Cervical facetectomy and its effect on spine strength

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Fourteen cervical spine motion segments consisting of two adjacent vertebral bodies and their connecting ligaments were tested in shear. Five had intact facet joints, five had bilateral facetectomy of 50% or less, and four had bilateral 70% facetectomy. Three to 5 mm of root could be exposed in the specimens with 50% facetectomy, and 8 to 10 mm in those with 70% facetectomy. Anterior-posterior shear tests were run alternately in compression and distraction. Facetectomy was found to have no effect on compression and distraction stiffness. Failure in the 70% facetectomized specimens was due to fracture of the remaining joint at 159 lbs. In the specimens with 50% facetectomy, a fracture load could not be established since failure of the specimen mounting occurred at 208 lbs, as it did in two of the specimens without facetectomy that were tested to failure. The difference in bone fracture at 159 lbs and mounting failure at 208 lbs is significant at p < 0.05. Bilateral resection of more than 50% of the facet joint significantly compromises the shear strength of a cervical spine motion segment.

KEY WORDS • facetectomy • cervical spine • spine dislocation

When the cervical spine is discussed, the word “stability” occurs frequently. The term implies a resistance to anatomical change, even in the presence of structural changes. This means that the remaining elements not subject to change must exhibit the necessary strength to withstand the forces applied to them. Sometimes clinical considerations suggest that certain structural changes may be beneficial, but the danger of alteration in spine strength may impose limits to these changes. We are talking about the clinical meaning of “stability,” but a problem arises in attempting to define what is meant by the concept, since the clinician and the bioengineer have different perspectives. In discussing this, White, et al., noted Humpty Dumpty's solution. “When I use a word,” Humpty Dumpty said, “it means just what I choose it to mean, neither more nor less” (Alice in Wonderland, Lewis Carroll). This approach does pose a problem in communication.

White and his colleagues offer a description of instability. “We define instability as the loss of the ability of the spine under physiologic loads to maintain relationships between vertebrae in such a way that there is neither damage nor subsequent irritation to the spinal cord or nerve roots and, in addition, no development of deformity with excessive pain.” This is a useful definition. If the individual contributions of the various components such as muscle, bone, and ligamentous structures can be evaluated, the factors that tend to cause instability can be analyzed and perhaps modified.

The strength of some of these components has been measured using isolated specimens. The contribution of the supporting ligaments, both singly and as a group, has been evaluated in the laboratory. If the individual ligaments are sectioned progressively, starting either posteriorly or anteriorly in an isolated motion segment, half of them must be cut before instability results, unless the articular facets are removed. Such extensive destruction rarely occurs except in severe trauma. Some measurements have also been made on the facets and their ability to influence spine strength. Work to date has been done with the facets either intact or absent, and the criteria regarding strength have therefore been developed for an all-or-none situation in the experiments performed.

Clinical situations arise where facet resection is necessary or advantageous. Facetectomy alone compromises spine strength principally by altering bone strength, since only the capsular ligaments among the supporting structures should be interfered with if the operation is properly performed. No measurements have been made concerning how the amount of facet removal affects the ability of the individual motion segment to maintain its normal alignment under in-
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creasing loads. We report the results of these measurements on isolated cervical motion segments obtained from cadavers.

Materials and Methods

Fourteen cervical motion segments were used. These consisted of adjacent vertebral bodies and their connecting ligaments. Three series of tests were run. Group I tests involved five fresh-frozen cadaver specimens that had been thawed and mounted as will be described. Group II tests were performed on five formalin-fixed specimens that had undergone a facetectomy of 50% or less on each side. The facet resection was performed utilizing a high-speed air drill and standard surgical technique. All ligamentous structures were left intact other than the capsular ligaments, which had to be destroyed in order to perform the facetectomy. A satisfactory facetectomy exposed the nerve root from the axilla distally. The superior and inferior margins of the root were well visualized and free from encompassing bone. Previous work has shown that the clinical estimate of the percentage of facetectomy was reasonably accurate. The estimate was checked at the end of the experiment when the motion segment was disarticulated.

Group III tests were performed on four specimens and were similar to those in Group II except that a 70% facetectomy was performed bilaterally. A 0.028-mm K wire was inserted into the exposed surface of each vertebral body; the K wires and exposed surfaces were then fixed to aluminum plates with methylmethacrylate cement. The aluminum plates, which were held parallel to each other, were attached to an MTS electrohydraulic tension-compression testing unit* and loaded in shear (Fig. 1). A crosshead speed of 0.01 in/sec was used until a load of 80 lbs was achieved. Load deflection curves were recorded for multiple cycles alternately in tension or compression. The specimen was then loaded until it failed due to compression, and load deflection curves were again recorded. Failure load and mode of failure were noted.

Results

Group I segments, which consisted of fresh-frozen specimens that had been thawed but had not undergone facetectomy, were less stiff than the fixed specimens. This represented greater elasticity of the fresh ligamentous structures as compared to the fixed specimens, as other investigators have shown. Compression and distraction stiffness (load divided by displacement) was similar in the fixed facetectomized groups. However, our principal interest was in bone strength at moderate to high loads. Once firm contact between opposing facet joints is established at higher loads, the principal resistance to shear is due to the opposing bone surfaces. Sedlin6 has shown minimal effects of formalin fixation on the mechanical properties of bone.

When 50% of the joint was removed, 3 to 5 mm of nerve root could be visualized. A facetectomy of 70% exposed 8 to 10 mm of nerve root, measured from the axilla (Fig. 2). The difference in length of root exposed reflects variations in the facet configuration from specimen to specimen. These anatomical variations also account for the differences noted between specimens in the loading curves.

There were two principal modes of failure (Table 1). In three of the four Group III specimens (70% facetectomy), fractures occurred in the remaining bone of the facet joint. One specimen also had fractures in the pedicles and on one side of the lamina. The ligamentous structures including the disc were not strong enough to prevent acute dislocation once fractures had occurred in the remaining facet. Four of the five Group II specimens (50% or less facetectomy) failed when one of the vertebral bodies tore loose from the acrylic cement attaching it to the mounting plate. One specimen failed because of fracture of the facet joint. Two of the non-facetectomized specimens were tested until they failed. In one the acrylic cement broke and in the other the joint ligaments tore. No bone fractures occurred.

The mean load at which bone fracture was the cause of failure was 159 ± 38 (standard deviation) lbs. When

* MTS electrohydraulic tension-compression testing unit manufactured by Materials Testing Corporation, Minneapolis, Minnesota.
Fig. 2. Left: Artistic representation of the C5-6 motion segment which has been disarticulated through the disc (D) and opened like a book (curved arrow). The observer is looking at the upper surface of C-6 and the undersurface of C-5. Approximately 50% of the facets (f) have been removed. Arrowheads indicate the medial borders of the remaining facets. Right: Actual specimen in which about 70% of the facets (f) have been removed bilaterally. Arrows indicate the medial borders of the remaining facets. D = intervertebral disc.

fixation of the specimen to the mounting plate failed, this occurred at $208 \pm 26$ lbs. The differences are significant at $p < 0.05$ with a confidence of greater than 95% (Table 2).

Discussion

Many clinical situations require facet removal to greater or lesser degrees. There is general agreement that total removal of a facet produces an unstable situation and leaves the cervical vertebrae prone to acute dislocation at the involved segment.

The facets form the posterior and posterolateral wall of the canal, containing the nerve root as it exits from the vertebrae. Good exposure of the root from its axilla distally for up to 5 mm can be obtained by removing less than 50% of the medial facet joint. Often, after removal of less than one-third, this degree of visualization can be obtained. This is usually more than adequate to decompress the root or allow removal of an osteophyte at the entrance to the neural canal or in the uncovertebral joint. To remove an osteophyte, the root is exposed and its cephalad and caudal borders are clearly defined. An opening in the posterior longitudinal ligament is made with an incision 2 to 4 mm in length. A small burr on a high-speed air or electric drill is then passed behind the ligament and the osteophytes beneath the root may be drilled off. The method works well with small to medium-sized lesions. Because of space limitations and the angulation of the drill, it may be difficult to get underneath the more central part of the root when the osteophyte is large (Fig. 3).

Some investigators believe that 8 to 10 mm of root should be visualized to decompress a cervical root in its canal (C Fager, personal communication, 1984). Our

### TABLE 1

<table>
<thead>
<tr>
<th>Type of Specimen</th>
<th>No.</th>
<th>Mode of Failure</th>
<th>Load (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I: fresh</td>
<td>1</td>
<td>dislocation</td>
<td>235</td>
</tr>
<tr>
<td>Group II: fixed,</td>
<td>4</td>
<td>fixation</td>
<td>212</td>
</tr>
<tr>
<td>50% facetectomy</td>
<td>1</td>
<td>fracture</td>
<td>135</td>
</tr>
<tr>
<td>Group III: fixed,</td>
<td>3</td>
<td>fixation</td>
<td>167</td>
</tr>
</tbody>
</table>

* Dislocation: supporting ligaments failed and allowed the superior vertebral body to move forward and the facets to override. No fractures occurred. Fixation: the cement joining the vertebral body to the mounting plate failed. The supporting ligaments and bone remained intact. Fracture: the facet joint remaining after facetectomy fractured, and the vertebral bodies dislocated in relation to each other.

### TABLE 2

<table>
<thead>
<tr>
<th>Type of Failure</th>
<th>No.</th>
<th>Load (lbs)†</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>fixation</td>
<td>6</td>
<td>$208 \pm 26$</td>
<td>2.165</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>fracture</td>
<td>4</td>
<td>$159 \pm 38$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Data analyzed by t-test.
† Mean load ± standard deviation.
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**FIG. 3.** Left: Artistic representation of the cervical spine with about 40% of the facet (f) resected. Five mm of root are exposed. Arrow points to an elliptical area outlined by a dotted line overlying the root and a white area below the root. This ellipse represents the area under the root that can be decompressed by opening the posterior longitudinal ligament and passing a high-speed burr beneath the ligament. The posterior ligament is also opened above the root to achieve better removal of an underlying osteophyte. L = the lamina below; and S = the tip of the spinous process. Right: Actual specimen showing the root (n). Open arrow indicates the opening in the posterior longitudinal ligament. Arrowheads outline the medial border of the remaining facet (f). Large arrow marks the lateral border of the facet. S = tip of the spinous process; L = the lamina below.

measurements indicate that 60% to 70% of the facet must be resected to expose this length of root. Bone removal of this degree compromises the strength of the remaining joint which may then fracture when subjected to the stress of a heavier load. The ligamentous structures and disc did not have sufficient strength to prevent vertebral body dislocation. It should be noted that Fager, who advocates a wide exposure of the root when performing a facetectomy, has not had a problem clinically with instability. Possibly the presence of active musculature provides a measure of strength. However, Perry and Nickel found that total paralysis of the cervical musculature does not result in vertebral body dislocation as long as the bone and ligaments are intact. The question of muscle contribution to “stability” requires further investigation.

When less than 50% of the joint was removed, failure occurred because of fracture in only one instance. The remaining specimens suffered fixation failure at 208 ± 26 lbs of shear and a fracture load for the bone could not be established. Joints with more than 50% of the facet removed bilaterally fractured at a mean load of 159 ± 38 lbs when stressed by shearing force. The difference in these loads is significant.

Frequently, the clinical problem requires that a nerve root be exposed on only one side, such as in a radiculopathy. It is possible that unilateral resection would result in a higher fracture strength. One specimen, not reported in our results, was tested after a unilateral resection and the fracture load was similar to the bilateral specimens. Conclusions should not be drawn from one result, however. We also wonder whether a significant torque factor could be introduced by a unilateral resection. Further work is necessary to clarify this.

These experiments were performed using specimens preserved in formalin, which decreases the elasticity of the supporting ligaments. However, since the purpose of the study was to evaluate bone strength under shear stress as a function of the amount of bone removed from the facets, we did not consider that our results were affected. This view was further supported by the fresh specimens with intact facets that were tested. Failure occurred by ligamentous disruption without fracture of the bone structure of the facet in one test. The ligaments were unable to prevent vertebral body dislocation before bone fracture occurred. In the other test, the mounting failed at the expected load.

Other investigators have shown that joint strength and stability at light loads are provided by the ligamentous structures. At least half of the ligaments must be sectioned for the motion segment to become unstable, unless the entire facet is removed. In our experiments,
the intact ligaments were unable to prevent dislocation if half of the joint was removed. Fracture of the remaining bone then occurred.

Based on these tests, we believe that the integrity of the majority of the facet is essential for joint strength. If possible, no more than 50% of the facet should be resected, since the strength of the remaining joint is decreased and will fracture under loads in the physiological range. If it is necessary to perform a wider resection, it may be worth considering additional means of strengthening and thus "stabilizing" the spine.

References

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