Built to Handle Everyday Exposure

Tensile performance after repeated cleaning and oral-bacteria biofilm exposure

Study 1 | Tensile Testing After Cleaning - Covalent Material Insights, May 2026

Study 2 | S. mutans Biofilm Degradation Pilot - University at Buffalo Materials Testing Facility, Apr/May 2026

Staining | 24- and 72-hour immersion in common beverages

Unplastic | Summary followed by both full test reports

Summary of Results

Both full reports follow

STUDY 1 - COVALENT MATERIAL INSIGHTS

Repeated cleaning

ASTM D638 Type V dogbones, Instron 68SC-5 with AVE3 video extensometer, n = 3 per group.

Group	Modulus [GPa]	UTS [MPa]	Strain at UTS [%]
CTRL	2.48 ± 0.13	37.02 ± 0.49	4.54 ± 0.46
CS14d	2.82 ± 0.53	37.10 ± 0.82	4.49 ± 0.29
UP28	2.66 ± 0.24	36.55 ± 0.70	4.85 ± 0.20

Result: All three groups showed comparable tensile behavior, with mean ± SD ranges overlapping for every property. Tensile strength stayed within 36.5-37.1 MPa across groups.

Values are mean ± standard deviation as reported by Covalent (report CM000060037, May 12, 2026).

STUDY 2 - UNIVERSITY AT BUFFALO (PILOT)

Oral-bacteria biofilm

Moses PHA, MosesPHA-2, and a PETG aligner control aged 2 weeks in *S. mutans* NCTC 10449 (BHI + 1% sucrose), deionized water, or air; cleaned with 70% IPA between cycles. n = 2 per condition.

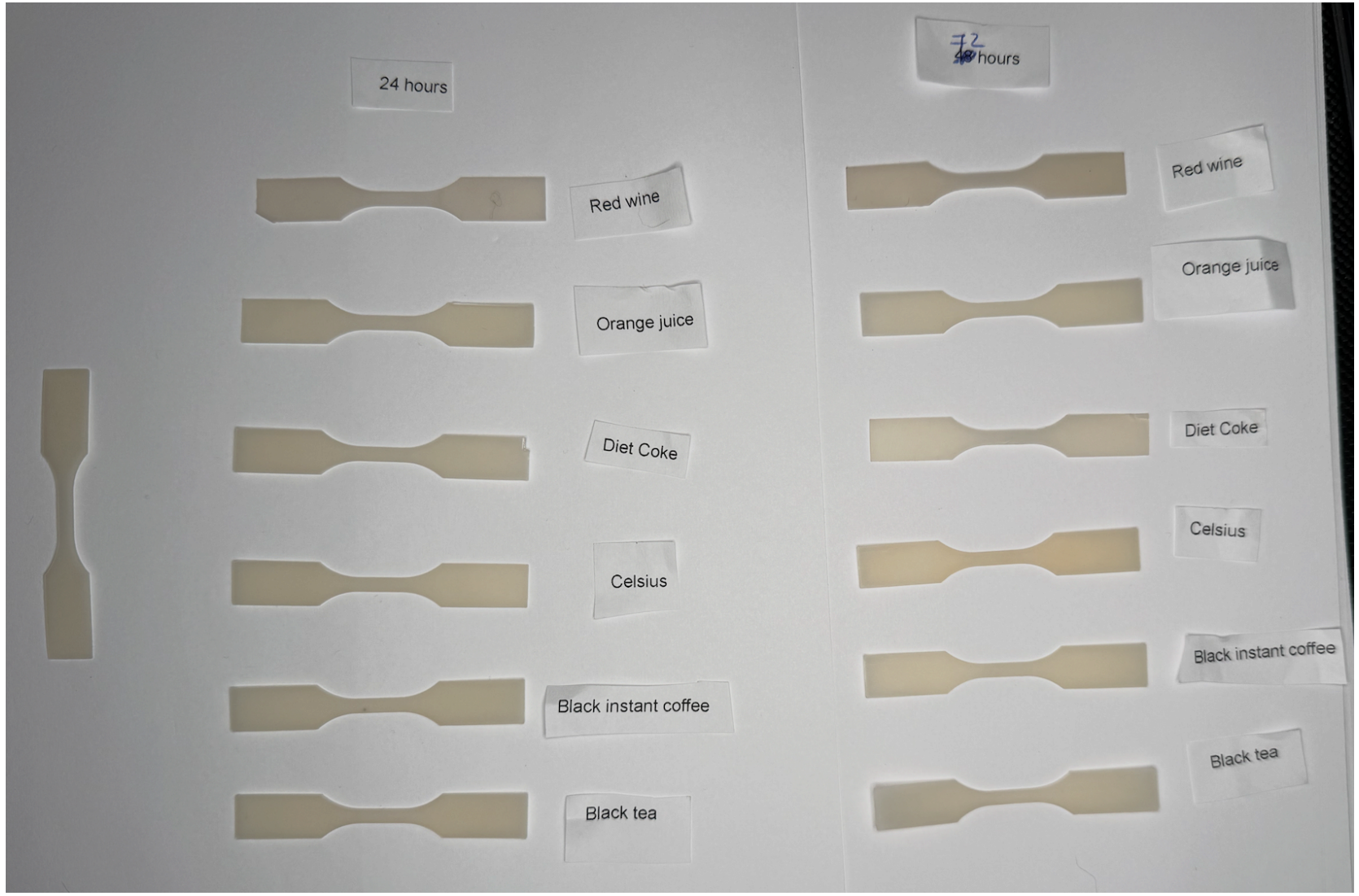
Max tensile strength [MPa]	Air	Water	Biofilm
PETG	56.54	55.40	55.23
Moses PHA (PB3410)	41.19	26.08	36.21
MosesPHA-2 (PV3020)	37.48	35.74	35.88

Lab conclusions: No noticeable aesthetic changes to any specimen; biofilm grew mainly on roughened surfaces; the pilot showed no discernible difference in strength after biofouling exposure.

Values as reported by the lab. Pilot study with n = 2, so no statistics were reported. In the full report, charts label Moses PHA as PB3410 and MosesPHA-2 as PV3020.

Stain Resistance

24- and 72-hour beverage immersion



IMMERSION TEST

Dogbone specimens were immersed in six everyday beverages and photographed after **24 hours** (left column) and **72 hours** (right column).

Beverages
Red wine
Orange juice
Diet Coke
Celsius
Black instant coffee
Black tea

The vertical specimen at far left is shown for comparison.

Visual comparison only; photo shown unedited.

STUDY 1 - FULL REPORT

Tensile Testing After Cleaning

Covalent Material Insights | ASTM D638, Type V | May 2026

COVALENT
Material Insights

Tensile Testing of Polymer Samples per ASTM D638, Type V

CM000060037

Andrea Westlie, Unplastic

Authors Josh Campbell, Ph.D.

Reviewers Shivesh Sivakumar, M.S.

May 12, 2026

Statement of Work and Summary of Results

COVALENT Material Insights

Goal:

- Quantify polymer performance via tensile testing per ASTM D638.

Methods:

- Mechanical Testing with Instron 68SC-5.
- Strain measurement via non-contact Instron AVE3 video extensometer.
- Method details in Appendix.

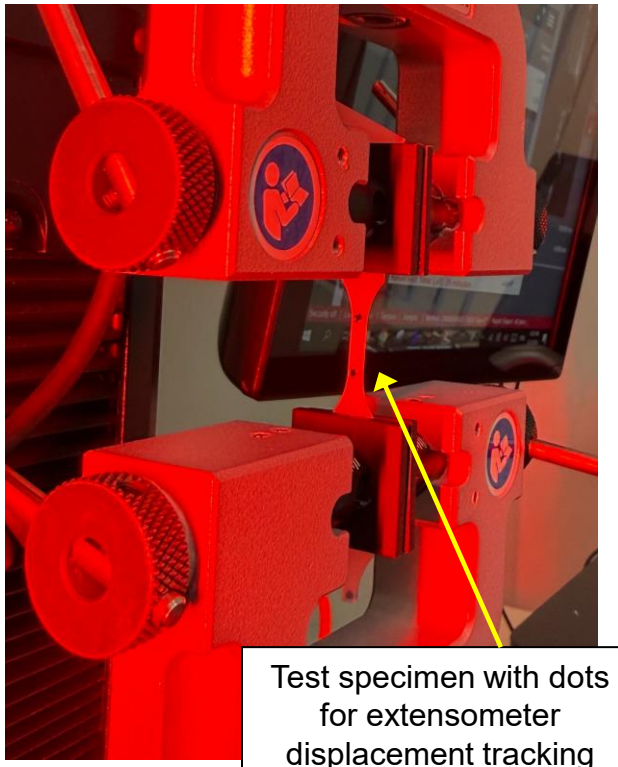
Summary of Results:

- The 3 polymer materials showed very comparable material properties.

Tensile Properties *(Average ± Std. Dev.*)*

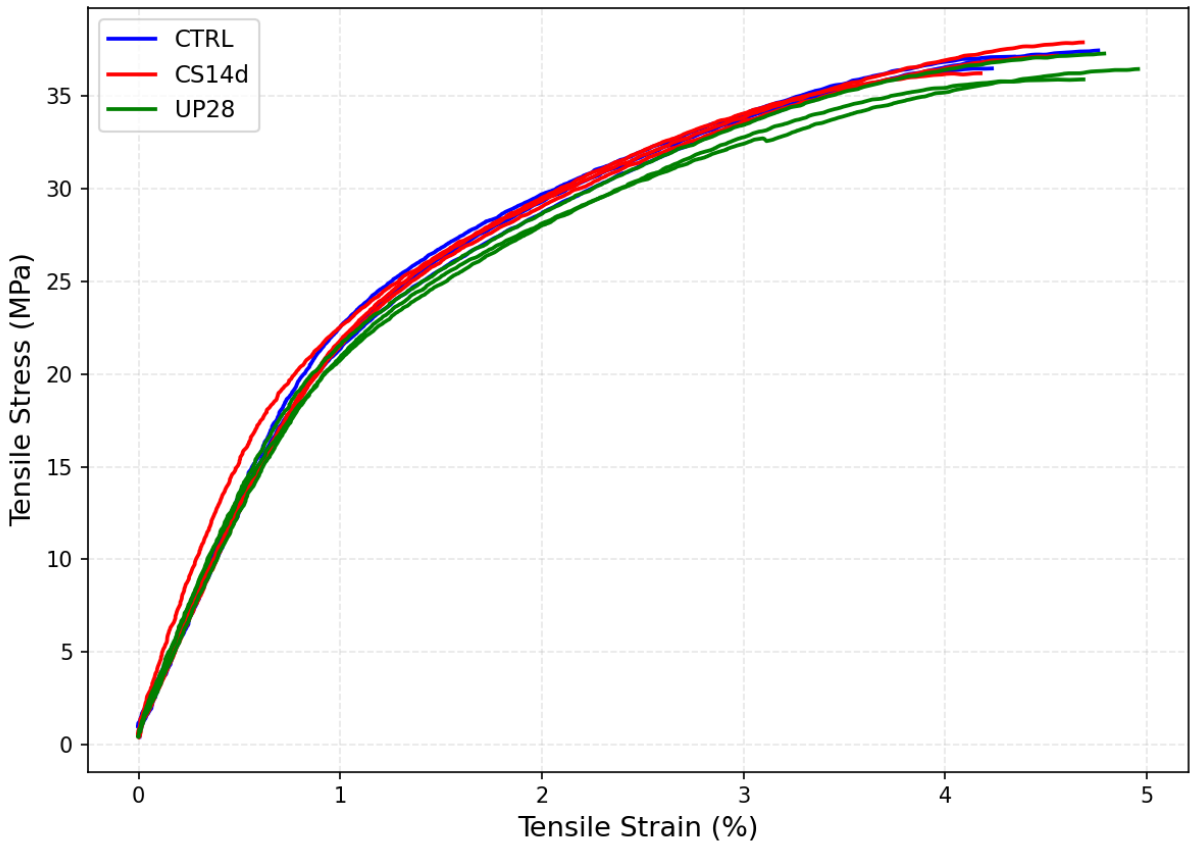
Material	Modulus of Elasticity [GPa]	Tensile Strength, UTS [MPa]	Strain at UTS [%]
CTRL	2.48 ± 0.13	37.02 ± 0.49	4.54 ± 0.46
CS14d	2.82 ± 0.53	37.10 ± 0.82	4.49 ± 0.29
UP28	2.66 ± 0.24	36.55 ± 0.70	4.85 ± 0.20

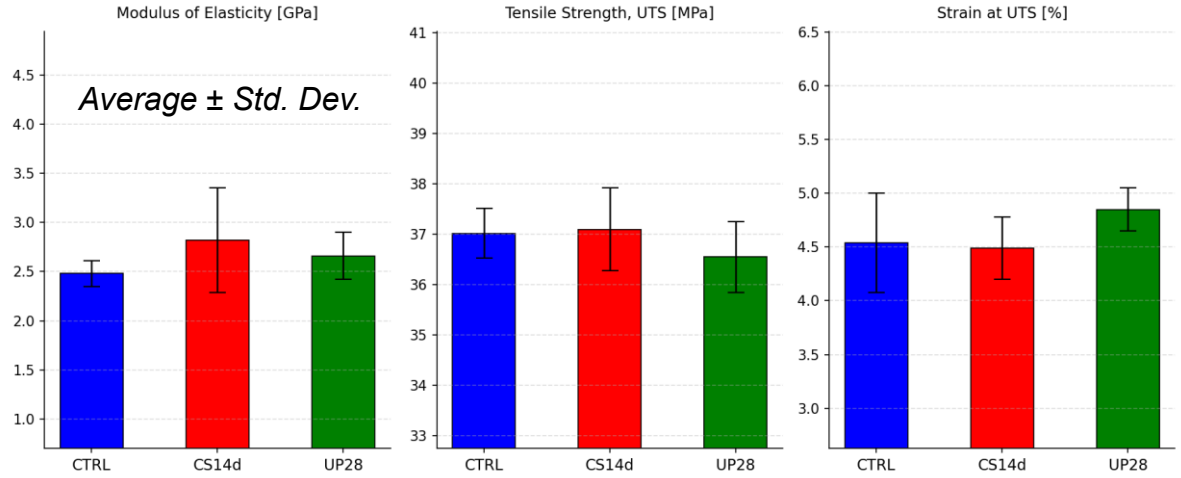
* *n=3*



Test specimen with dots for extensometer displacement tracking

Results – All Material Samples



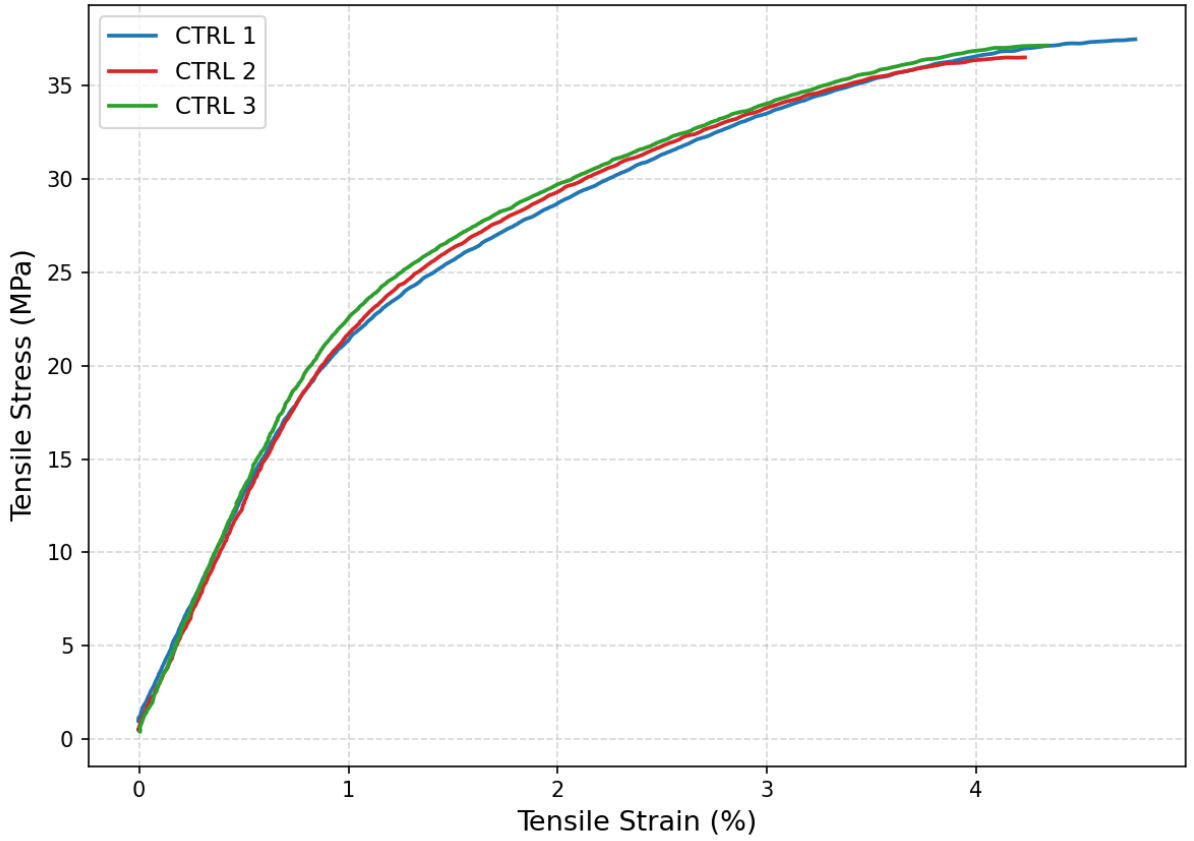


Results Table *(previously presented on slide 2)*

Material	Modulus of Elasticity [GPa]	Tensile Strength, UTS [MPa]	Strain at UTS [%]
CTRL	2.48 ± 0.13	37.02 ± 0.49	4.54 ± 0.46
CS14d	2.82 ± 0.53	37.10 ± 0.82	4.49 ± 0.29
UP28	2.66 ± 0.24	36.55 ± 0.70	4.85 ± 0.20

- All materials showed comparable tensile behavior with Mean +/- Standard Deviation range overlapping for all properties.
- Tensile data are plotted up to the Ultimate Tensile Strength.
  - Strain after UTS was minimal.
  - Artifacts in strain signal occurred at fracture due to elastic rebound being high relative to the total strain values.
- Due to above factors, material ductility is compared in terms of Strain at the Ultimate Tensile Strength.

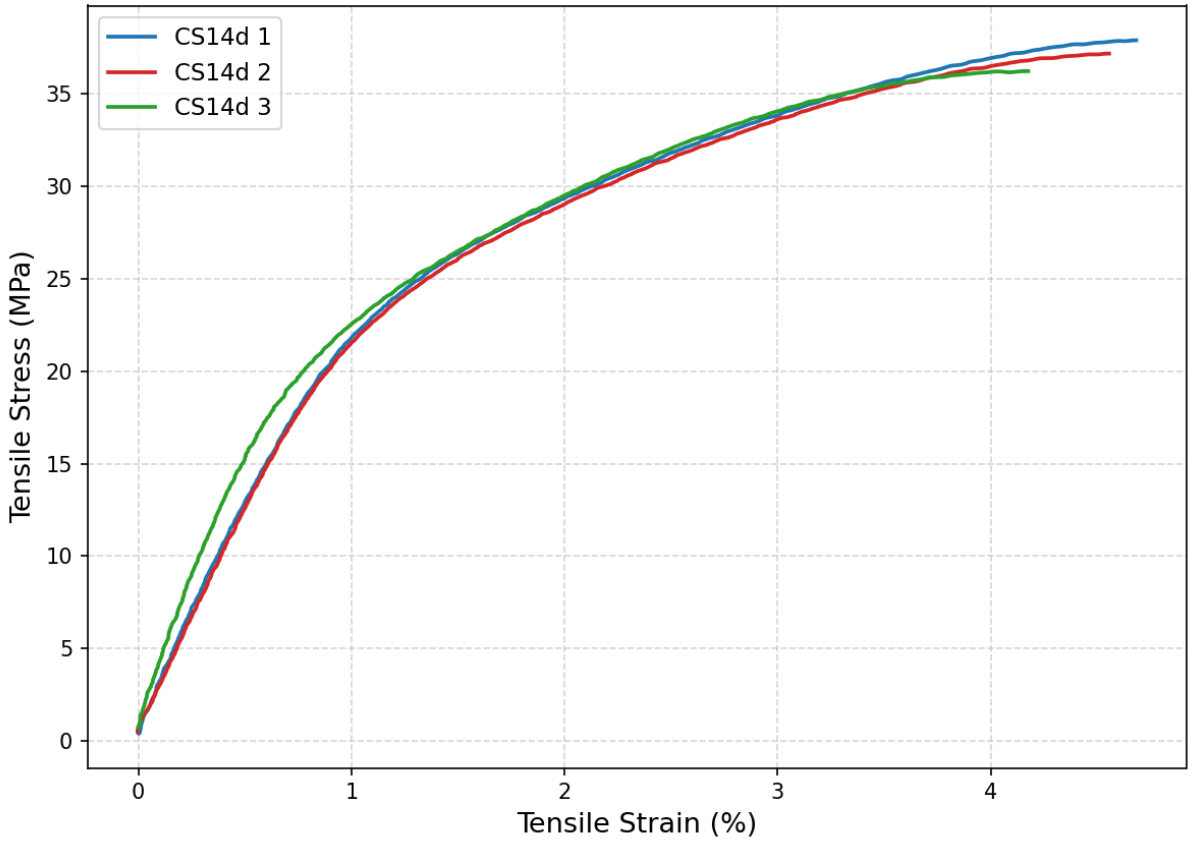
Results – CTRL Sample



Replicate	Modulus of Elasticity [GPa]	Tensile Strength, UTS [MPa]	Strain at UTS [%]	Thickness [mm]
1	2.47	37.44	5.07	0.78
2	2.36	36.49	4.22	0.85
3	2.62	37.13	4.33	0.86
Mean	**2.48**	**37.02**	**4.54**	**0.83**
Std. Dev.	0.13	0.49	0.46	0.04

- Highly repeatable tensile behavior for 3 replicates.

Results – CS14d Sample

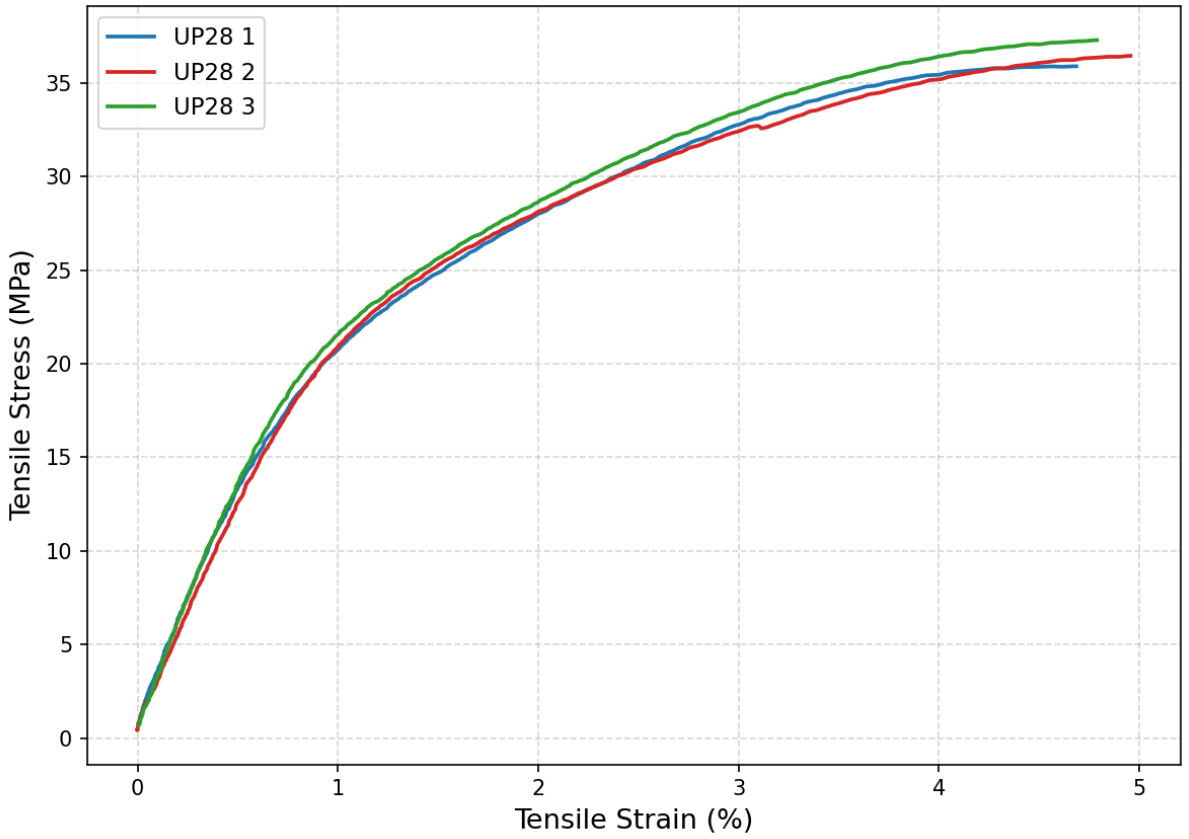


Replicate	Modulus of Elasticity [GPa]	Tensile Strength, UTS [MPa]	Strain at UTS [%]	Thickness [mm]
1	2.65	37.86	4.75	0.88
2	2.40	37.19	4.56	0.82
3	3.42	36.24	4.18	0.78
Mean	**2.82**	**37.10**	**4.49**	**0.83**
Std. Dev.	0.53	0.82	0.29	.05

Slight differences, as compared to CRTL specimen:

- Higher Modulus mean and standard deviation.
- Higher variation in Ultimate Tensile Strength (UTS).
- Lower variation in Strain at UTS.

Results – UP28 Sample



Replicate	Modulus of Elasticity [GPa]	Tensile Strength, UTS [MPa]	Strain at UTS [%]	Thickness [mm]
1	2.76	35.90	4.69	0.74
2	2.39	36.45	5.08	0.87
3	2.84	37.30	4.79	0.65
Mean	**2.66**	**36.55**	**4.85**	**0.75**
Std. Dev.	0.24	0.70	0.20	0.11

Slight differences, as compared to CRTL specimen:

- Higher Modulus and Strain at Ultimate Tensile Strength (UTS).
- Lower Ultimate Tensile Strength.

Appendix 1 – Experimental Method

Instrument	Instron 68SC-5 (Appendix 2)
Test Methods	• ASTM D638
Samples	• Type V dog bone samples, received ‘ready to test’
Load Train	• 500 N load cell • 250 N screw action grips • 25 mm x 25 mm serrated jaw faces
Testing Rate	• 1 mm/min
Testing environment	• Ambient: 24.5 °C, 41.8% RH
Extensometer	• Instron AVE3 *(Appendix 3)*

Appendix 2 – Instrument: Instron 68SC-5

Parameter	Value
Maximum Load	5000 N
Load Accuracy	± 0.5% of reading down to 1/1000 of load cell capacity
Speed Range	0.005 to 2000 mm/min
Crosshead Travel	Up to 1120 mm (44 in.)
Software	Bluehill Universal

Appendix 3 – Instrument: Instron AVE3 Video Extensometer

Parameter	Value
Applications	Plastics, metals, composites, textiles, films, elastomers, paper, components, biomaterials (nearly any material)
Loading	Tensile, compression, bend
Resolution	0.5 μm
Accuracy	±1 μm or 0.5% of reading (whichever is greater)
Gage length range	4 – 175 mm

STUDY 2 - FULL REPORT

S. mutans Biofilm Degradation Pilot

University at Buffalo Materials Testing Facility | April/May 2026

Unplastic Tensile S.Mutans Biofilm Degradation Pilot Results

April/May 2026

Materials Testing Facility

University at Buffalo

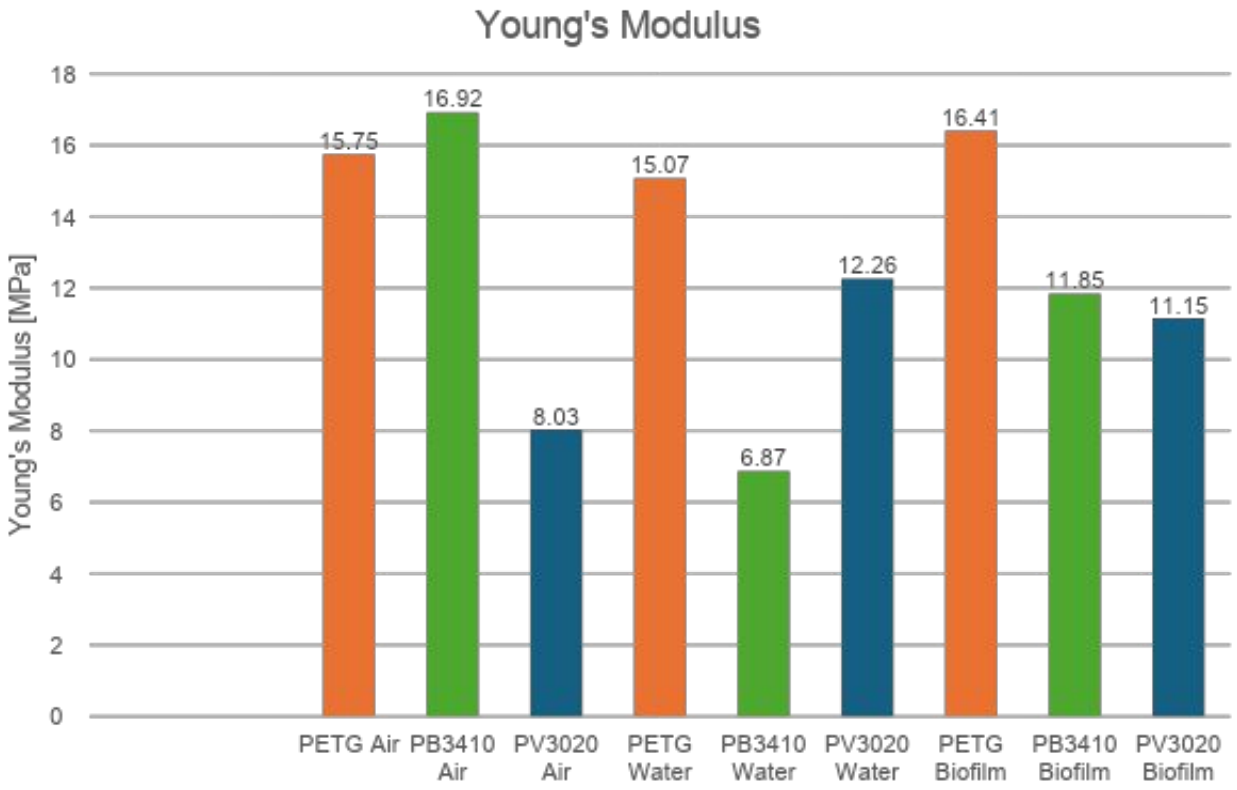
Project Scope

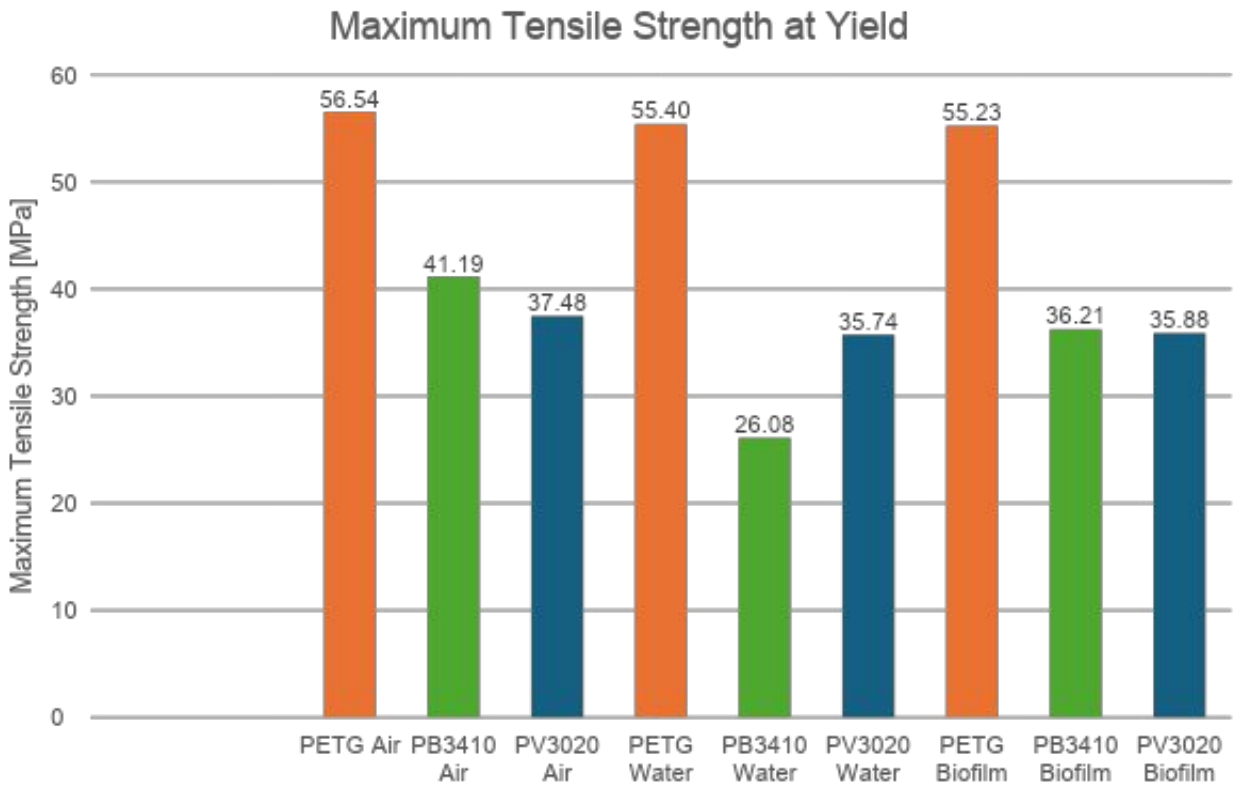
- Artificial aging of two experimental (PHA) and one PETG aligner groups dogbone specimens in S.Mutans (2ea), Deionized water (2ea), and air (2ea) for two weeks
- Tensile testing to failure of specimens after two weeks

Protocol Description

- Based on ASTM D638-22
  - Type V dogbone specimens
- 70% isopropanol wipes cleaning to disinfect and remove biofilms from specimens before each biofilm cycle (5 cycles; every 2-3 days; 3 weeks)
  - S.Mutans NCTC 10449 strain in brain heart infusion broth with 1% sucrose
- Tensile testing
  - Specimen width and thickness measured at three locations along gage length to calculate respective average dimensions
  - Wedge grips used to fixture specimens to universal testing machine (Dillion Quantrol TC2i)
  - Crosshead speed:10mm/min until break
  - Elastic slope recorded (Young's Modulus calculated)
  - Nominal Displacement recorded (nominal strain calculated)
  - Maximum tensile load recorded (max tensile strength calculated for failure at yield or fracture

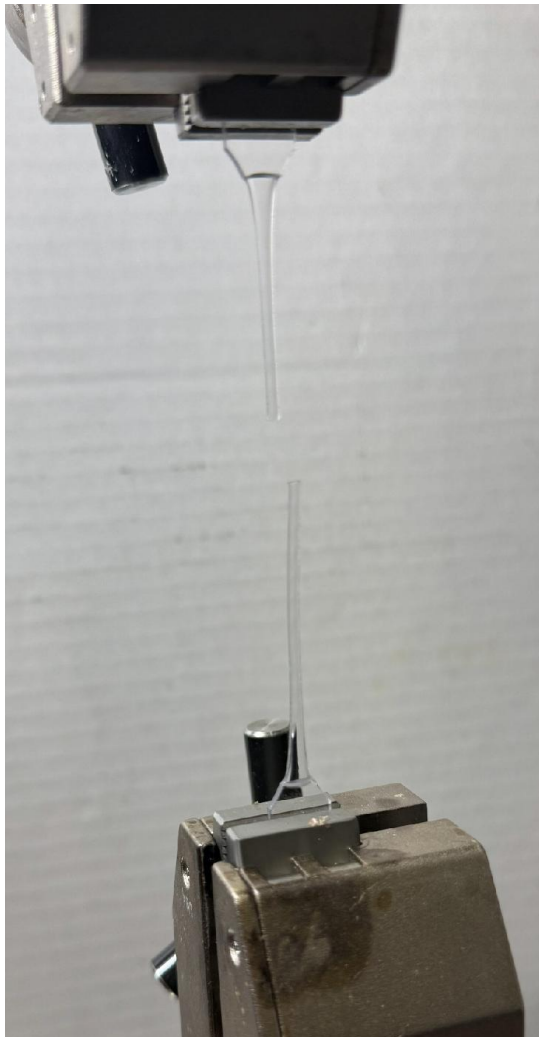
Tensile Testing Results

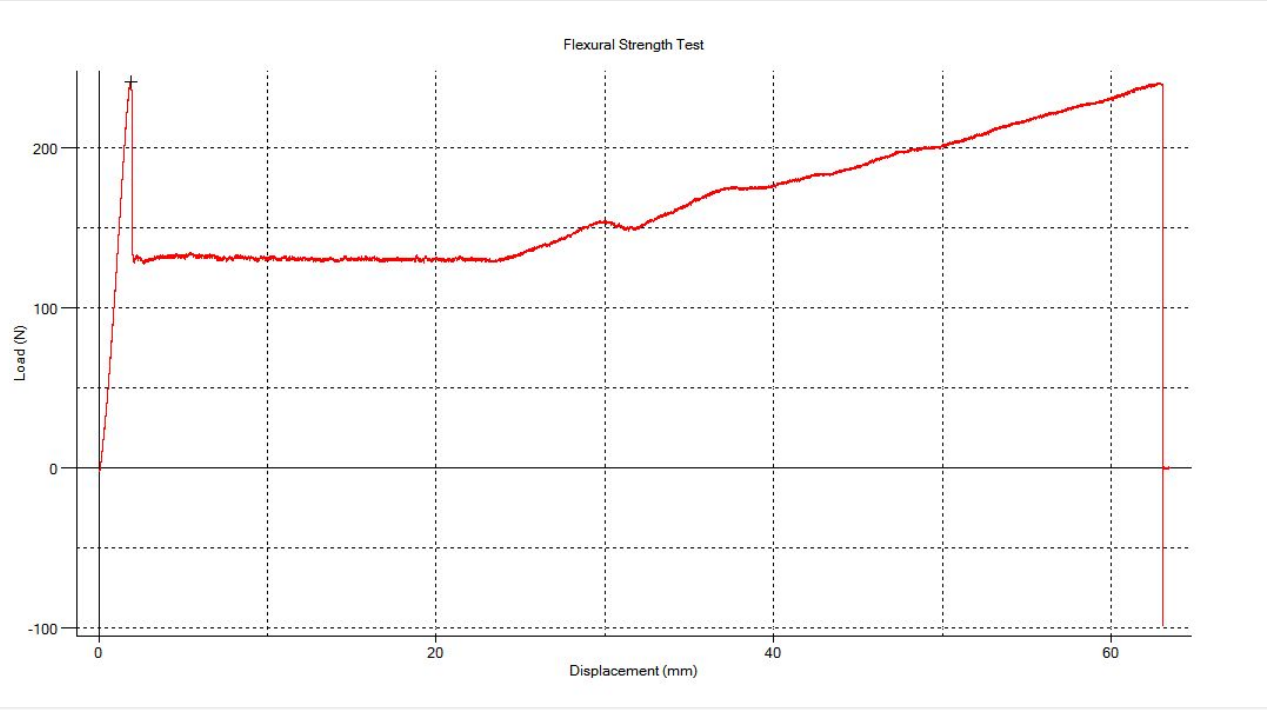




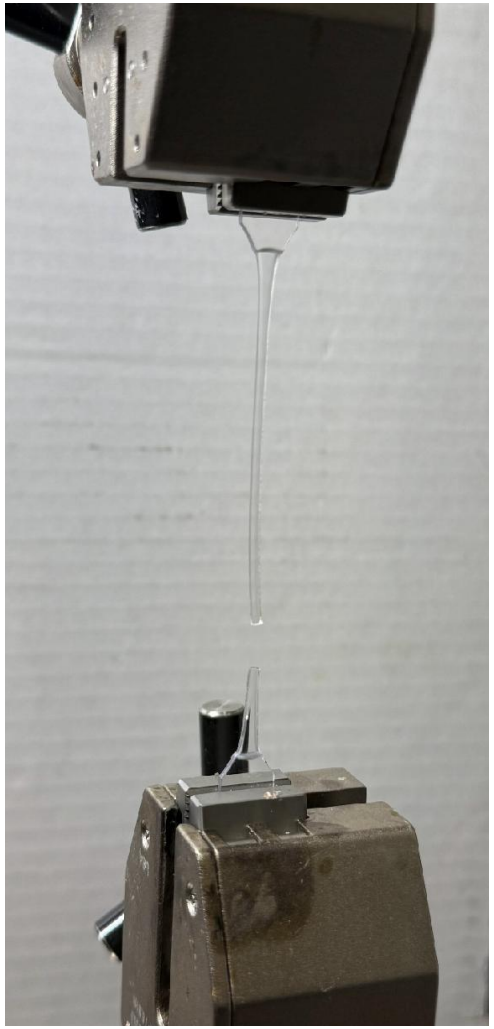
Representative Curves and Specimens

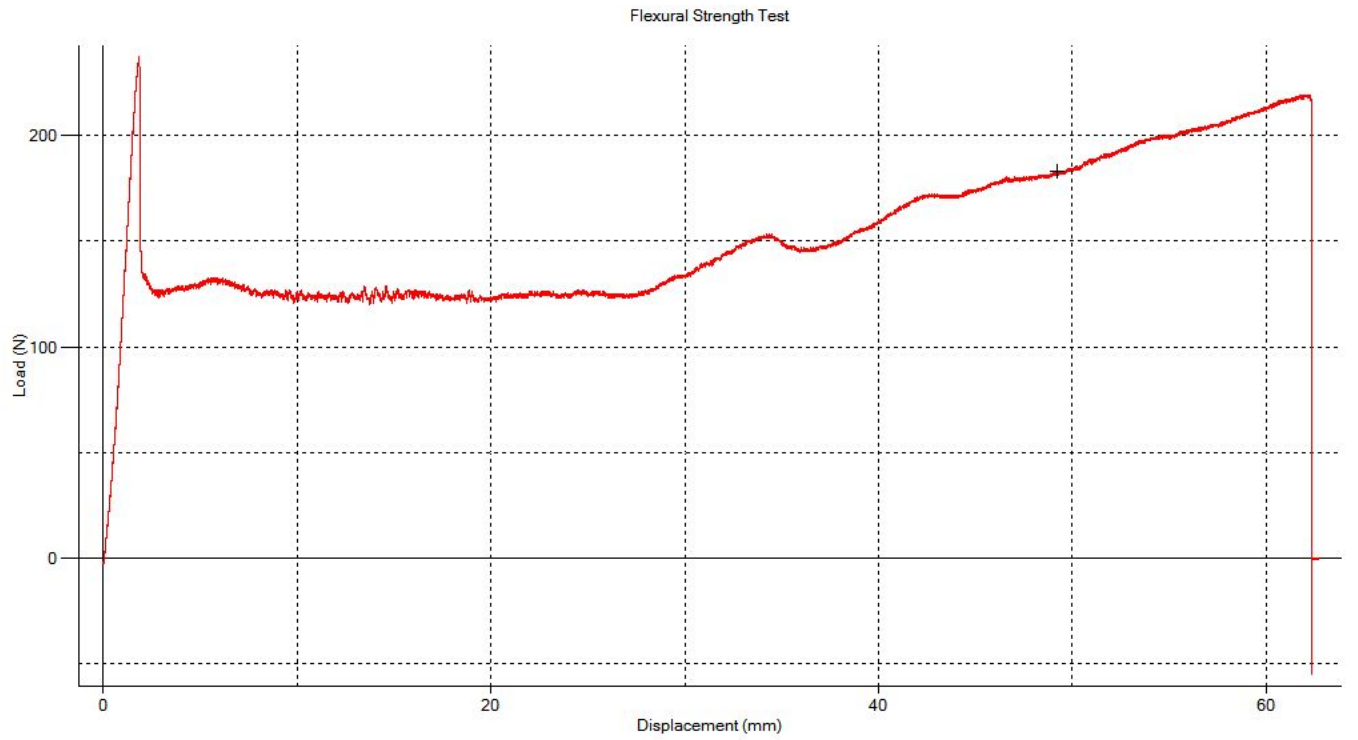
PETG - Air



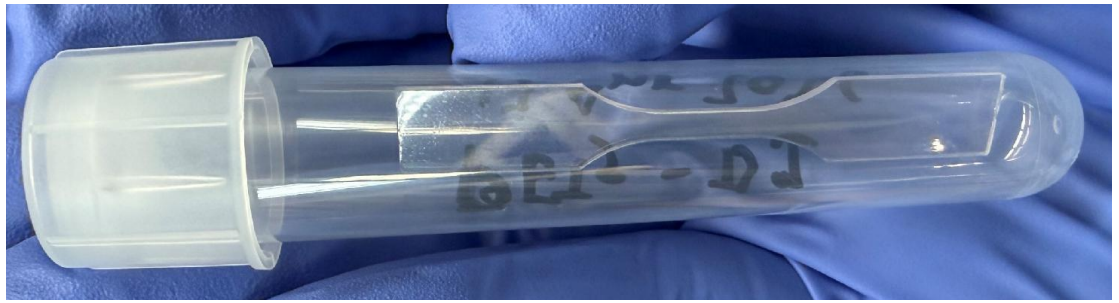

Flexural Strength Test
200
100
0
-100
Load (N)
0
20
40
60
Displacement (mm)

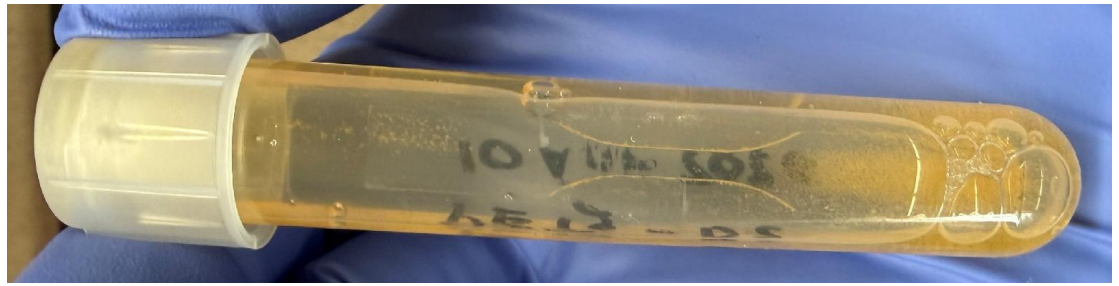
PETG - Water

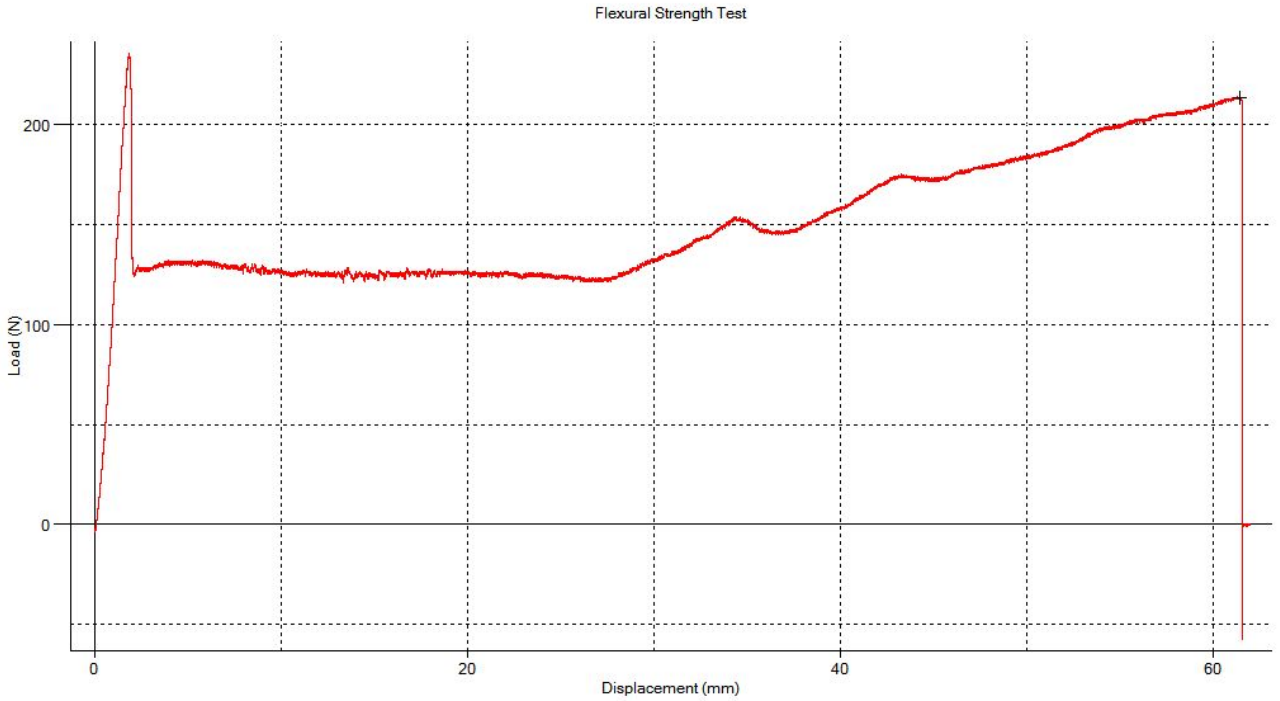



Flexural Strength Test
200
100
0
Load (N)
0
20
40
60
Displacement (mm)

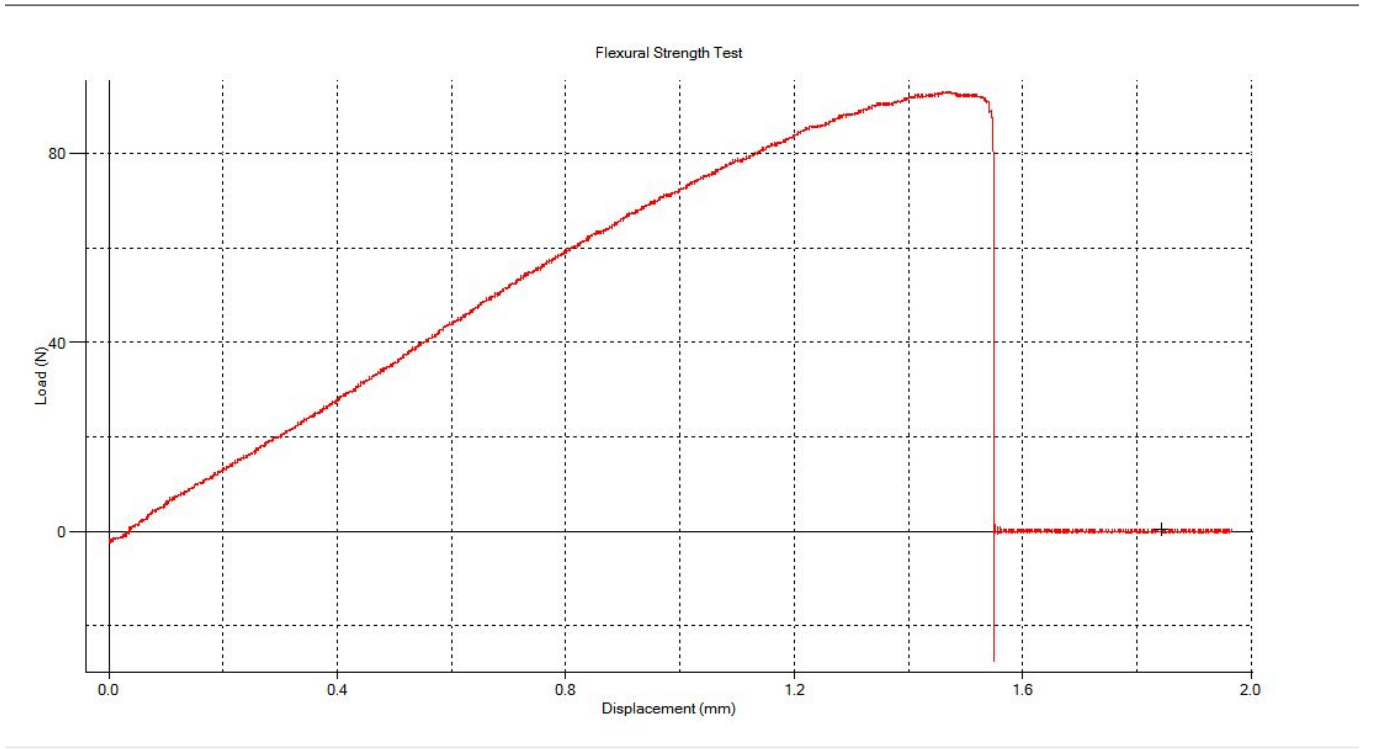
PETG – S.Mutans



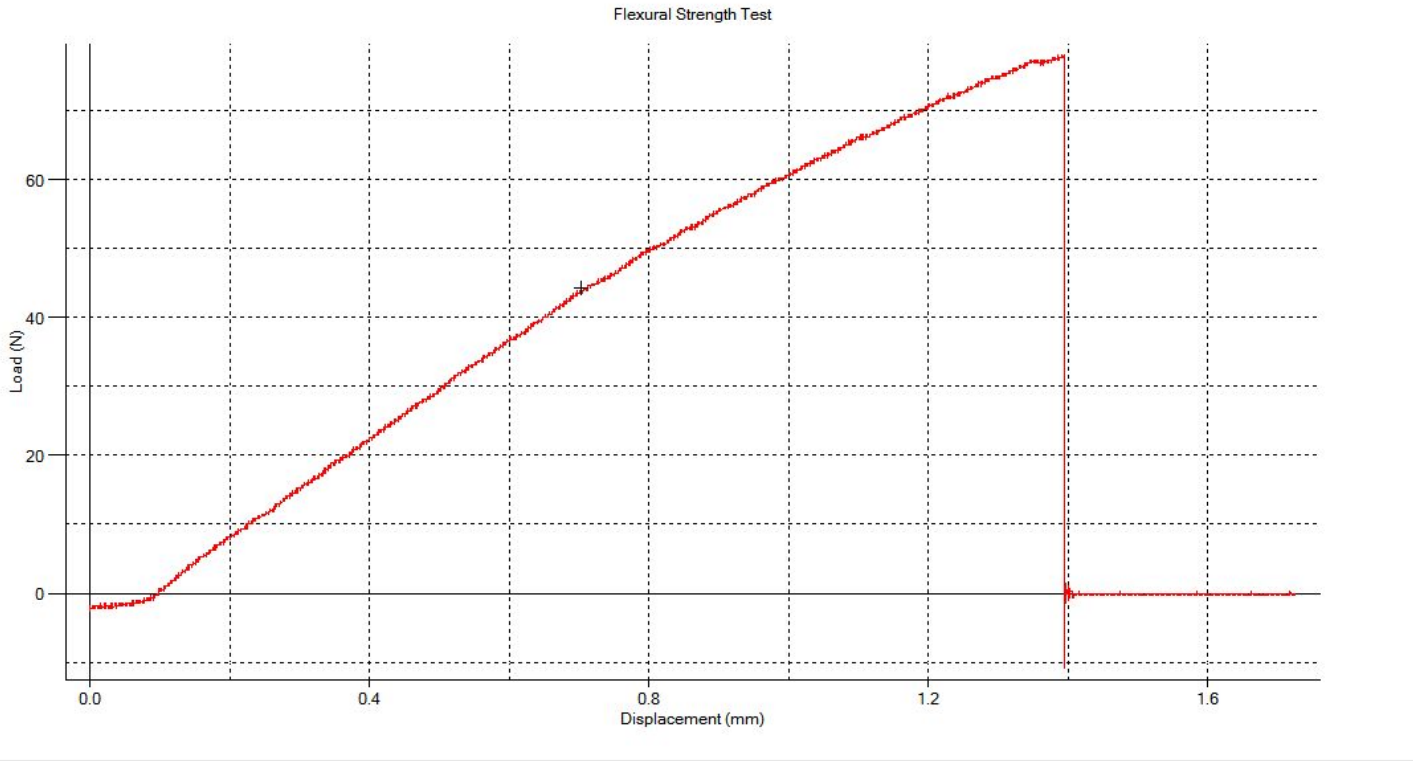




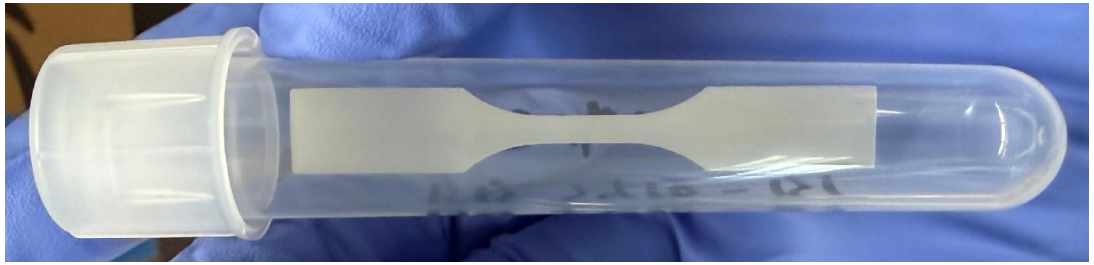
Moses PHA - Air

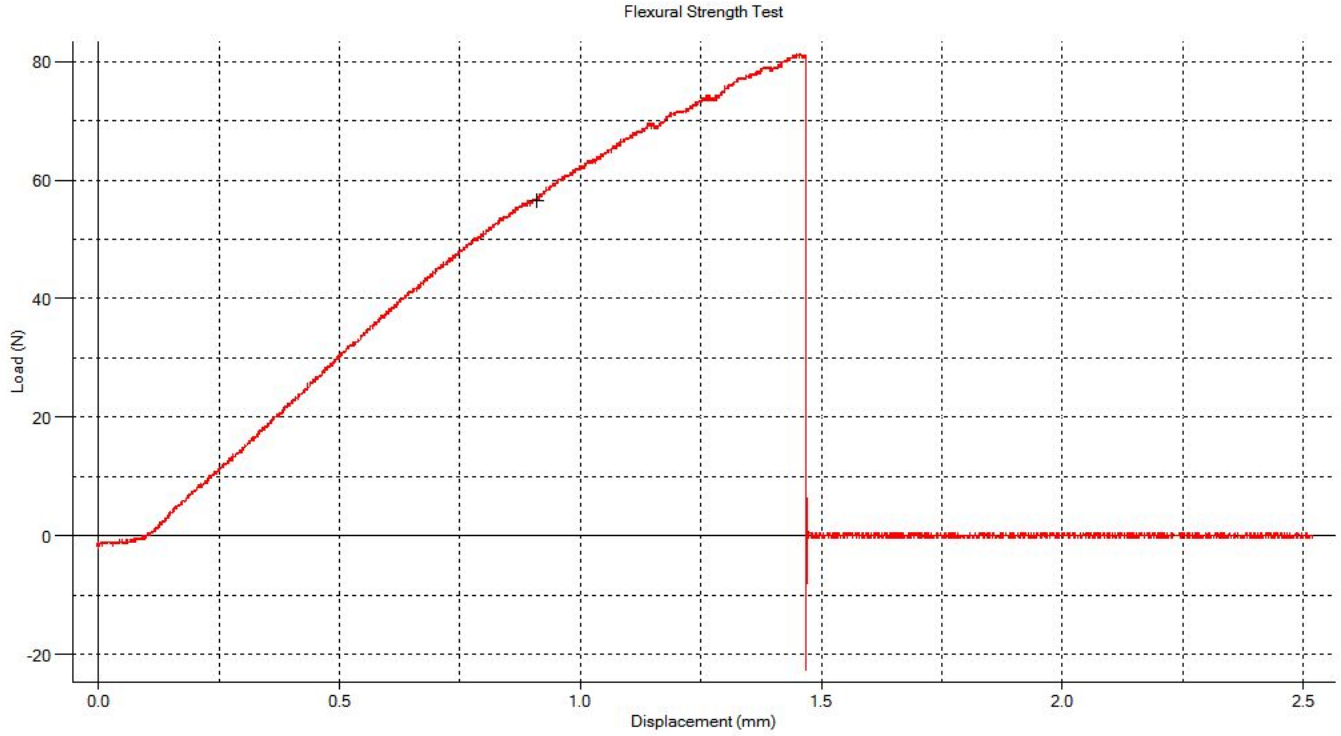


MosesPHA - Water

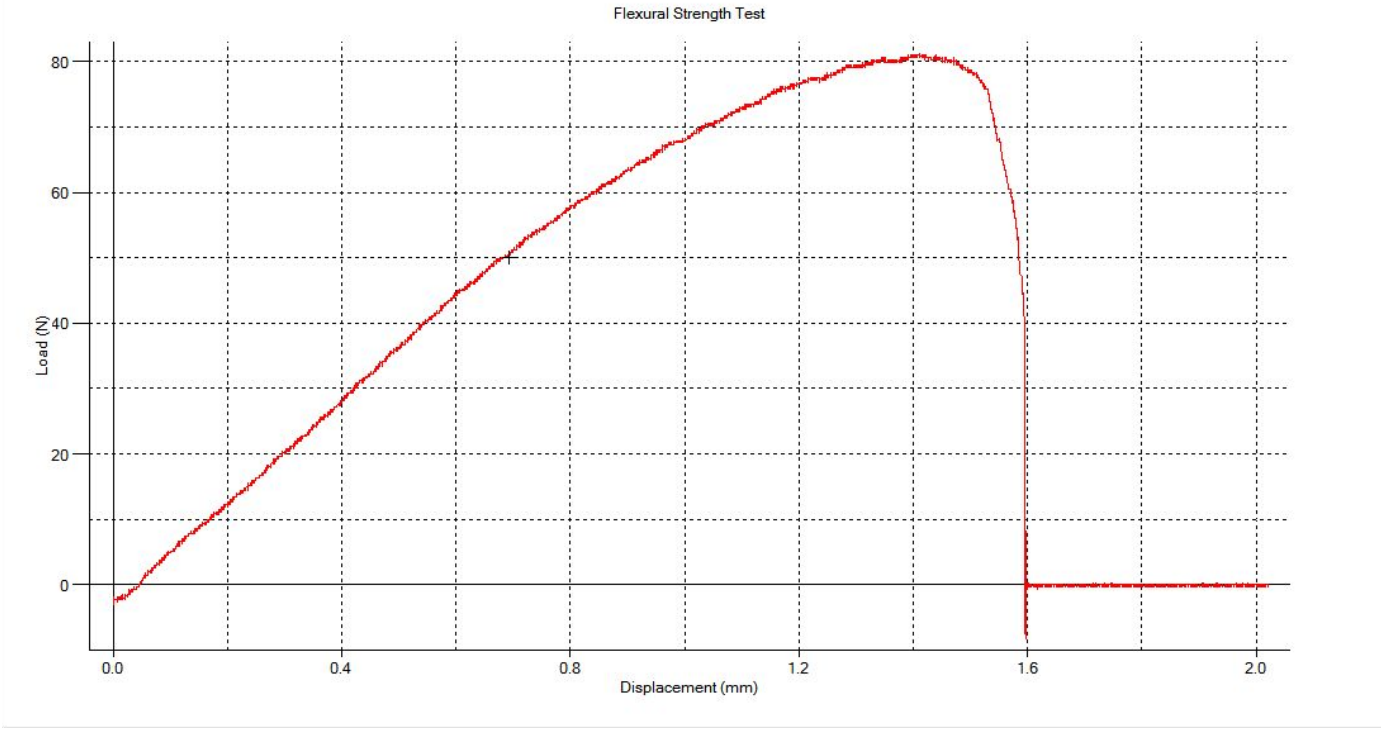


MosesPHA – S.Mutans

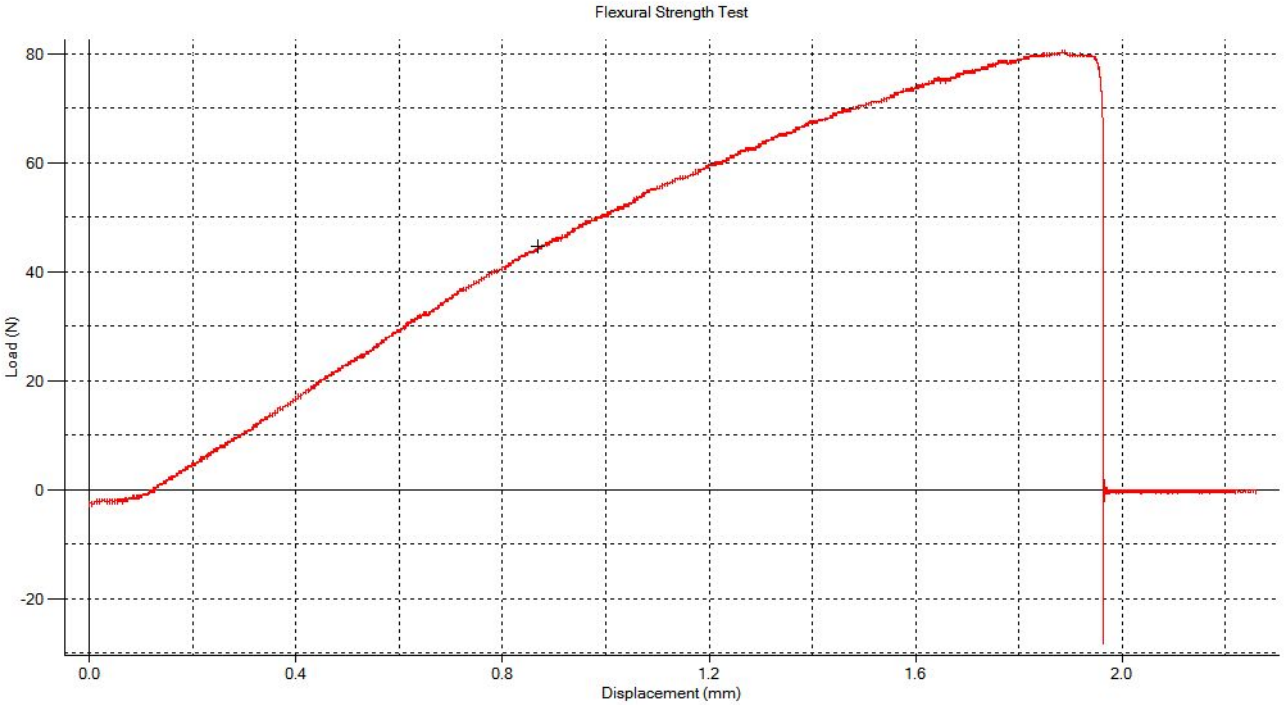




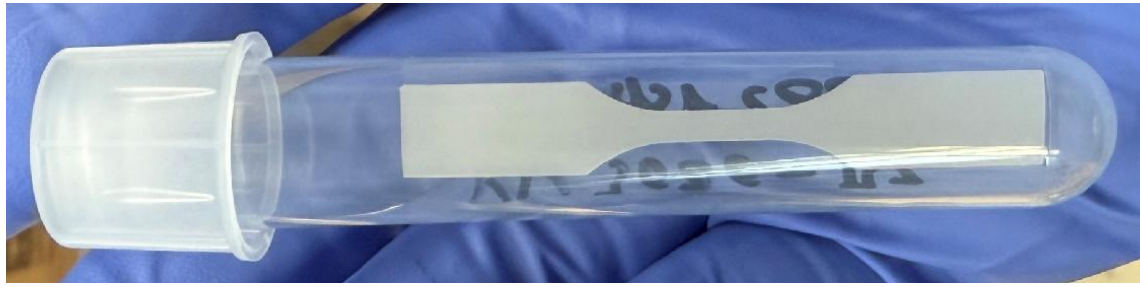
MosesPHA-2 - Air

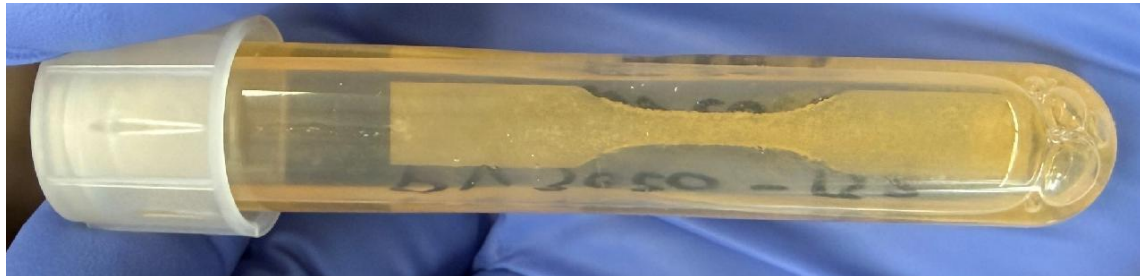


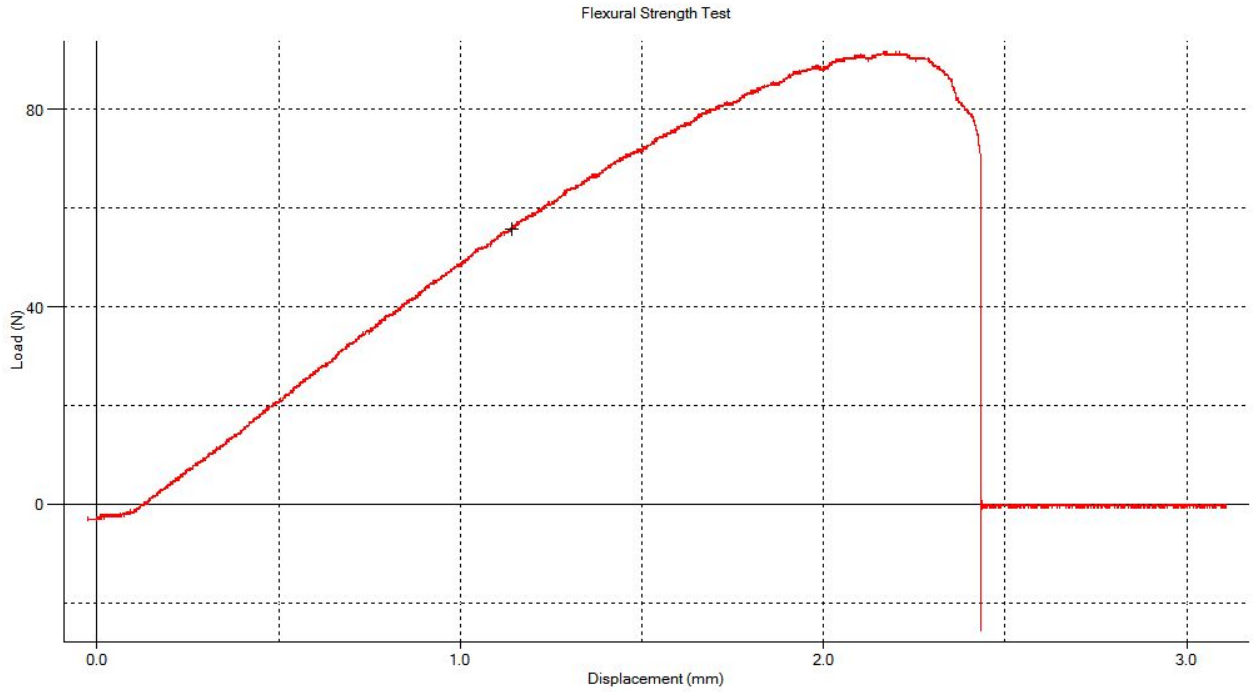
MosesPHA-2 - Water



MosesPHA-2 – S.Mutans







Conclusions and Recommendations

- No noticeable aesthetic changes to any specimens
- Biofilms appeared to mainly grow on roughened surfaces
- The pilot showed no discernable difference in strength of the specimens after exposure to biofouling