# Biomechanical Investigation of Porcine Soft Oral Tissues

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**Statement of Purpose:** Oral tissue is a complex biological system that is exposed to a wide range of mechanical loading conditions. The magnitude of physiological stress levels soft periodontal tissues are subjected to, and how they behave under applied stress, has received little attention, and represents an obstacle for the development of biomaterials that behave with appropriate biomechanical traits. With this as our motivation, an *in vitro* uniaxial mechanical analysis was performed on model soft periodontal tissue to further our understanding of these complex tissues. Due to its close resemblance to human periodontal tissues, porcine periodontal tissue from both lingual and alveolar sites were assessed to gain insight to how human oral tissues may respond under similar loading conditions.

**Methods:** Clinically healthy porcine oral tissue from freshly slaughtered 6-9 month-old animals was obtained from Animal Technologies Inc. (Tyler, Texas). Tissue sections from the attached gingiva, alveolar mucosa, and buccal mucosa were dissected from the lingual and buccal aspects within 24 hours of sacrifice. Tissue sections were stored in 0.15 M phosphate buffered saline (PBS) containing 0.2% penicillin (Gibco Life Technologies, Grand Island, NY) (pH 7.4) at $4^{o}$C until analysis. Uniaxial mechanical tests (uniaxial tensile, stress relaxation, and dynamic compression) were performed using an Instron testing machine (Model 5542, Norwood, MA). Tissue strips (3 mm x 30 mm) (n=10) were cut from isolated tissue for both uniaxial tensile and stress relaxation tests, whereas tissue was cut into 5 mm-diameter disc (n=8) for dynamic compression analysis. Dynamic compression tests were performed by cyclic displacements of the top indentor with a triangular waveform over a range of strain amplitudes (5%, 10%, and 15%) and loading frequencies (0.1 Hz, 0.5 Hz, and 1 Hz). The time dependency of the tissue behavior was determined after 25 compression cycles. During testing, the tissue was kept hydrated with phosphate-buffered saline, PBS (0.15 M, pH 7.4) to mimic the physiological environment.

**Results:** Stress-strain relationships and tensile properties were deduced from the load-displacement data. These results have shown that different anatomical sections of the porcine periodontal tissue display regional variations in their mechanical properties. Attached gingiva (dissected from the buccal aspect) demonstrated the highest tensile strength (3.9 ± 1.2 MPa) and Young's modulus values (19.8 ± 6.2 MPa) (Figure 1). Alveolar mucosa showed a more rapid decay in its stress-relaxation curve (for a relaxation time of 360 s) compared to the other regions, i.e. demonstrating a higher viscoelastic behavior. The attached gingiva was the least viscoelastic amongst all regions.

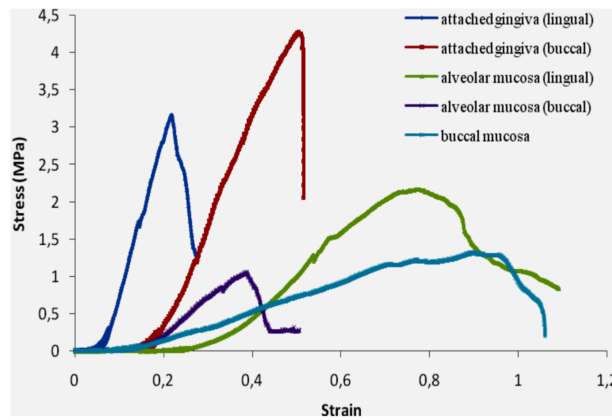


Figure 1: Representative stress-strain curves for different sections of the porcine periodontal tissue. The attached gingiva showed higher tensile strength and Young's modulus values compared to alveolar and buccal mucosa.

During dynamic compression the first cycle generated the largest peak stress, after which the peak stress value of each cycle decreased to a near steady state. The peak stress values gradually increased with an increase in strain frequency and amplitude for each tissue section. Stastical analysis confirmed that the peak stress value for the attached gingiva (buccal) was significantly higher than the attached gingiva (lingual) ($p < 0.01$). Significant differences in peak stress values also existed between the buccal and lingual alveolar mucosa ($p < 0.05$). The relative stiffness of the disks was measured during both the initial and steady-state hysteresis loops and are referred to as $E_{int}$ and $E_{ss}$, respectively. The highest initial ($E_{int}$) (7.8 ± 1.1) and steady-state ($E_{ss}$) (0.9 ± 0.1) modulus values were also found in the attached gingiva (buccal) (at 15% strain, and 1Hz). The ANOVA revealed a significant effect of the strain amplitude and strain frequency on the values of $E_{int}$ and $E_{ss}$ for the attached gingiva ($p < 0.001$), alveolar mucosa ($p < 0.05$), and buccal mucosa ($p < 0.05$).

**Conclusions:** This investigation is the first to report that the biomechanical properties of porcine soft oral tissues display significant regional variations. The region-specific characteristics of the porcine soft oral tissue biomechanics are likely due to variations in the composition and organization of the extracellular matrix (ECM) components. Due to the recognized similarities between the human and porcine periodontal tissues the mechanical data presented in the current study provides important insight into the biomechanical behavior of human soft oral tissues so that materials can be developed, or modified, to interact more appropriately as periodontal implants.