± 1.76</td>
</tr>
<tr>
<td>rt lateral bending</td>
<td>2.87 ± 1.43</td>
<td>4.24 ± 2.42</td>
<td>3.50 ± 1.38</td>
</tr>
<tr>
<td>flexion</td>
<td>2.19 ± 2.24</td>
<td>1.24 ± 1.56</td>
<td>7.38 ± 3.02</td>
</tr>
<tr>
<td>extension</td>
<td>-1.92 ± 2.23</td>
<td>-3.48 ± 2.74</td>
<td>-1.90 ± 1.31</td>
</tr>
</tbody>
</table>

* Values presented are means ± standard deviations.

Rj is the relative rotational angle between two vertebrae (Rx, Ry, or Rz) for the injured/stabilized specimen at the corresponding load step, and Ro is the corresponding relative rotational angle for the intact specimen.

Normalization of motion serves to factor out speci-

**Fig. 5.** Load-deformation curves showing the axial rotation of an intact specimen (left), an injured specimen stabilized with an anterior plate (center), and an injured specimen with posterior wire stabilization (right).
men variability and helps to make comparisons between specimens more meaningful. Analysis of coupled motions involves manipulation of smaller numbers, making it difficult to draw any conclusions. For this reason, as in previous studies, normalization of the data was limited to the major angular rotations corresponding to the maximum loading condition (bending moment 1.0 Nm). While the results obtained from submaximum loading were not fully normalized, they were examined for each specimen (in each testing parameter) and found to follow the same trends of angular deformation as seen with maximum loading, only to a lesser degree.

The average normalized relative rotations, at maximum load, of the injured/stabilized spines are depicted in Fig. 6. As can be noted from the preceding discussion, a normalized relative rotation value of zero would indicate that the stability of the injured/stabilized specimen is identical to that of the intact specimen. Therefore, a positive value indicates that the intact specimen was stronger than the injured/stabilized spine and, conversely, a negative value denotes that the injured/stabilized spine resisted motion more than the intact specimen.

The injured/plate-stabilized spines were more stable than the intact specimens in all modes of testing. The injured/posterior-wired specimens were more stable than the intact spines when loaded for axial rotation and flexion testing. They were not as stable as the intact specimens in the lateral bending or extension testing modes.

The average normalized relative rotations (expressed in percentage degrees as opposed to angular degrees) of the plate-stabilized and posteriorly stabilized specimens were compared to each other using repeated measures of analysis of variance. These results indicated a significant difference between the stability provided by the two constructs in extension ($p < 0.0364$), left lateral bending ($p < 0.016$), and right lateral bending ($p < 0.030$). The plate was more stable than the posterior construct in flexion loading; however, the difference was not statistically significant. There was no significant difference between the two fixation methods in the ability to resist axial rotation.

**Discussion**

**Treatment Alternatives**

Treatment of cervical spine injuries consists of realignment of the spine, decompression of the spinal cord and nerve roots (which may be especially important in the management of an incomplete neurological deficit), and long-term stabilization. Operative intervention is generally indicated when the above-mentioned goals are not accomplished by conservative therapy (traction or external stabilization).

Traumatic lesions may be managed surgically via a posterior approach through which decompression may be accomplished with laminectomy, lateral discectomy, and/or foraminotomy. Bilaterally dislocated facets requiring surgical reduction are most effectively approached through a posterior exposure. Posterior stabilization can be achieved with wire and bone grafting to the spinous processes, laminae, or facets. Limitations of the posterior approach for fusion include extensive disruption of the posterior bone elements (in cases of pedicular, facet, or laminar fracture) and ventral spinal cord compression. When an anterior procedure is indicated, persistent cervical instability has been treated with either posterior fusion or external immobilization.

Internal fixation lessens or negates the requirement for postoperative immobilization, which is otherwise necessary to stabilize the patient while the fusion mass heals. Additionally, internal fixation may decrease the number of levels requiring fusion, may increase the probability of successful fusion, and is conducive to early patient mobilization. Internal stabilization with articular mass plates may be performed through a posterior exposure. Cervical vertebral body plates provide a means of achieving immediate internal stability via an anterior route. Utilization of such devices allows ventral decompression of the cervical neural elements and internal fixation through a single exposure. Anterior cervical plating systems have been used extensively to treat posttraumatic instability when conservative management is inappropriate or fails.

Safe and appropriate application of cervical instrumentation requires a knowledge of the biomechanics of each system. Quantitative biomechanical assessment can be performed only in the laboratory setting. Although there are limitations with any experimental model, careful evaluation of these devices using fresh high-quality human cadaveric spines can provide useful information.

**Study Model**

We have examined the biomechanics of the Caspar anterior cervical plate and a posterior wiring construct in a human cervical spine model with anterior and posterior instability. This experimental model differs slightly from those used by other investigators in that stabilization is performed over two motion segments.
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(C4–6) rather than one. Our results indicate that the anterior plate resists extension and lateral bending significantly more than posterior wiring. The anterior plate also provides more stability in flexion loading than the posterior construct; however, this difference is not statistically significant. The two constructs provide similar stability in axial rotation.

Biomechanical tests on human cadaveric spines may suffer from poor specimen quality. The average specimen age in this study was 68 years. The bone quality of each specimen was evaluated radiographically and clinically (at the time of testing) and only spines without significant degenerative disease or osteoporosis were used. Nevertheless, the quality of the ligaments and intervertebral discs in these specimens may differ substantially from that of a young trauma victim. Degeneration of the ligaments or discs should not alter the stability provided by the two fixation methods in this model because the discs are removed and the ligaments severed across the tested levels. Furthermore, degenerative cervical spine disease most commonly results in a decrease in motion across the affected segments. One may speculate, therefore, that a spinal specimen from a young individual may have more motion than that obtained from an elderly person. If this is true, then normalization of data obtained from older, less mobile spines will result in an overestimation of the relative stability provided by any stabilization procedure.

The paraspinous musculature was removed prior to testing. It is not clear how this affects the stability of the cervical spine. Muscles provide resistance against the extremes of motion (as do the spinal ligaments) and may alter stress distributions within the cervical spine. Biomechanical studies, however, suggest that muscle contraction may be positively associated with traumatic injuries.40 All in vitro models lack muscular support. In our model, normalization of the data with respect to the intact spine served to minimize the influence of any support that may or may not have been provided by the paraspinous musculature.

We attempted to simulate a teardrop fracture with posterior ligamentous instability. During the development of the model, the PLL was transected (in addition to the other posterior ligaments) and the specimen became totally disarticulated. The PLL was therefore not fully incised in the experimental specimens so the spines would remain in one piece. Other models of posterior ligamentous injury have spared the PLL.25 Although the PLL resists flexion and is frequently injured in patients with flexion/compression injuries, we do not consider that leaving this ligament intact significantly affected our results. Flexion stability following either plate fixation or posterior wiring was significantly greater than that of the intact specimen (repeated measures analysis of covariance of baseline adjusted means, p = 0.014). If the PLL provided meaningful resistance to flexion in our injury model, then this difference would not occur.

We always tested the anterior construct prior to evaluating the posterior stabilization. Because the order of the procedure testing was not random, error may have been introduced.

Previous Biomechanical Studies

Only a limited number of laboratories have investigated the biomechanical properties of anterior cervical spine implants in human cadavers. Ulrich, et al.,25 examined various stabilization procedures using a spine preparation limited to C5 and C-6. A vertical tensile force was applied to the base of the C-5 spinous process to create flexion, and motion was measured with vertical and horizontal displacement transducers. Each spine was studied while intact and after disruption of the posterior ligaments, and the respective tilting angles and translation were calculated. The authors concluded that an anterior H-shaped plate, in the setting of posterior instability, did not provide the same degree of strength as a posterior hook-plate and, furthermore, that postoperative external immobilization was necessary to prevent abnormal flexion if an H plate only was used in such situations. Axial rotation, lateral bending, and extension were not examined nor were the data statistically analyzed.

In a later study, Ulrich, et al.,22 examined the ability of cadaveric C5–6 preparations to resist flexion and torsion. After evaluation of the intact segment, the supraspinous ligaments, interspinous ligaments, ligamentum flavum, and capsular ligaments were incised. Repeat testing of the injured segment, interestingly, demonstrated an increase in flexural stability. This phenomenon was not observed in the previous work of these investigators.24 While the authors attributed the apparent increased stability of the injured/noninstrumented specimen to diminished disc preload, it may also represent an error in data accumulation. The ability of the injured/stabilized segments to resist flexion and torsion was examined. The anterior H plate was the least strong of the constructs when tested in flexion; however, it was more rigid than the intact specimen. In this model, the anterior plate did not restore torsional stability. Complete segmental instability was also evaluated. The spines were totally separated at the C5–6 level and the discs replaced with a bone graft. Stabilization was then accomplished by posterior laminar wiring, posterior hook-plate placement, anterior H plating, and combined anterior and posterior plating. While the data from this investigation suggests that the flexural stability provided by the anterior plate was less than that of the intact specimen, no statistical analysis was performed.

The biomechanics of cervical stabilization procedures have also been studied by Coe, et al. These investigators, applying loads to simulate compression, flexion, extension, and rotation, focused on the C5–6 motion segment. The specimens were first tested while intact, then a simulated destructive-flexion Stage 3, according to the classification of Allen, et al.,4 was created by sectioning the posterior ligaments to allow bilateral C5–6 facet dislocation. The stability of eight different constructs was examined before and after cyclic loading (100 cycles). The most useful testing parameter before cyclic loading was the static flexion test. There was no statistical difference in the flexural stiffness provided by the various constructs; however, the anterior plate failed to reduce posterior strain to the level of the intact spine, and this difference was statistically significant. There
was no statistical difference in the ability of the constructs to reduce anterior strain or torsional instability. The biomechanical strength of the constructs following cyclic loading was similar.

Montesano, et al.,\(^7\) compared the effectiveness of anterior plate stabilization to that of posterior wiring following complete posterior ligamentous injury, and concluded that the stiffness produced by posterior wiring equaled that of the intact specimen and was greater than that provided by anterior plate fixation. Specific details of the experimental design were not presented, and the data were not examined statistically.

Several factors limit the usefulness of these studies. First, failure to place an intervertebral graft in conjunction with the anterior plate may have affected the results.\(^9,10,34,35\) Schulte, et al.,\(^21\) studied the immediate biomechanical stability of the cervical spine following discectomy without intervertebral grafting, with placement of a Smith-Robinson graft, and with grafting and anterior plating. They demonstrated that placement of the iliac crest graft significantly increased stability as compared to stability after simple discectomy, and the strength across the treated segment was further increased with the addition of the anterior cervical plate. Furthermore, clinical experience has demonstrated that plating should not be carried out over an intact vertebral disc.\(^3,4,5\) Failure to replace the disc with a bone graft, therefore, most likely added to the flexion instability of anterior plate fixation in these models.

Osteoporotic bone is a relative contraindication to any plate/screw fixation. Of the studies described, only Montesano, et al.,\(^7\) screened for osteoporosis (by computerized tomography) prior to accepting spines for study. Specific reference concerning poor bone quality of the specimens is made by two investigators,\(^3,4\) and the use of osteoporotic specimens may have adversely affected the biomechanical performance of the anterior plates.

Finally, only Coe, et al.,\(^9\) subjected their data to statistical testing. Unless a statistical difference between two groups of data can be shown, one must conclude that the groups are identical.

**Clinical Application**

Vertebral body fractures have been treated by corpectomy, strut graft placement, and immobilization when surgery is indicated for neural decompression or to prevent a kyphotic deformity. A large experience with internal fixation using anterior cervical plates has been accumulated with excellent overall results.\(^3,6,8,11,18,19,23\) This study provides biomechanical evidence that supports the observed clinical effectiveness of bicortical anterior plate stabilization of traumatic cervical spine injuries. Anterior cervical plates secured with unicortical screws are available and these systems may be safer and easier to apply. Sophisticated biomechanical analysis of unicortically secured anterior cervical plates has not been performed, however, and therefore we are unable to state whether these devices would provide more, less, or the same degree of stability as bicortically secured plates.

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