Fusionless Scoliosis Surgery: The Effect of Clinically Relevant Implants on the Intervertebral Disc
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Introduction: Fusionless surgical techniques for correction of scoliosis have gained popularity due to theoretical advantages over standard fusion surgery. Purported advantages include preservation of physiologic growth, motion and function of the spine and reduced damage to intervertebral discs and surrounding tissues at instrumented and subadjacent levels. A variety of implants have been investigated for the fusionless treatment of scoliosis, including relatively rigid shape memory alloy (SMA) staples, and relatively flexible anterolateral bone anchors with ligament tethers. Despite the efficacy of fusionless implants shown in short term clinical series and animal studies, little is known concerning the impact of these implants on the disc and surrounding structures over time.

The objective of this study is to analyze the regional histology of instrumented and subadjacent intervertebral discs and endplates in healthy spines treated with clinically relevant fusionless scoliosis implants. We hypothesize that 1) a more flexible fusionless scoliosis surgery implant (bone anchor ligament tether, LIGAMENT) will produce fewer degenerative changes in the disc and endplate compared to a more rigid implant construct (STAPLES), and 2) the subadjacent disc and endplate will not demonstrate significant evidence of degenerative changes in either fusionless scoliosis implant strategy.

Materials and Methods: As part of a larger animal study protocol, this study was approved by our institutions’ IACUC committees. Eighteen 8-week-old Spanish Cross-X female goats were divided into three groups. The STAPLE group (n=6) received a two SMA staple construct over each of five levels of the anatomical right thoracic spine (T7-T12). The LIGAMENT group (n=6) received a bone anchor ligament tether construct over the same levels, tensioned to a force equivalent to that of the STAPLE group. The final group (n=6) served as age- and gender-matched controls.

Cobb angles were measured on ventro-dorsal (V-D) radiographs that were obtained on each animal monthly and at necropsy. After six months of observation, all 18 goats were sacrificed and their spines were immediately harvested. Tissues surrounding the spines were removed by scalpel dissection. Instrumented (T10-11) and subadjacent (T13-L1) spinal segments were isolated from the spine and each section was paraffin embedded, cut, and prepared for staining. Standard hematoxylin and eosin (H&E) staining was performed for microscopic histological analysis. Cell density was recorded as the number of cell nuclei per mm². Cellular apoptosis was determined by Terminal deoxynucleotidyl transferase-mediated dUTP nick end labeling (TUNEL) and Caspase-3 immunohistochemical staining. Endplates were evaluated on H&E stained specimens for density of blood vessels (positive cells) in instrumented discs compared to both sub-adjacent and control discs. There was more apoptosis in the concave annulus of instrumented discs compared to the nucleus and convex annulus. There was a moderate inverse correlation (r = -0.522) between cell density and density of TUNEL-positive cells in the concave annulus of instrumented discs (p<0.01).

Decreased blood vessel density was present in all instrumented endplates compared to subadjacent and control specimens. There was no difference in vascular integrity between subadjacent endplates and controls, or between concave and convex endplates at instrumented levels. Trabecular thickening and bone drift were present in instrumented discs of both treatment groups, but not in subadjacent discs or controls. There was notable flattening of the tidemark in all instrumented vertebrae in both treatment groups, but not in controls.

Discussion: The data in this study demonstrate significant alterations in the instrumented intervertebral discs and endplates of spines treated with fusionless scoliosis implants, with few changes at the subadjacent level. The most notable changes are 1) a decrease in cell density and increase in cell apoptosis in instrumented discs compared to controls, and 2) preservation of endplate vascularity, disc cell density and matrix composition at the subadjacent level. Despite large differences in the progression of Cobb angles, there were no differences between the LIGAMENT group and the STAPLE group on discs at instrumented levels.

As fusionless scoliosis surgery continues to develop as a viable alternative to fusion surgery, the impact of these implants on the health of the disc and endplates will require careful evaluation. Our data demonstrate that both rigid and flexible fusionless scoliosis implants result in a loss of cell viability in intervertebral discs at instrumented levels but do not disrupt matrix proteoglycans or water content. Also, the subadjacent discs are relatively spared from cellular or matrix changes. Whether the regional alterations induced by these implants are reversible will require further investigation. Additional studies may also further define suitable implants, conditions and surgical timing to optimize scoliosis correction with minimal detrimental effects to the spine.

Acknowledgements: The authors would like to thank Dr. Kent Bachus, Dr. Misti Seppi, and Dr. Roy Bloebaum for their assistance with this project.