# Mechanical Testing of Porcine Trachea

## The Challenge:

### Characterize the Mechanical Response of Tracheal Rings Under Multiple Loading Configurations

## Background

The trachea, a stiff cartilaginous tube that regulates airflow to the lungs, was long treated as a linearly elastic material. However, more recent studies have noted the importance of accounting for its viscoelastic properties when considering potential causes of tracheal trauma or when designing artificial trachea replacements. Tracheal damage can occur as a result of compression, like blunt trauma, or as a result of tension, such as the increased internal pressure that presents in patients with a mechanical ventilation aid.

## Meeting the Challenge

An ElectroForce® BioDynamic® 5500 test instrument was used to investigate the response of the trachea under compressive and tensile loading (Figure 1). Trachea samples were loaded under a variety of conditions to examine the viscoelastic tissue response as characterized by:

- Creep
- Stress Relaxation
- Hysteresis

Typical viscoelastic characteristics include increasing deformation at a constant load, decreasing stress at a constant strain, and different loading/unloading responses on the stress-strain curve.


**Figure 1 – The ElectroForce® BioDynamic® 5500 test instrument is ideal for biological tissue testing.**

## Materials and Methods

Six-month-old porcine trachea was obtained from a local slaughterhouse and stored in saline solution. The trachea was then cross-sectioned between cartilage rings to obtain ring samples. The width, inner diameter, and outer diameter of each sample were recorded prior to experimentation for stress and strain calculations.

The BioDynamic 5500 test instrument was selected to meet the needs of the sample size and material properties. This system utilizes the patented ElectroForce linear motor to obtain high resolution data in low force applications. The frictionless motor design ensures precise control over testing parameters with the WinTest® software package. The system, which has a 13 mm stroke capacity, was equipped with a 250 g load cell to perform testing in both load and displacement control. Displacement sensors are calibrated within 0.5% of full scale, and load cells are calibrated to ASTM E4 standards for high accuracy measurements.

The instrument's compact size is suitable for applications that require testing inside of a cell culture incubator. The mounting fixtures can be easily changed to perform a variety of mechanical testing experiments. Standard fixtures were selected to test the tracheal rings in this study. Samples were mounted to the test instrument in three ways. For compression tests, samples were placed between platens in an axial or longitudinal position (Figure 2 A,B, respectively). For tensile testing, the samples were clamped between two grips in an axial position (Figure 2C).

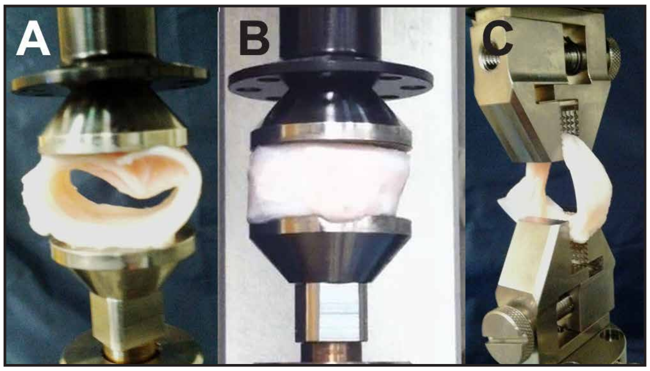


**Figure 2 – Samples were loaded in three different configurations: (A) axially between platens, (B) longitudinally between platens and (C) axially clamped with grips.**

## Results

Viscoelastic materials exhibit a creep response when they are held at a particular load. Creep testing was performed by compressing rings in the axial and longitudinal configurations. The samples were compressed to 120 g of force and held for four minutes while the strain was observed (Figure 3). A nonlinear deformation response was observed in both compression configurations, consistent with viscoelastic material behavior. Compressed samples appeared to have greater longitudinal strength than axial strength.

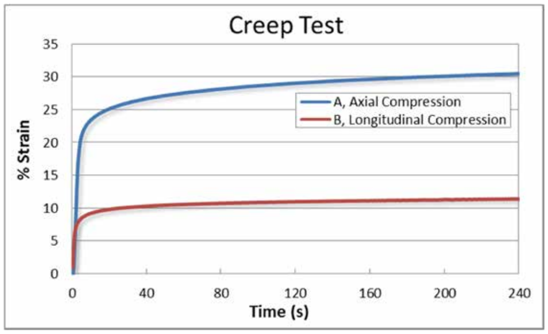


**Figure 3 – Rings were loaded and held at 120 g of force for four minutes while the nonlinear deformation response was observed.**

Viscoelastic materials also exhibit stress-relaxation, in which a nonlinear stress response is observed when a constant strain is applied. Stress relaxation tests were performed with the sample under tension and compression. Samples were either pulled (+) or compressed (-) to 25 % strain and held for four minutes while the stress response was allowed to equalize. Results (Figure 4) indicate that the tensile strength of the tracheal ring is greater than the compressive strength.

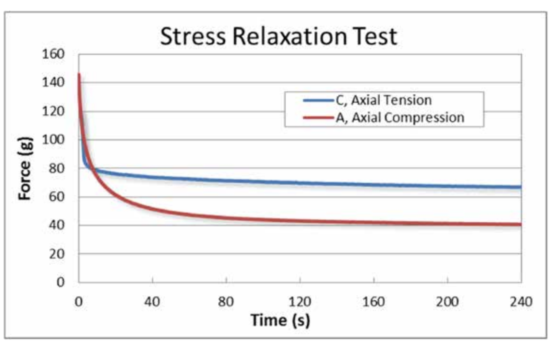


**Figure 4 – Axially-mounted samples were pulled or compressed to ± 25% strain for four minutes while the nonlinear stress response was recorded.**

The hysteresis response was investigated by cyclically preconditioning a ring sample, followed immediately by loading and unloading. The ring was placed between two platens in the axial position, and 25 g of force was applied at a frequency of 1.0 Hz for 10 cycles. The sample was then compressed with 50 g of force (corresponding to 30% compressive strain), and the load was subsequently removed. A lag between the loading and unloading portions of the curve can be seen in Figure 5. The area between these portions of the curve signifies the energy that is dissipated as a result of the material's viscoelastic nature.

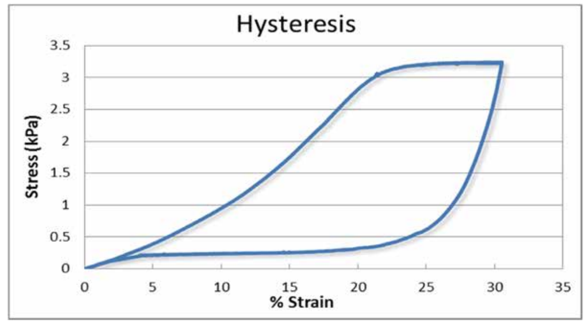


**Figure 5 – A ring placed axially between platens was loaded and then unloaded to demonstrate hysteresis.**

## Summary

The ElectroForce® BioDynamic® 5500 test instrument was used to illustrate the viscoelastic properties of the trachea. The user-friendly system was operated in load control to demonstrate creep behavior, and in displacement control to demonstrate stress relaxation. A third protocol was defined in the WinTest® software package to cyclically precondition a sample prior to loading and unloading. The resulting stress-strain curve demonstrated a hysteresis lag between loading and unloading.

This highly adaptable instrument is ideal for characterization of biological materials, such as the tracheal samples in this study. The compact size of the system is suitable for use inside of a cell culture incubator, and the system is compatible with customer-designed fixtures and chambers. On top of these application-specific attributes, biological tissue testing also requires a high level of precision, accuracy, and control. The ElectroForce BioDynamic 5500 test instrument offers all of these features along with an easy-to-use interface, making it ideal for biological tissue testing.

*Specifications are subject to change.*

Bose Corporation – ElectroForce Systems Group
10250 Valley View Road, Suite 113, Eden Prairie, Minnesota 55344 USA
Email: electroforce@bose.com – Website: www.bose-electroforce.com
Phone: 952-278-3070 – Fax: 952-278-3071