INTRODUCTION: In an earlier experiment, coil springs were stretched and attached to produce a compressive force across the lumbar intervertebral discs of thirteen dogs for up to twenty-seven weeks (Spine 1998:23:2524-37). We tested the hypothesis that a high compressive force applied to the lumbar intervertebral disc (in vivo) over a period of time initiates changes in proteoglycans and collagen expression. In that experiment, changes in proteoglycans and collagen were observed in the seven dogs in which the highest values of force had been applied for the greatest number of weeks. This suggests that the protocol identified the threshold necessary to produce a change. Thus, an important corollary emerged: at lower values of force for a lesser number of weeks, compressive force does not effect a change in the amount of proteoglycans and collagen produced by the disc cells.

We therefore decided to re-visit our dog model, only this time to apply compressive force for up to a year at which time we could expect to observe obvious signs of degeneration. To this end, coil springs were stretched and attached to produce a compressive force across the lumbar intervertebral discs of dogs. The dogs were then kept for up to fifty-three weeks (in contrast to twenty-seven weeks maximum in the earlier experiment), and their lumbar spines were removed.

MATERIALS AND METHODS: Twelve adult (2-year-old) male hound dogs (20-27 kg) obtained after Institutional Animal Care and Use Committee approval was obtained. Under general anesthesia, the lumbar spine was approached posteriorly through a midline incision. Three adjacent vertebral levels (L1/L4) were exposed. The fine details of the surgical procedure for attaching a pair of screws to each of the vertebral bodies of L3 and L4, and attaching the springs to each pair of screws have been described before (Spine 1998:23:2524-37). The same methods were used in spacing the screws to estimate the force applied by the springs at insertion, and for measuring the distance between the springs at removal for later calibration with dead weights.

The pair of springs was positioned on either side of the vertebral body so as to produce a pure compressive force on the disc (See Fig. 1). The combined compressive force on a disc was the sum of the compressive forces exerted by the two springs; this ranged from about 92 N to 156 N. Attachment of the springs resulted in a small amount of immediate deformation followed by long-term creep of the disc, so that the compressive force exerted by the springs changed very slightly with time as the endplates came together. However, this coming together of the endplates was not discernable from subsequent radiographs during the time-course of the experiment. The coming together of the endplates did not reduce the force exerted by the springs to any great extent.

The dogs were killed between 39 and 53 weeks after surgery and their lumbar spines were removed and radiographed. The L3/L4 disc and the controls (T13/L1 and L4/L5) were excised and examined for visible signs of degeneration. The discs were then assessed using immunohistochemical analysis and enzyme linked immunosorbent assay (ELISA). They were also assayed for apoptosis.

Statistics: A nonparametric hypothesis test (the Friedman test) was used for the amounts of proteoglycan and collagen for each of the three disc regions: nucleus, inner anulus, and outer anulus. In addition, pairwise comparisons between the experimental level and each of the control levels were performed using the Wilcoxon signed rank test.

RESULTS: Visibly, no obvious signs of degeneration in the discs (L3/L4) that had been under compression for up to a year could be observed. There was no disc bulging, anular fissures, or disc space narrowing. Some changes were observed at the microscopic level, although no thickening of the endplate was apparent. The ELISA analysis provided statistically significant data for all three regions of the disc (nucleus, inner anulus, and outer anulus). When comparing the compressed disc (L3/L4) with either of the control discs (T13/L1 and L4/L5): 1) the nucleus contained less proteoglycans, and more collagen I and II in the experimental disc (L3/L4); 2) the inner anulus contained less proteoglycans and collagen I in the experimental disc (L3/L4); and 3) the outer anulus contained more proteoglycans and less collagen I in the experimental disc (L3/L4) (See Fig 2). The collagen II differences for the inner and outer anulus were not significant.

DISCUSSION: Our biochemical results are extremely clear. There are statistically significant differences at the nucleus, inner anulus, and outer anulus between the compressed discs and the control discs. The increases in collagen I and II in the nucleus could suggest a transformation in which the gel-like nucleus becomes more like the fibrous anulus. However, any changes or transformation that resulted from a year’s compression on L3/L4 did not manifest as degeneration in a visible form.

The disadvantages of this experiment are: 1) the pressure inside the dog discs under normal circumstances is unknown. In other words, we do not know the datum above which our applied pressure is acting; 2) the dog (like the mouse and rat) has notochordal cells in the disc, while those in the adult human are greatly diminished; 3) although some dogs are afflicted with disc degeneration, mechanical factors, specifically in the dog, may play a very small role; 4) the ELISA assay is unable to distinguish between the size of the molecules. In other words the discs may contain partial or complete proteoglycans or collagens, and the ELISA counts all of them.

The advantages of this experiment are: 1) the compressive force was applied to the dog disc for up to fifty-three weeks (this is roughly equivalent to seven years in human life); 2) adult dogs with no growth plates were used; 3) the pressures seen by the dog disc through the action of the springs, roughly span the pressure variation seen by the human disc in life 4) springs apply a compressive force to the disc without restricting motion to any great extent.

Springs across the disc allow the disc to flex and twist while still maintaining the compressive force. This means that the mechanical aspects of disc nutrition were relatively normal during the experimental period.

CONCLUSION: It has long been hypothesized that occupational loading conditions relate to disc degeneration. As far as we are aware, this is the first long-term experiment carried out to test this hypothesis. We found that compression applied to the lumbar intervertebral discs of dogs for up to a year does not produce degeneration in any visible form. However, it does produce microscopic changes and numeric changes in the amounts of proteoglycans and collagen. Our results add no credence to the commonly held belief that high compressive forces play a causative role in disc degeneration.