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Preventing Colorectal Anastomosis Failure with Finite Element Method (FEM) Validated with Ex-Vivo Model

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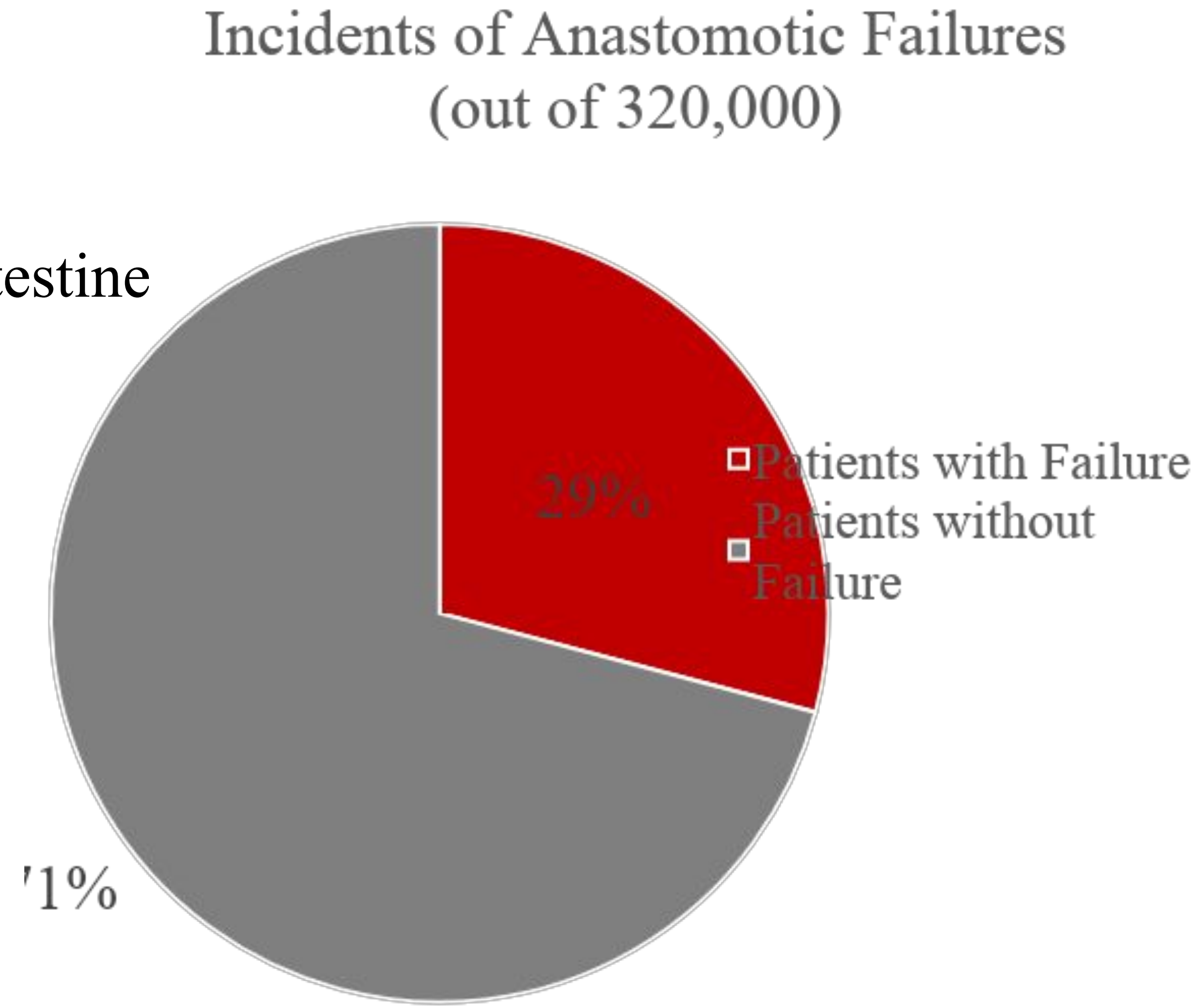
Background

- Intestinal anastomosis
  - Connecting proximal and distal ends of intestine with sutures or staples
- Anastomotic leakage patients:
  - Extended hospitalization
    - Average 19 days instead of 7 days
  - Tremendous financial impact
    - $28.6 million in total additional costs



AIMS

- Develop reproducible ex-vivo and finite element models (FEM) that can understand, predict, and eventually prevent failure of colorectal anastomoses
  - Phase 1 (*completed*):
    - Determine mechanical properties of porcine colorectal tissue for FEM
  - Phase 2 (*in progress*):
    - Ex-vivo testing to compare end-to-side and end-to-end colonic anastomoses
    - Develop FEM of the two anastomoses
    - Compare results and adjust the FEM accordingly

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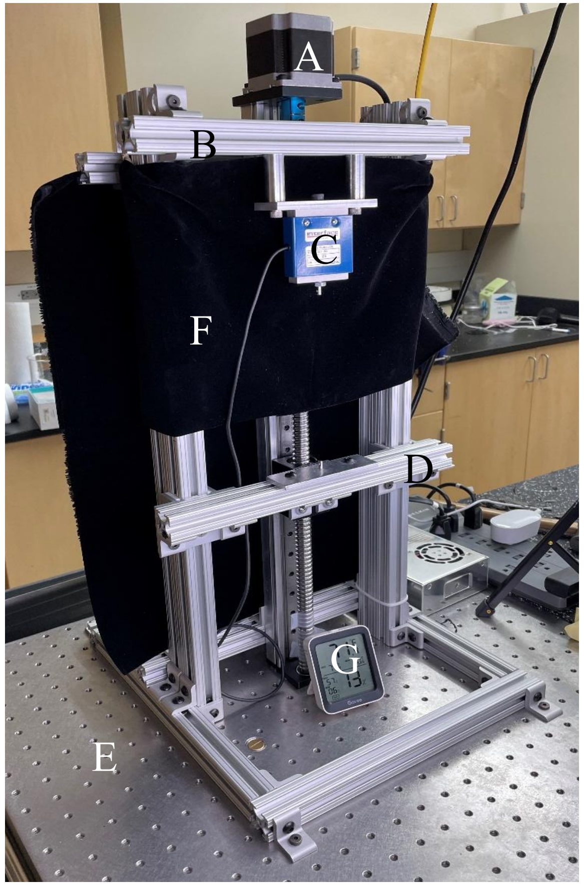
Materials and Methods – Phase 1

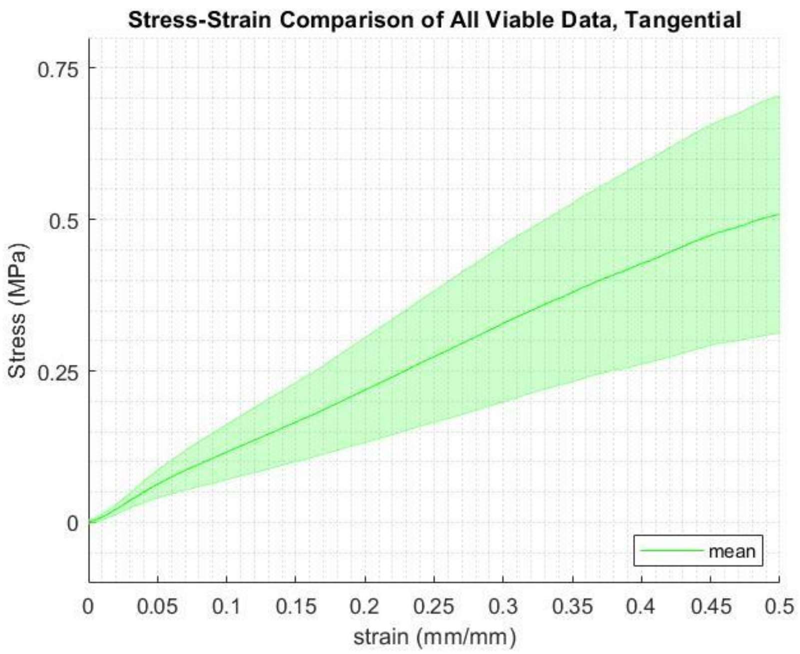
- Uniaxial tensile testing phase:
  - Longitudinal and tangential orientations
  - Load cell and calibrated optical imagery were used to develop stress-strain relationships
  - Data was used in developing a constitutive model for the material in both orientations

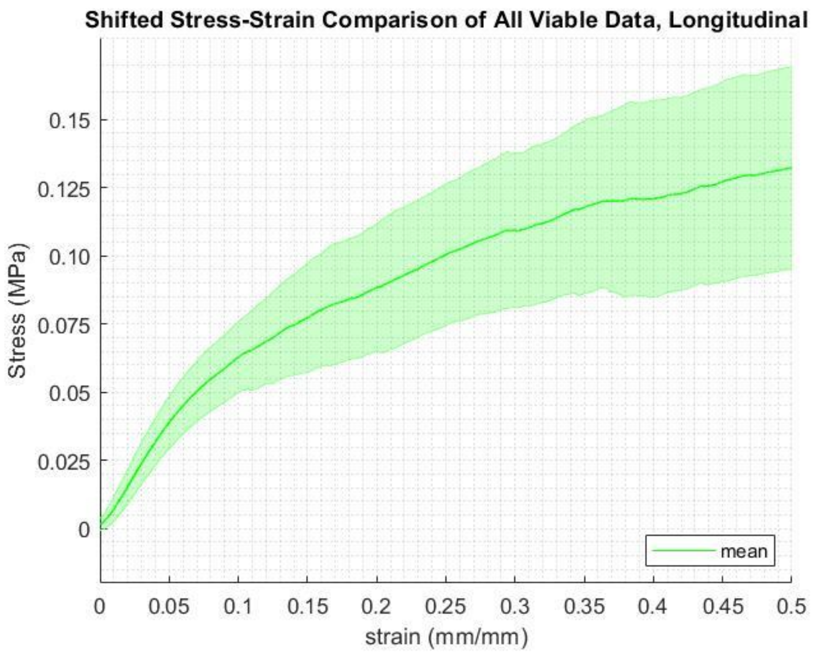


A. Stepper Motor and Ball Screw Assembly
B. Solid Mount Upper Support Bar
C. Interface 25N Load Cell
D. Load Applying Bar
E. Optical Table
F. Light Absorbing (Non-Reflective) Backdrop
G. Govee Smart Thermo Hygrometer
H. GoPro Hero 10 Camera with 18-140mm Lens (not shown)

Results – Phase 1

- Results showed that the material behaves as hyperelastic in both longitudinal and circumferential directions
- The colorectal tissues are significantly stronger in the tangential direction





Tensile Testing specimen

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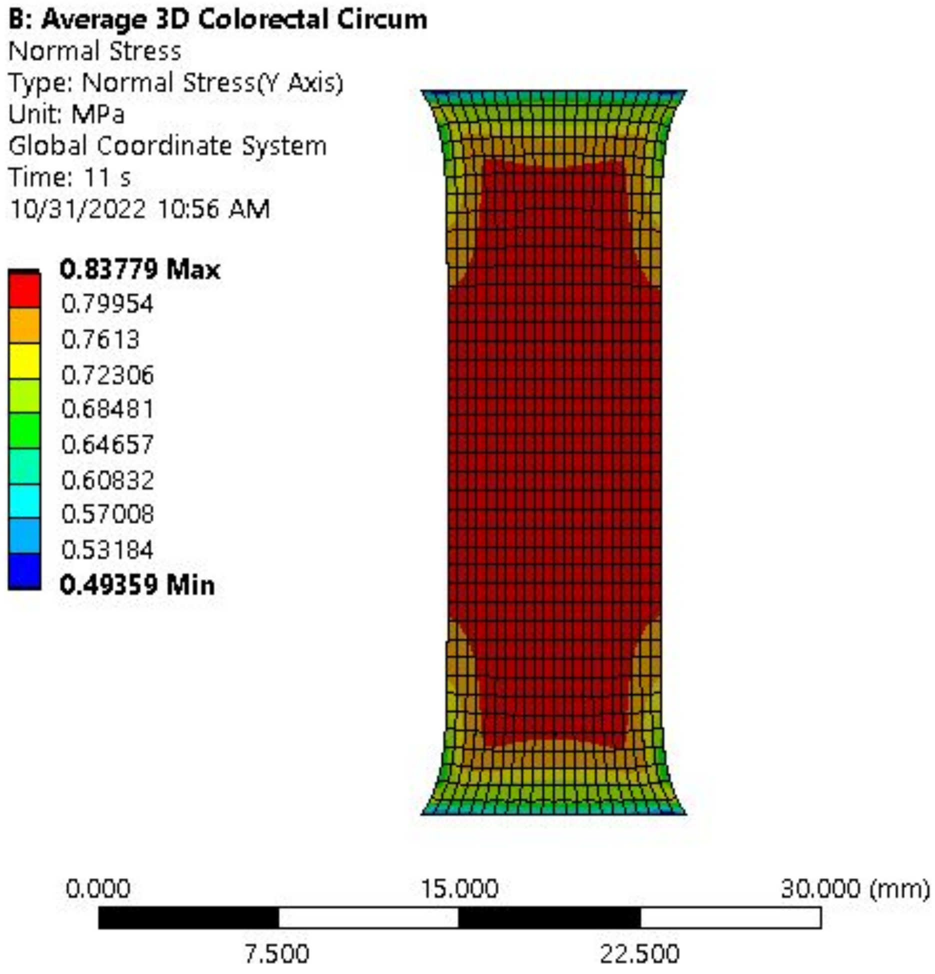
Finite Element Model – Constitutive Model

- Tensile testing data were used to fit a 5th order Mooney-Rivlin hyperelastic model for both longitudinal and tangential orientations.
- These material models were incorporated in FEM of the experiments.
- Results showed that these models were fairly accurate.

Material Orientation	Difference of Numerical and Experimental Results
Longitudinal	5.168%
Tangential	6.61%

Normal Stress (Y Axis) for Tangential Specimen

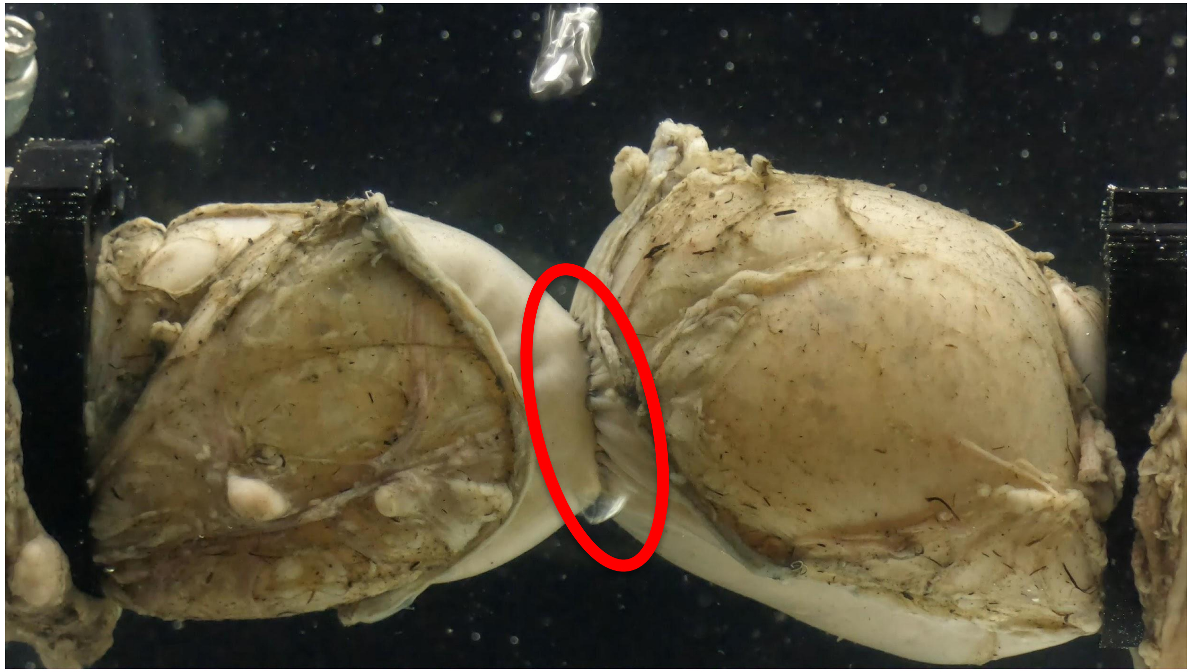


Materials and Methods – Phase 2

- Burst Testing:
  - End-to-end and end-to-side stapled orientations were tested
  - Pressure transducer, load cell, and optical imagery were used to monitor failures and to record data leading up to that point
  - Experiment was submerged in water to near internal body temperature

A. Load Cell Interface WMC-45N
B. Omega 0-5psi Pressure Transducer
C. Specimen
D. Pre-Tensioning Stage
E. Tank Temperature Regulator
F. Air Input from pump
G. GoPro Hero 10 Camera with 18-140mm Lens (not shown)

Materials and Methods – Phase 2

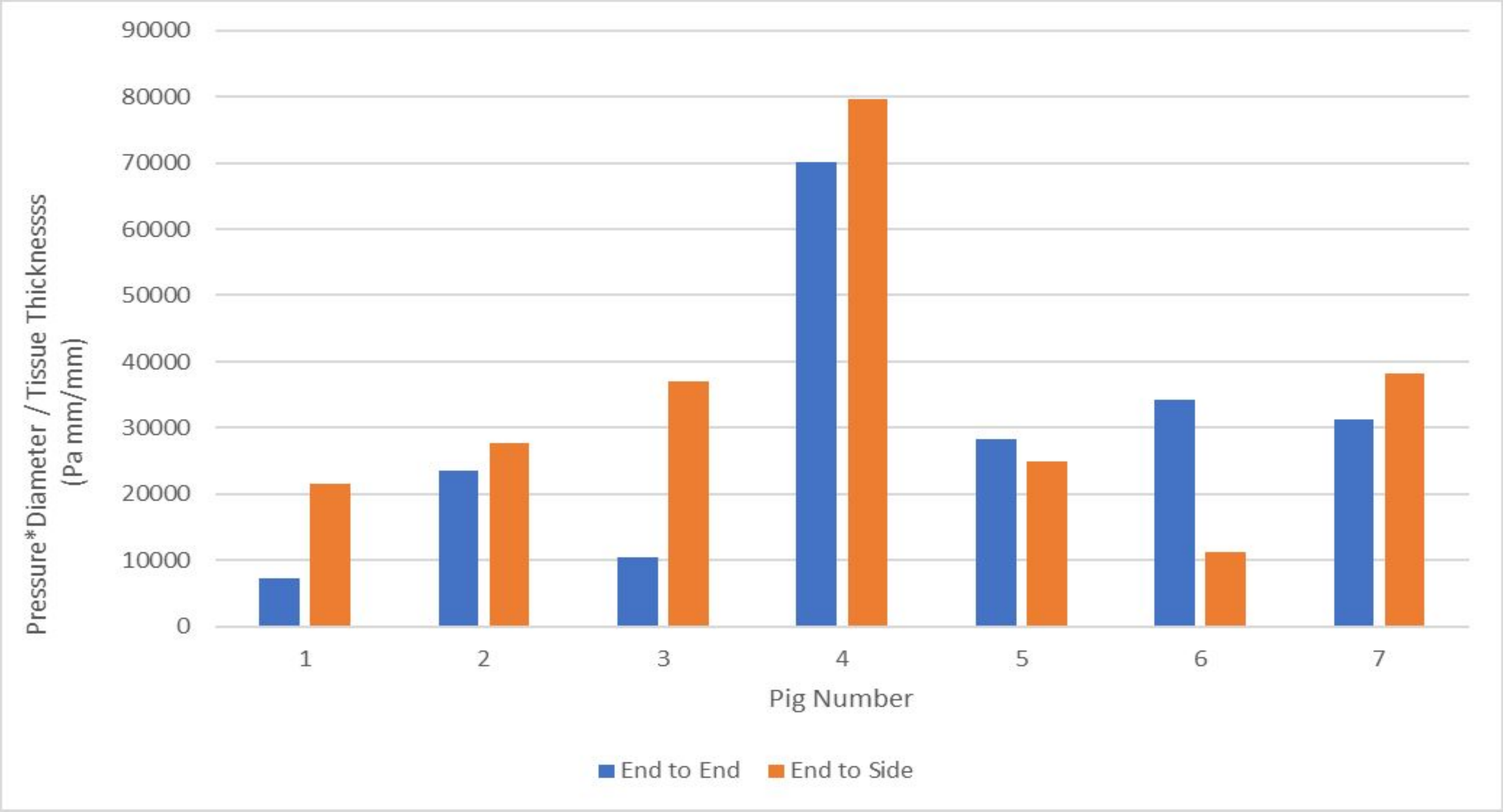


End to End Anastomosis

End to Side Anastomosis

Preliminary Results – Phase 2

- High variability but end to side seems to have a higher failure pressure in general



Discussion

- Experiments have yielded parameters that will be used to create predictive constitutive colorectal anastomosis finite element models.
  - Uniaxial testing results confirm observations of other researchers that the colorectal tissue is an orthotropic material with significantly stronger characteristics in the tangential direction.
  - Preliminary inflation data indicate that end to side anastomoses may withstand more pressure than end to end anastomoses.
- Findings of this project may change the way colorectal surgery is practiced and positively impact patient care.

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