INTRODUCTION

Unilateral facet injuries encompass a wide spectrum, including subluxations, dislocations, and fractures; however, the range of instability varies greatly depending on the pattern of injury produced. Currently, there is little in the way of established guidelines to direct the most appropriate treatment [1]. This is partially due to a lack of biomechanical studies focused on evaluating changes in spinal stability following various injury patterns. In addition, the extent of anatomical disruption secondary to unilateral facet injury is poorly understood and few studies have been able to quantify the associated instability [2,3,4].

The aims of this study were to develop an experimental method that reliably produces a unilateral cervical facet dislocation in cadaveric C4-5 and C6-7 spinal segments, identify the associated soft tissue injuries through careful dissection of the specimens after dislocation, and to quantify the resulting instability.

MATERIALS & METHODS

Nine fresh-frozen cadaveric cervical spines (mean age: 59 ± 23 years) were used. Prior to testing, each specimen was thawed and cleaned of musculature, without disruption of ligaments, bone, or disc. C4-5 and C6-7 single motion segments were isolated and potted at the cranial and caudal ends.

To assess the intact stability of each motion segment, flexibility testing was performed using a spinal loading simulator, developed as a modification to an existing materials testing machine (Instron® 8874, Canton, MA). This device applied independent flexion-extension, lateral bending, and axial rotation to the spine. Specimens were loaded at 3/5's up to the target load of 1.5 Nm for each simulated movement, hence the extremes of physiologic motion was not obtained at 3x. This device applied the loading method described (Instron® 8874, Canton, MA) to the spine.

3D kinematics were captured using an Optotak® Certus motion capture system (NDI, Waterloo, ON, Canada) for 8/9 specimens. Markers were attached to the upper and lower potting fixtures to represent the cranial and caudal vertebrae. Landmarks were digitized, creating a coordinate system on each vertebrae to determine the relative anatomic motions.

Figure 1. (A) Specimens were fixed between the cranial and caudal potting fixtures. (B) Motion was tracked through infrared markers attached to each fixture. (C) Two loading arms were connected to the cranial fixture to apply motion to the specimen.

Following intact testing, unilateral facet dislocations were created by applying dead weights to induce a destructive flexion and contralateral bending force and then applying increasing axial rotation with the simulator, at a rate of 0.5°/s, until impending dislocation (i.e. perched facet) was visualized [2]. Post-injury flexibility testing was then performed using the same protocol as the intact state.

Systematic inspection and dissection was then performed to determine the integrity of the facet capsules, the supraspinous and interspinous ligaments, the ligamentum flavum, the anterior and posterior longitudinal ligaments, as well as the annulus and nucleus pulposus. The degree of disruptions were qualified as either being stretched or completely disrupted, and quantified by use of percentage. Range of motion (ROM) and neutral zone (NZ) for each simulated motion both pre- and post-injury were analyzed using paired t-tests.

RESULTS

An impending unilateral facet dislocation (perched facet) was achieved in all specimens tested by the loading method described. This method did however cause a facet fracture in three of the specimens tested. These specimens were included in all of the data analysis.

Post-injury dissections revealed that the capsules were the most severely damaged structure; all specimens had some capsular injury with 8/9 being bilateral. 8/9 specimens had >50% of the nucleus pulposus and annulus disrupted, most often occurring contralateral to the facet dislocation. 8/9 specimens also had at least 50% of the ligamentum flavum torn, with the ipsilateral one being more commonly injured. The interspinous and supraspinous ligaments were never completely torn, but were stretched in 3/9 and 4/9 specimens respectively. The anterior and posterior longitudinal ligaments were completely spared in all but one specimen, which had a small intrasubstance tear contralaterally.

Both ROM and NZ were affected by the dislocating maneuver, with the largest increase seen in contralateral axial rotation (Table 1).

Table 1. Average Range of Motion (ROM) and Neutral Zone (NZ) data before and after the unilateral facet injury. Neutral zone includes both directions in one plane of motion (i.e., flexion-extension combined).

<table>
<thead>
<tr>
<th>Motion</th>
<th>Pre-ROM</th>
<th>Post-ROM</th>
<th>Pre-NZ</th>
<th>Post-NZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>5.6 ± 2.1</td>
<td>8.5 ± 3.1</td>
<td>2.0 ± 1.4</td>
<td>3.8 ± 3.6</td>
</tr>
<tr>
<td>Extension</td>
<td>3.3 ± 0.6</td>
<td>3.9 ± 1.4</td>
<td>2.5 ± 1.2</td>
<td>8.9 ± 3.3</td>
</tr>
<tr>
<td>Ipsilateral Axial Rot.</td>
<td>3.1 ± 0.9</td>
<td>4.1 ± 3.4</td>
<td>13.8 ± 4.2</td>
<td>3.4 ± 1.1</td>
</tr>
<tr>
<td>Contralateral Axial Rot.</td>
<td>3.5 ± 1.2</td>
<td>13.8 ± 4.2</td>
<td>0.001</td>
<td>3.4 ± 1.1</td>
</tr>
<tr>
<td>Ipsilateral Lateral Bend</td>
<td>3.9 ± 2.3</td>
<td>7.3 ± 4.9</td>
<td>1.7 ± 0.7</td>
<td>3.4 ± 1.1</td>
</tr>
<tr>
<td>Contralateral Lateral Bend</td>
<td>4.1 ± 1.1</td>
<td>6.7 ± 4.0</td>
<td>0.012</td>
<td>3.4 ± 1.1</td>
</tr>
</tbody>
</table>

DISCUSSION

Despite the relatively common occurrence of unilateral facet injuries, few biomechanical studies quantify both the associated instability and anatomic disruption. Most studies either independently attempt to quantify the instability present [2], or evaluate the soft tissue damage required for, or present, in a unilateral facet injury [3,4].

This study succeeds in determining both the instability present and the extent of anatomic disruption in a dynamically-produced unilateral facet injury. Results of this study found a large increase in both ROM and NZ following the unilateral facet injury, especially in axial rotation. Dissection revealed the disc, facet capsule, and ligamentum flavum to be very important to prevent dislocation, as these structures were damaged in nearly every case. Treatment for unilateral facet perch or subluxation should consider the demonstrated discoligamentous injury and primarily prevent rotation as the main instability.

REFERENCES