# INTRA-ANNULAR BILATERAL SPINAL COMPRESSION: NOVEL MEMS SENSORS

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## INTRODUCTION

Surgical treatment of late stage childhood spinal deformities is successful but invasive. With the goal of creating early, minimally invasive surgical methods, preclinical studies on prototype implants have shown that spine growth may be slowed unilaterally [1]. Spine curvatures were associated with histomorphometric structural gradients of vertebral physes[2]; the mechanism is presumed to be compressive stress gradients across the intervertebral joint, comprised of disc and two growth plates. A clinically successful implant design would require the application of compression levels sufficient to inhibit growth without significantly affecting disc viability.

Many studies have measured spinal pressures in the fluidic disc nucleus. However, to determine side-to-side compression differences in the annulus, thin, flat transducers are required, with sensor faces oriented transversely. The purpose was to design and develop a MEMS transducer capable of measuring compressive stress in the annulus of the intervertebral disc.

## METHODS

Piezoresistive sensors were chosen for size, range, and ability to be placed remotely from signal conditioning circuitry. Commercial sensor dies in a full Wheatstone bridge configuration (SM5108: 0.65 $mm^3$ , Silicon Microstructures Inc., Milpitas, CA) permitted absolute pressure measurements at physiological levels. Carriers of various lengths and pad sizes were tested to define the thinnest functional device. Dies were electrically connected in a clean room complex (Class 10) using photolithography, micro-maching, and wire-bonding techniques [3] The sensors were designed into a small, thin, metallic package (2.5 mm width, 12.5 mm length, 0.8 mm thickness) to withstand dynamic *in vivo* stresses and to allow for firm attachment to vertebrae (Fig. 1).

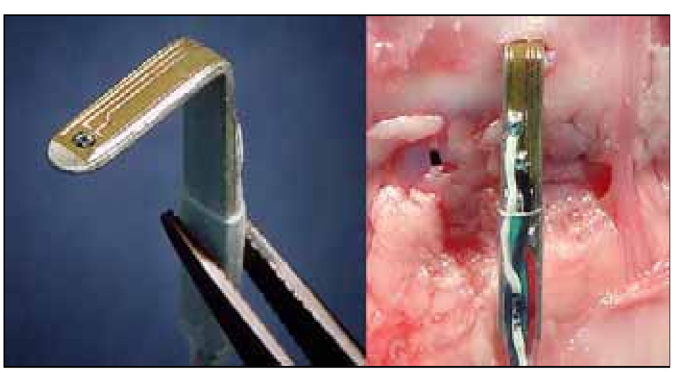

**Figure 1:** Packaged sensors were small, thin, and rugged.

Packaged sensors were calibrated under both fluid and solid contact conditions by first using a dynamic nitrogen pressure chamber (0-1.6 MPa) with commercial reference pressure sensor, and then using solid contact confined compression tests [3]. Sensors were then placed into the annulus of porcine vertebral motion segments that had been mounted into a materials test system. The segment was tested in cyclic compression (0.05 Hz) with simultaneous acquisition of load and pressure.

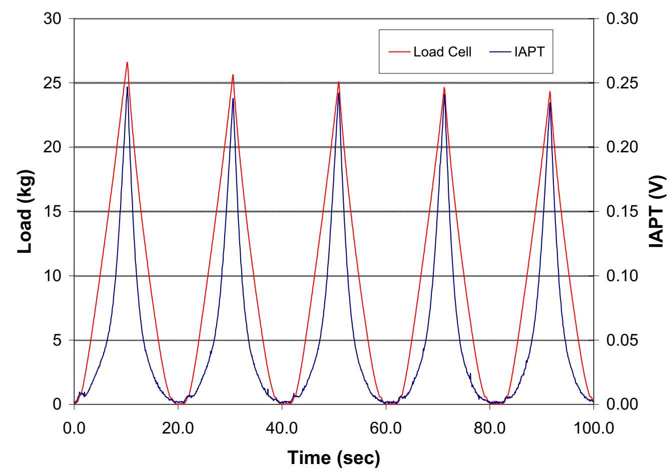


**Figure 2:** Intra-annular pressure transducer followed load cell.

## RESULTS AND DISCUSSION

Intra-annular pressure transducers (IAPT) were successfully connected and packaged to withstand compressive stresses to at least 1.6 MPa. Calibrations performed in fluid versus solid contact tests did not differ significantly; sensors performed consistently with linear output and small offset voltages. Preliminary *in situ* tests indicated that applied loads and sensor response (IAPT) were well-correlated (Fig. 2), and that the sensor is likely to withstand the physiological environment. Testing continues to determine the effects of shear and torsional loading, dynamic range, and long-term reliability prior to their intended application in vivo.

## CONCLUSIONS

Novel subminiature (MEMS) compression sensors were successfully fabricated, packaged, and calibrated as isolated transducers as well as *in situ* in the annulus of the intervertebral disc. Further characterization and consideration for *in vivo* and other biomechanical uses are warranted.

## REFERENCES

1. Bylski-Austrow DI, et al. *Proc. 50th Orthopaedic Research Society*, #1087, 2004.
2. Bylski-Austrow DI, et al*Proc. 51st Orthopaedic Research Society*, #1331, 2005.
3. Sauser FE, Glos DL, Bylski-Austrow DI, Papautsky I. *Proc. IEEE Engineering in Medicine and Biology*, 2004.