Cervical Total Disc Replacement Using Tissue-Engineered Intervertebral Discs Combined with an Anterior Bio-resorbable Stabilization System in an Ex Vivo Canine Model

Ibrahim Hussain; Gernot Lang MD; Jorge Mojica Santiago BS; Rodrigo Navarro-Ramirez MD, MS; Lawrence J Bonassar PhD; Roger Hartl MD

Weill Cornell Brain and Spine Center, Department of Neurosurgery, New York, NY

Click To Add Logo

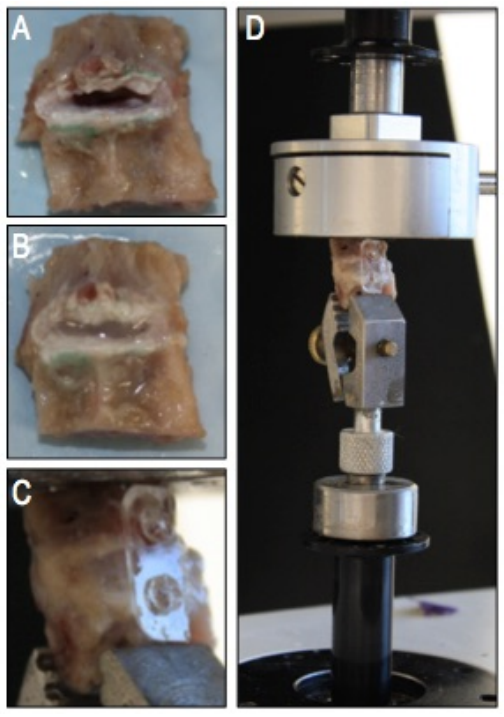
Introduction

Total disc replacement using tissue-engineered intervertebral discs (TE-IVD) offers an alternative biological treatment option for degenerative disc disease. Our group has previously developed a unique TE-IVD that demonstrated efficacy in maintaining disc height, physiological hydration, and tissue integration in beagle models in vivo. However, biomechanical properties were inferior to native IVD and implant displacement occurred in several cases. We now investigate the biomechanical responses of our TE-IVDs combined with an anterior bio-resorbable stabilization system (BSS) in an ex vivo canine cervical spine model (Figure 1A-B).

Methods

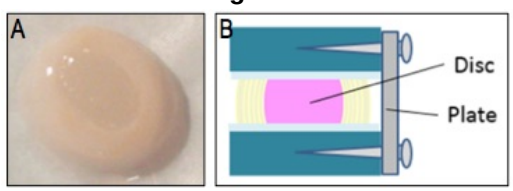
Using techniques previously described (1,2), TE-IVDs with an inner nucleus pulposus cell-laden alginate layer surrounded by an outer annulus fibrosus cell-laden collagen layer were developed. Cervical spine motion segments (N=12) of mature beagles were dissected and assessed as intact, after discectomy (Dx), with implanted TE-IVD (IVD-), and with implanted TE-IVD plus BSS (IVD+) (Figure 2A-C). Using a mechanical testing frame (Figure 2D), unconfined stress relaxation tests were performed. Equilibrium and

Figure 2



Canine cervical motion segment following 1) discectomy; B) implantation of a TE-IVD; and C) implantation of a TE-IVD with anterior BSS. D) Biomechnical testing frame with cervical motion segment mounted in an ELF 3200 (EnduraTec, Mount Airy, NC); fixed with a clamp at the inferior vertebral body and a small impermeable platen mounted above.

Figure 1

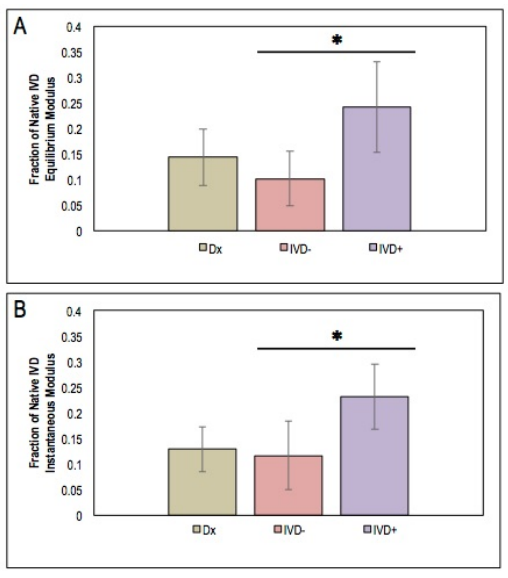


A) Tissue-engineered intervertebral disc (TE-IVD) composed of an inner nucleus pulposus cell-laden alginate layer surrounded by an outer annulus fibrosus cell-laden collagen layer. B) Schematic representation of a TE-IVD with an anterior bio-resorbable stabilization system, analogous to an anterior plate used in ACDF surgeries.

Results

Intact motion segments showed equilibrium and instantaneous moduli of 174 ± 36 kPa and 1760 ± 430 kPa, respectively, with mechanical properties from all other groups significantly lower. After normalizing to their corresponding intact motion segment mechanics, the IVD- group demonstrated relatively similar biomechanical properties to the Dx group, suggesting partial displacement and that low magnitudes of loads are shared by the construct. However, the IVD+ group demonstrated a 2-fold increase in equilibrium and instantaneous moduli ($p<0.05$) over the IVD- group (Figure 3A-B), with no implant displacement observed.

Figure 3



A) Equilibrium modulus and B) Instantaneous modulus normalized to the corresponding intact motion segment. N=12, Mean±SD, *$p<0.05$.

Conclusions

The biomechanical properties of motion segments with BSS increases the stability of TE-IVD constructs and mitigates implant displacement in canine cervical spines ex vivo, providing the impetus for future in vivo studies.

Learning Objectives

By the conclusion of this session, participants should be able to 1) Describe how tissue-engineered intervertebral discs (TE-IVD) are produced, 2) Discuss, in small groups, the primary biomechanical properties used to evaluate TE-IVDs compared to native IVD and how they are tested, and 3) Understand how and why canine spine models are being used for pre-clinical testing of TE-IVDs prior to eventual human trials.

References

1) Moriguchi Y, et al. In revision, Sci Tranl Med.
2) Grunert P, et al. J Neurosurg Spine. 2014;20(4):443-451.