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Swab Tensile Testing Results and Procedures

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Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Swab Tensile Testing Results and Procedures

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1. Tensile Testing Results

This tensile test is to mimic the worst-case scenario of the swab being caught on an obstruction when being pulled out of the nasopharyngeal space. It is to determine how much tensile force the swab can withstand without breaking. A variety of different swabs (different materials and different geometries) were tested using the protocol outlined in Section 2 (Tensile Testing Procedure). Not all of the swabs were pre-treated using the Autoclave. For those swabs that were pre-treated using the Autoclave, the tensile tests were performed within 6 hours of completion of the Autoclave pre-treatment, with the exception of the Injection Molded samples. For the Injection Molded samples, the tensile tests were performed within 24 hours of the completion of the Autoclave pre-treatment. The FormLabs-USF and FormLabs-Northwell were printed at LLNL using FormLabs Surgical Grade V1 Resin on a Form 3B Printer. All other samples were provided by HP.

The results are shown in Tables 1, 2, and 3 and Figures 1 and 2. Table 1 and Figure 1 show the force required to break the swab. Table 2 and Figure 2 show the elongation of the swab at the break point. Unless otherwise noted, the force and elongation at the break point were automatically measured by the Bluehill Universal Software as the point at which the force changed by 40%. Comparison data for the commercial Puritan and Copan swabs was estimated from the graphs of results from the Harvard-Army Team. (These graphs are reproduced in Figure 3.) It is not certain that the test procedure used by the Harvard-Army Team and the test procedure outlined in Section 2 (Tensile Testing Procedure) are identical. Table 3 shows the breakpoints of the swabs. Figures 25 – 28 in Section 2 (Tensile Testing Procedure) show examples of the different breakpoint locations. Figures 4 – 7 show images of the various designs tested. All of the samples using the HP PA11 and HP PA12 materials have identical designs. The Injection Molded, FormLabs-USF, and FormLabs-Northwell have different designs.

Summary of Results:

- The force required to break the swabs is comparable to that for the commercial Puritan and Copan swabs, with the exception of the FormLabs-USF and FormLabs-Northwell. The FormLabs-USF and FormLabs-Northwell swabs take 0.5-3X the force required to break than the other swabs.
- The elongation to break for the swabs is comparable to that for the commercial Puritan and Copan swabs, with the exception of the HP PA11 material swabs and the FormLabs-Northwell swabs. This increased elongation length for these swabs does not pose any significant additional clinical risk.
- On average, the HP PA11 material had a larger force required to break and a larger elongation to break than the HP PA12 material.
- On average, the Autoclave pre-treatment increased the force required to break and increased the elongation to break for both the HP PA11 and HP PA12 material.
- On average, the Vapor Polishing of the HP PA11 material increased the force required to break and increased the elongation to break.
- The HP PA12 material and the FormLabs material (Surgical Guide V1 Resin) swabs predominately broke in the neck region. The HP PA11 material swabs predominately

broke at the joint between the head and neck, although there was significant variation in the break locations. The variation in the break locations of the HP PA11 material is likely a contributor to the significant variation in results observed in the HP PA11 material compared to the other materials.

Load to Break (N)												
Sample #	**HP PA11 - Box A**	**HP PA11 - Box A**	**HP PA11 - Box B**	**HP PA11 - Vapor Polished**	**HP PA12 - Box A**	**HP PA12 - Box A**	**HP PA12 - Box B**	**Injection Molded**	**FormLabs - USF**	**FormLabs - Northwell**	**Puritan**	**Copan**
Autoclaved	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	??	??
1	56.53	34.75	47.41	58.24	38.90	28.91	37.59	42.80	102.59	73.71		
2	50.10	30.56	47.05	57.42	35.60	21.17	30.93	40.69	99.60	73.33		
3	29.21	32.80	40.46	47.88	40.50	34.37	36.43	42.00	105.54	75.59		
4	30.22	26.00	32.54	44.94	34.93	5.47 *	31.10	42.48	103.38	73.88		
5	60.59	47.52	41.32	57.42	34.81	21.48	17.00	42.88	104.97	73.25		
6	34.00	48.68	33.79	53.98	42.97	27.08	31.68	44.17	100.90	73.31		
7	43.43	50.39	52.61	19.70	32.55	30.58	28.96	36.49	102.09	76.25		
8	55.59	16.21	46.71	59.08	36.48	18.10	28.68		107.89	74.69		
9	62.49	50.95	36.31	54.34	35.56	33.53	29.00		102.77	75.47		
10	28.44	48.14	44.71	50.63	34.24	32.25	31.23		104.01	73.08		
Mean	**45.06**	**38.60**	**42.29**	**50.36**	**36.65**	**25.29**	**30.26**	**41.64**	**103.37**	**74.26**	**58 ****	**35 ****
St Dev	**13.68**	**12.19**	**6.57**	**11.75**	**3.18**	**8.94**	**5.55**	**2.50**	**2.38**	**1.15**		

* Test did not end cleanly - Manual estimation of break point

** Estimated from graphs provided by the Harvard-Army Team

Table 1. Summary of the force required to break the swab as measured by the Bluehill Universal Software (except for the samples noted: HP PA12 – Box A #4, Puritan, and Copan).

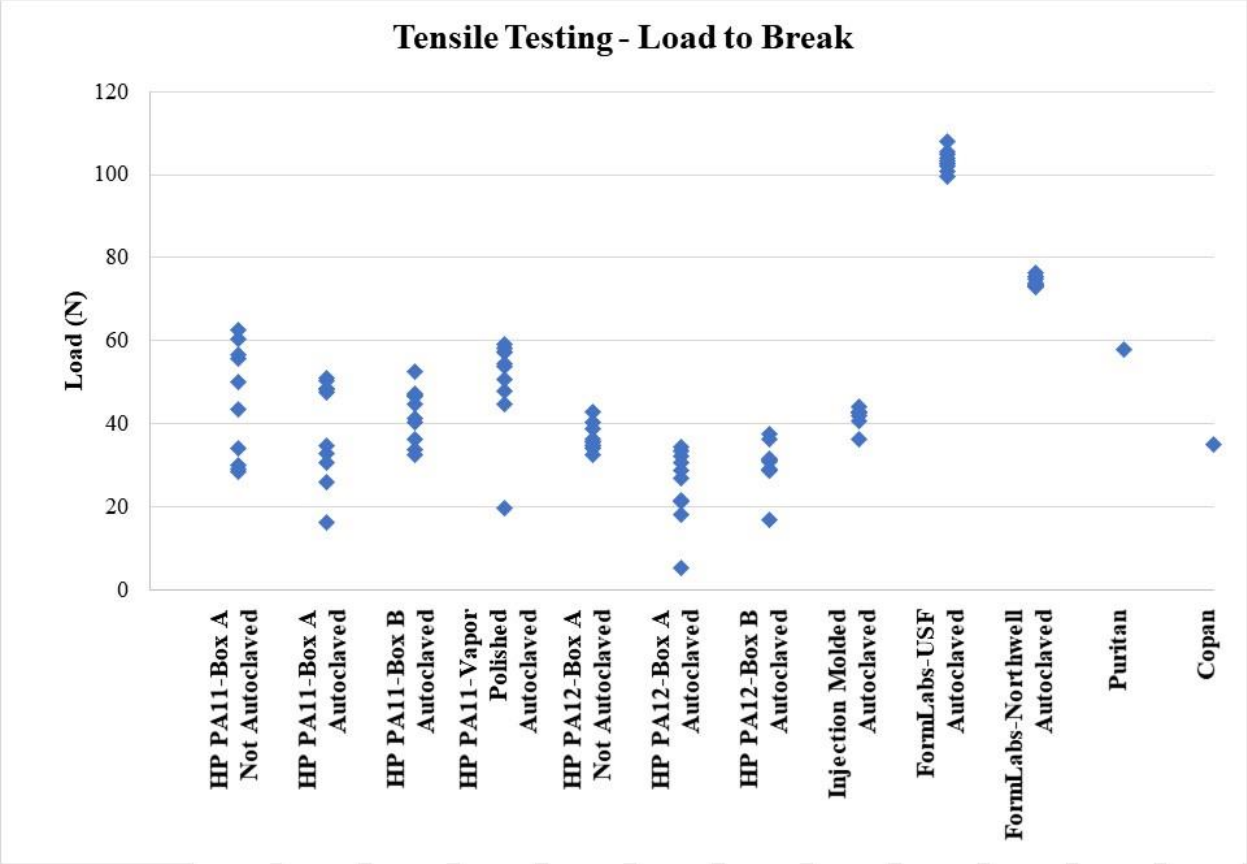


Figure 1. Summary of the force required to break the swab as measured by the Bluehill Universal Software (except for the samples noted: HP PA12 – Box A #4, Puritan, and Copan).

Elongation at Break (mm)												
Sample #	**HP PA11 - Box A**	**HP PA11 - Box A**	**HP PA11 - Box B**	**HP PA11 - Vapor Polished**	**HP PA12 - Box A**	**HP PA12 - Box A**	**HP PA12 - Box B**	**Injection Molded**	**FormLabs - USF**	**FormLabs - Northwell**	**Puritan**	**Copan**
Autoclaved	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	??	??
1	3.60	6.29	21.07	16.81	1.55	2.06	2.90	5.50	7.03	14.17		
2	2.77	4.53	19.81	15.13	1.50	1.39	2.41	4.14	5.12	11.65		
3	1.17	5.76	8.12	8.75	1.83	2.40	2.94	5.38	5.35	8.91		
4	1.19	3.20	6.07	6.87	1.49	1.61 *	2.29	5.35	5.56	11.89		
5	6.88	11.83	8.60	17.86	1.52	1.46	1.29	6.15	5.91	11.41		
6	1.45	21.70	6.76	13.48	2.19	2.01	2.46	7.01	6.55	9.69		
7	1.98	14.39	21.71	19.84	1.36	2.31	2.14	3.45	6.75	8.68		
8	3.19	1.53	11.72	12.62	1.60	1.27	2.00		3.14	9.57		
9	7.45	15.85	6.76	10.90	1.49	2.53	2.18		6.50	7.9		
10	1.20	12.94	11.70	8.75	1.53	2.45	2.41		8.42	10.46		
Mean	**3.09**	**9.80**	**12.23**	**13.10**	**1.61**	**1.95**	**2.30**	**5.28**	**6.03**	**10.43**	**1.78 ****	**5 ****
St Dev	**2.32**	**6.51**	**6.27**	**4.32**	**0.24**	**0.48**	**0.47**	**1.19**	**1.40**	**1.87**		

* Test did not end cleanly - Manual estimation of break point

** Estimated from graphs provided by the Harvard-Army Team

Table 2. Summary of the elongation at the breakpoint of the swab as measured by the Bluehill Universal Software (except for the samples noted: HP PA12 – Box A #4, Puritan, and Copan).

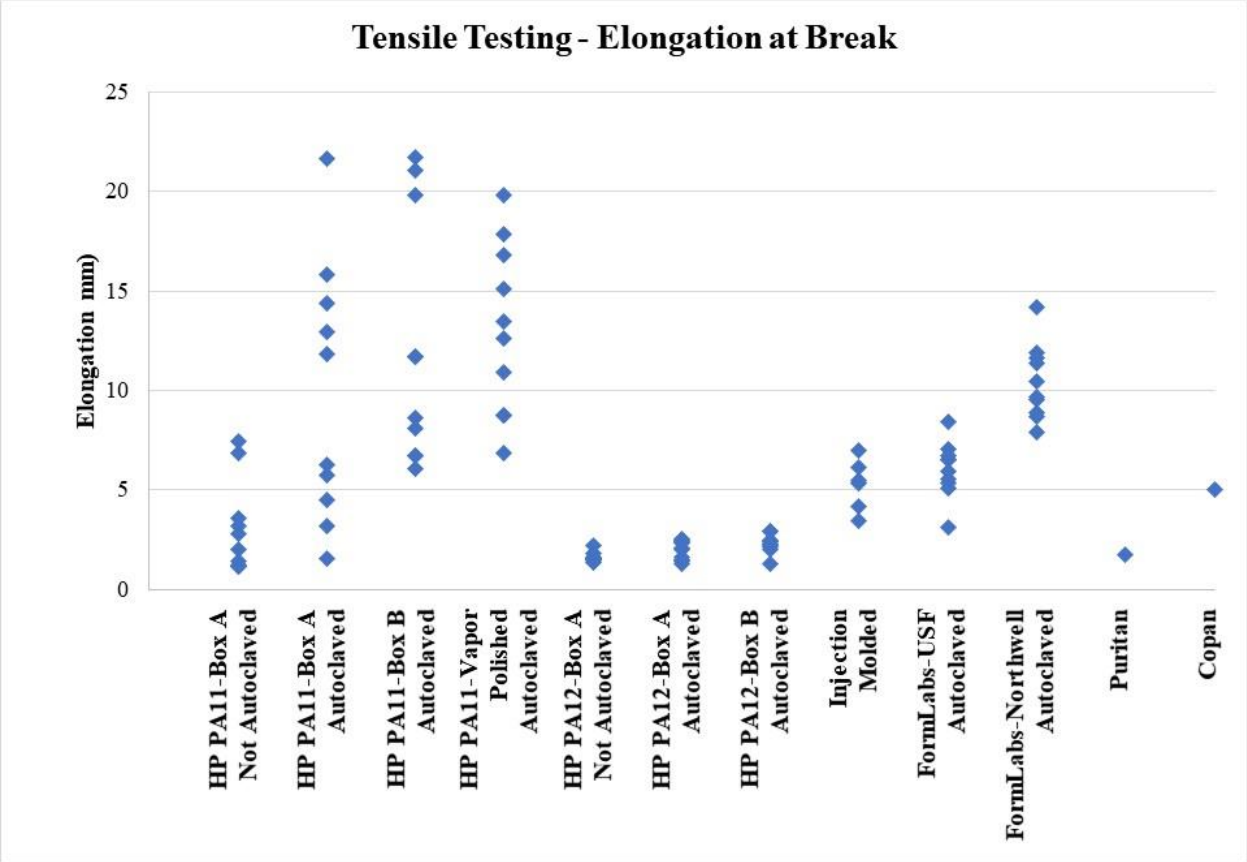


Figure 2. Summary of the elongation at the breakpoint of the swab as measured by the Bluehill Universal Software (except for the samples noted: HP PA12 – Box A #4, Puritan, and Copan).

	Break Location									
Sample #	**HP PA11 - Box A**	**HP PA11 - Box A**	**HP PA11 - Box B**	**HP PA11 - Vapor Polished**	**HP PA12 - Box A**	**HP PA12 - Box A**	**HP PA12 - Box B**	**Injection Molded**	**FormLabs - USF**	**FormLabs - Northwell**
Autoclaved	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
1	Head-Neck	Head	Neck	Head-Neck	Neck	Neck	Neck	Neck	Neck	Neck
2	Head-Neck	Head-Neck	Neck	Head-Neck	Neck	Neck	Neck	Neck	Neck	Neck
3	Head-Neck	Head	Head-Neck	Neck	Neck	Neck	Neck	Neck	Neck	Neck
4	Head-Neck	Head-Neck	Head-Neck	Head-Neck	Neck	Head-Neck	Neck	Neck	Neck	Neck
5	Head-Neck	Head-Neck	Head-Neck	Neck	Neck	Neck	Head	Neck	Neck	Neck
6	Head-Neck	Neck	Head	Head-Neck	Neck	Neck	Neck	Neck	Neck	Neck
7	Multiple *	Neck	Break Point	Head	Neck	Neck	Neck	Neck	Neck	Neck
8	Head-Neck	Head	Head-Neck	Head-Neck	Neck	Neck	Neck		Neck	Neck
9	Head-Neck	Head-Neck	Head-Neck	Head-Neck	Neck	Neck	Neck		Neck	Neck
10	Head-Neck	Head-Neck	Head-Neck	Neck	Neck	Neck	Neck		Neck	Neck

* Swab shattered into multiple pieces during testing.

Table 3. Summary of the breakpoints of the swabs. Examples of the different breakpoint locations are shown in Figures 25 – 28. (There is no data provided on the breakpoints of the commercial Puritan and Copan swabs.)

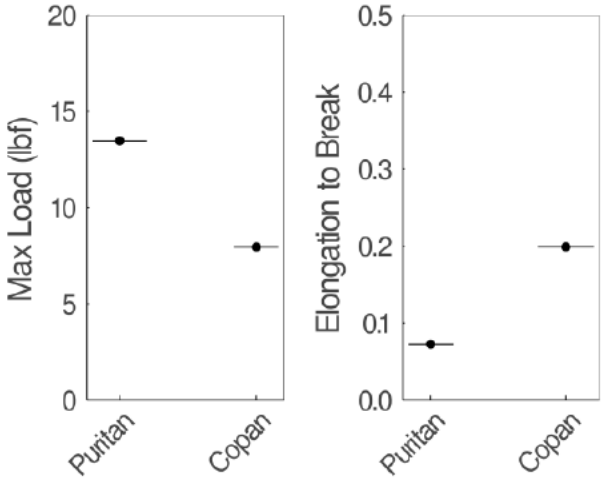


Figure 3. Reproductions of the graphs for results from the Harvard-Army Team used for estimating the force required to break the swabs and the elongation at the breakpoint for the commercial Puritan and Copan swabs.)

Figure 4. Images of the HP swab designs. (All of the HP swabs have the same design.)

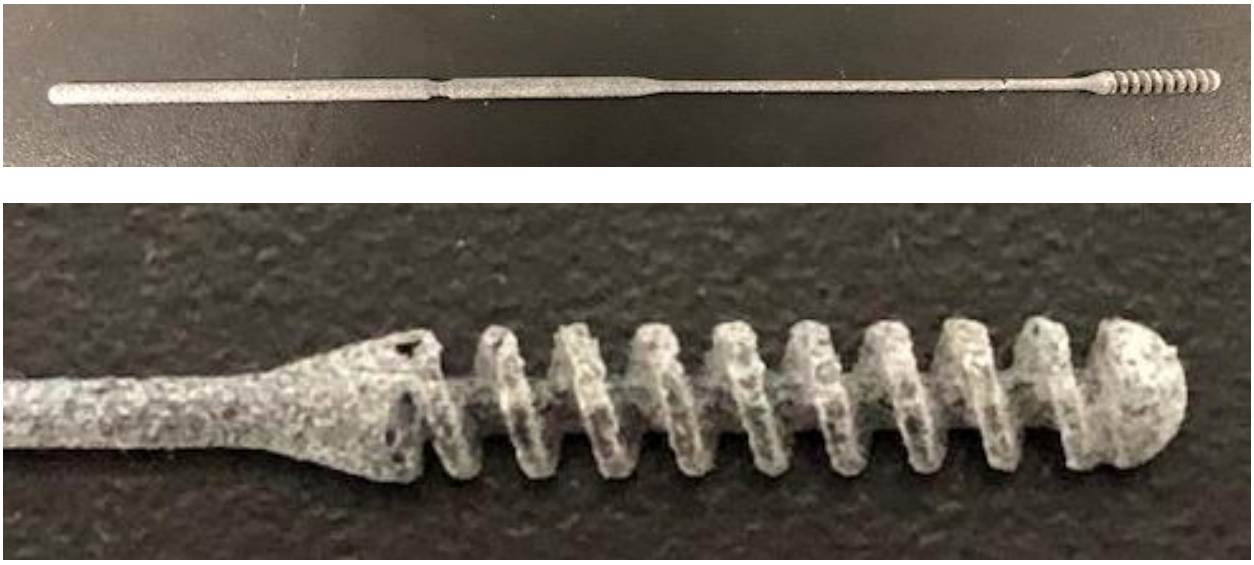


Figure 5. Image of the Injection Molded design.

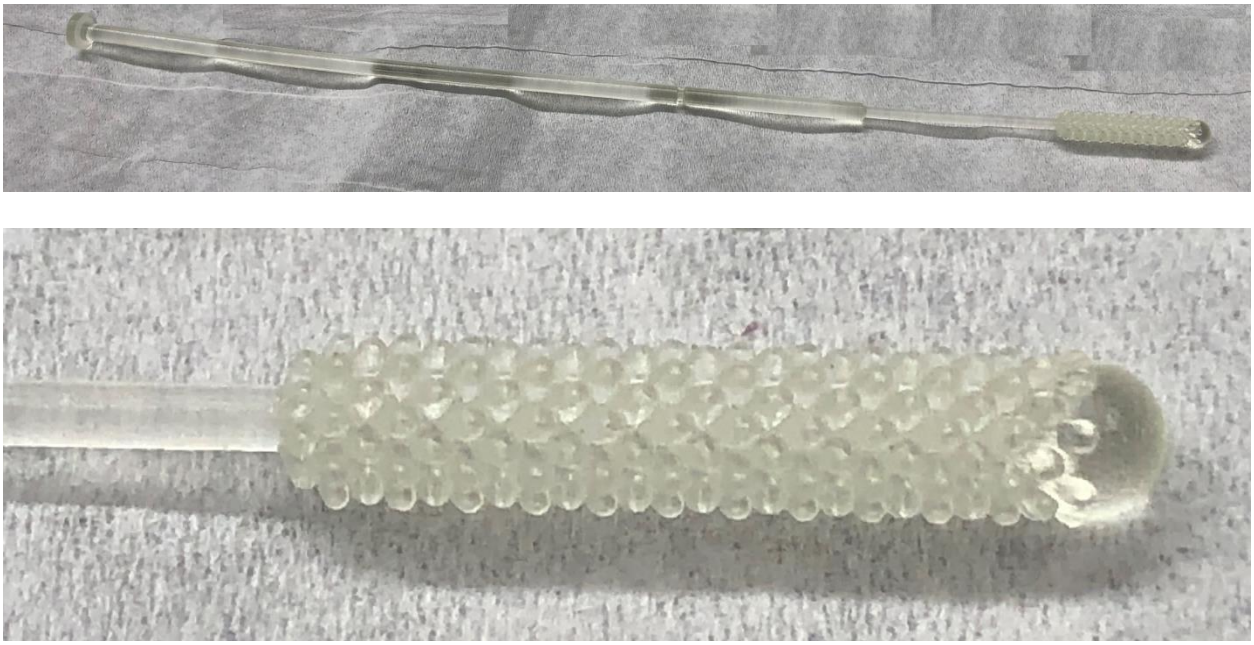


Figure 6. Image of the FormLabs-USF design.

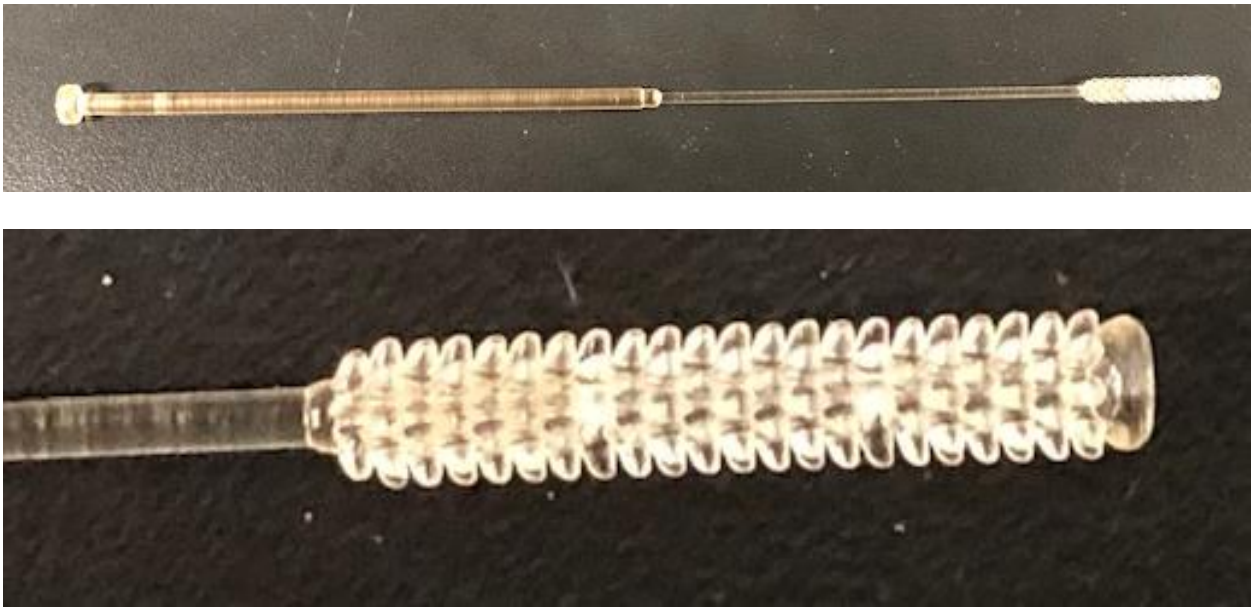


Figure 7. Image of the FormLabs-Northwell design.

The following figures (Figures 8 – 18) show the data collected during the tensile tests (Force vs. Elongation). Figure 5 shows an overlay of the representative samples from each swab type. Figures 9 – 18 show all of the samples for the individual swab types.

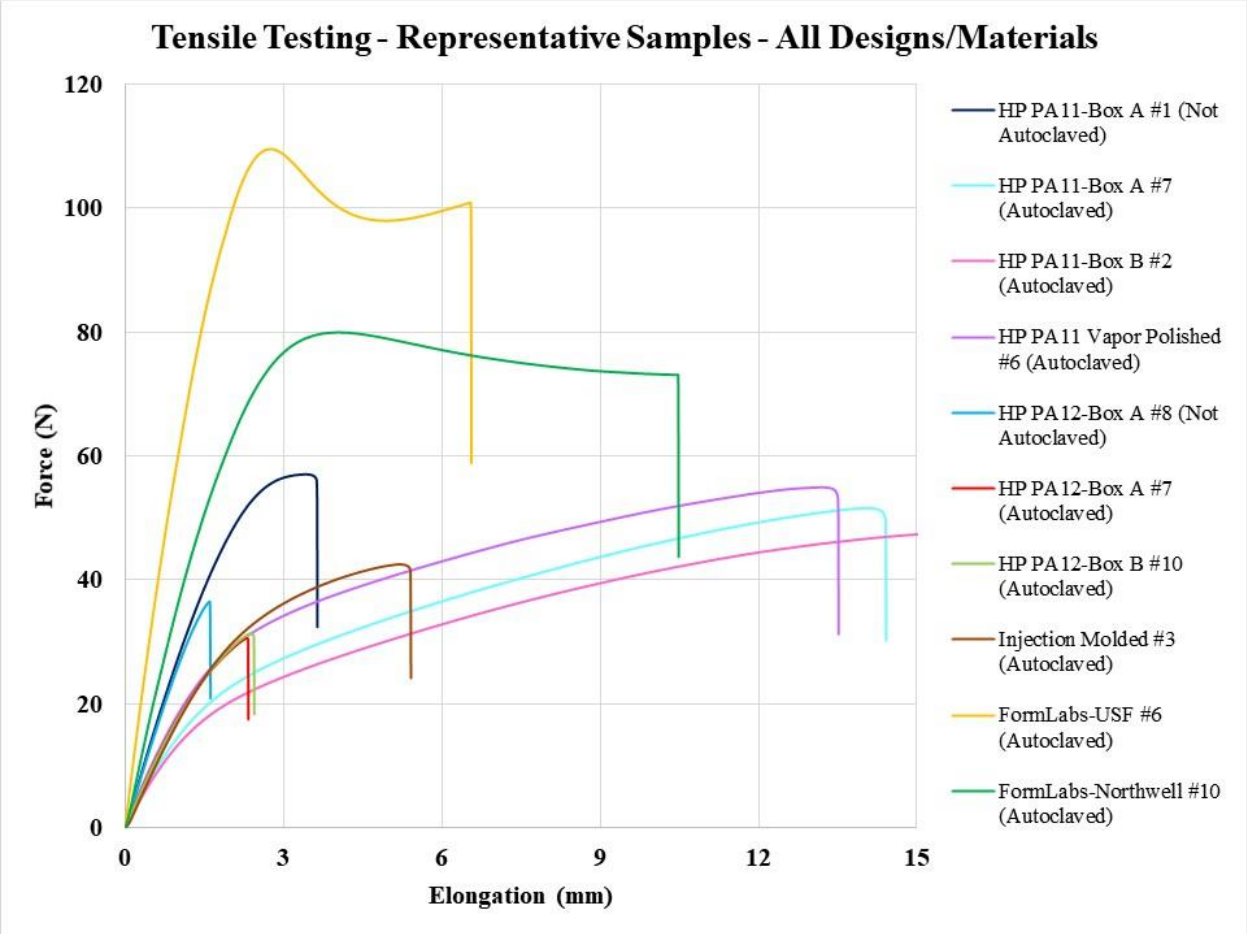


Figure 8. Force versus elongation data collected during the tensile tests for representative samples for all of the swab types tested. The samples shown here are all for swabs that broke at the Neck location (except for the PA11 – Box A – Not Autoclaved Sample, which broke at the Head-Neck location).

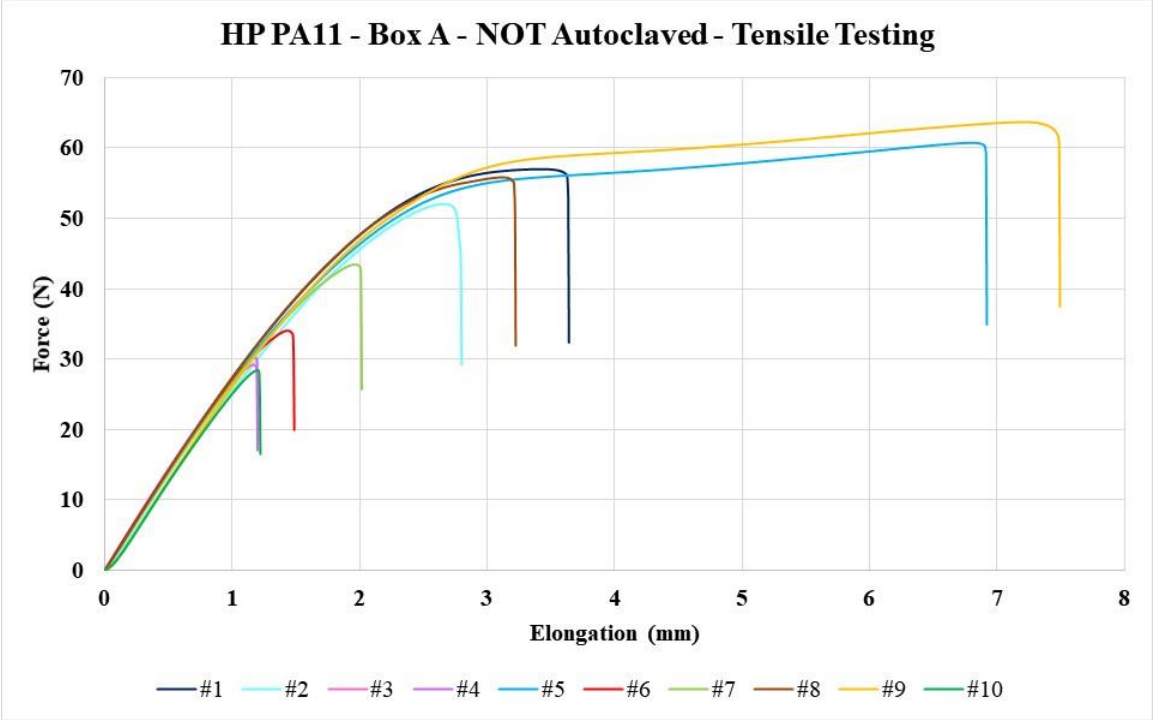


Figure 9. Force versus elongation data collected during the tensile tests for the Not Autoclaved HP PA11 – Box A samples.

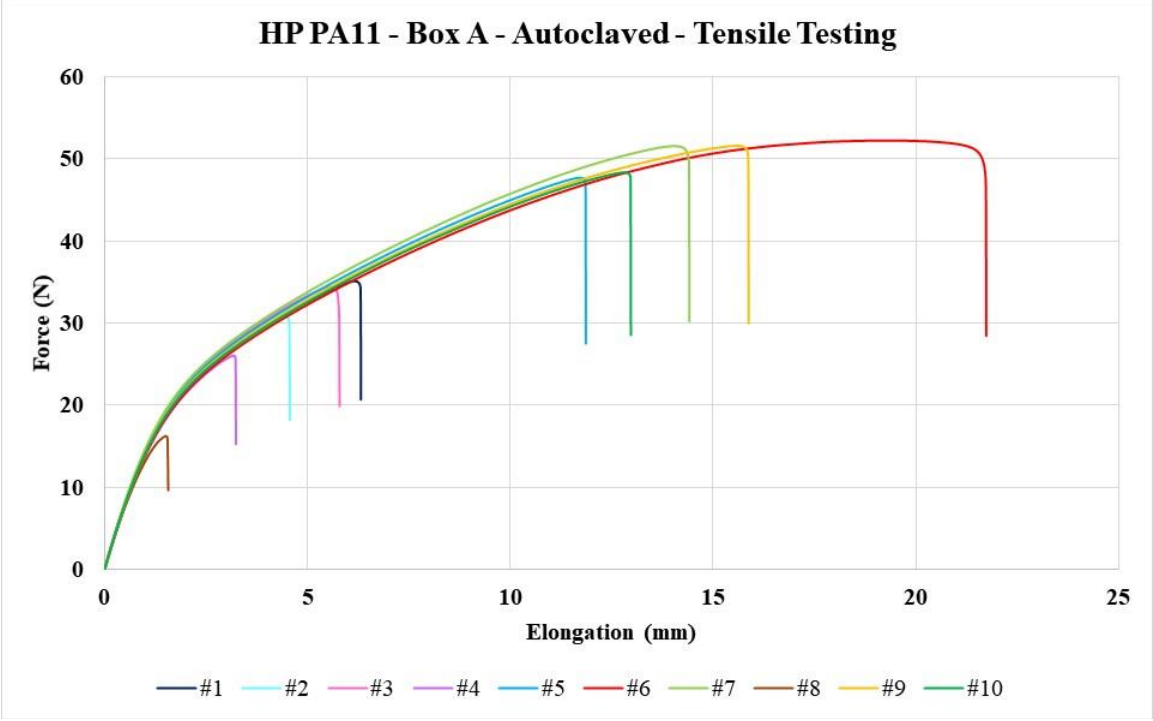


Figure 10. Force versus elongation data collected during the tensile tests for the Autoclaved HP PA11 – Box A samples.

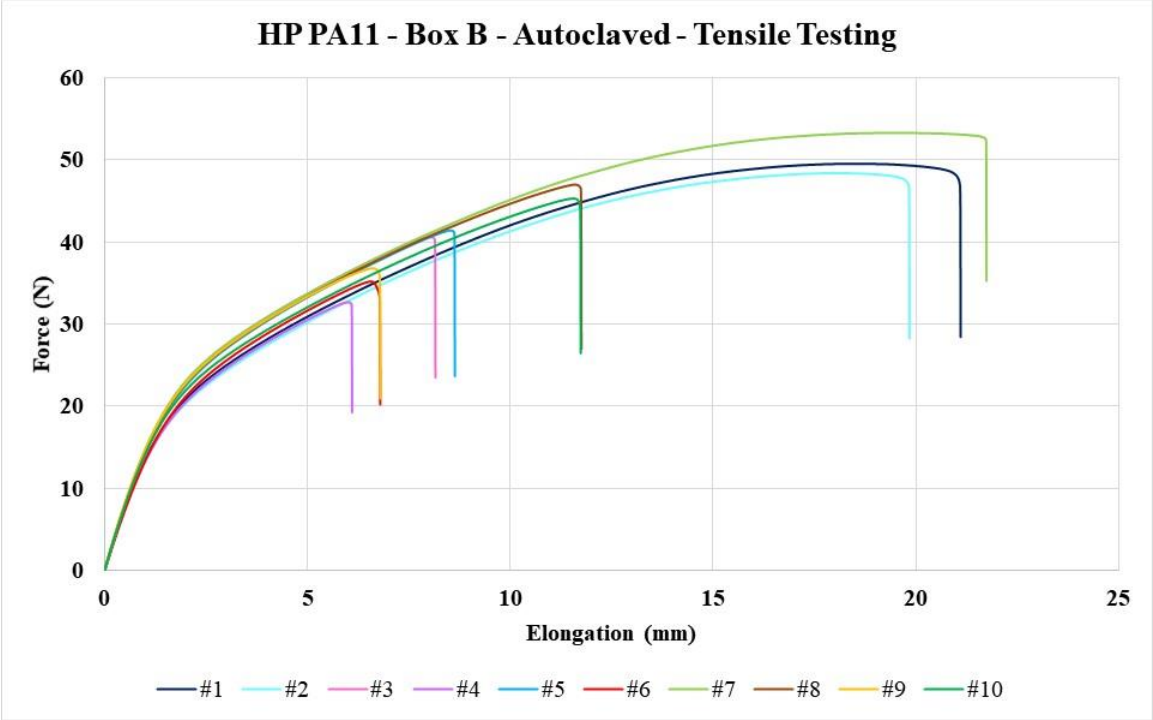


Figure 11. Force versus elongation data collected during the tensile tests for the Autoclaved HP PA11 – Box B samples.

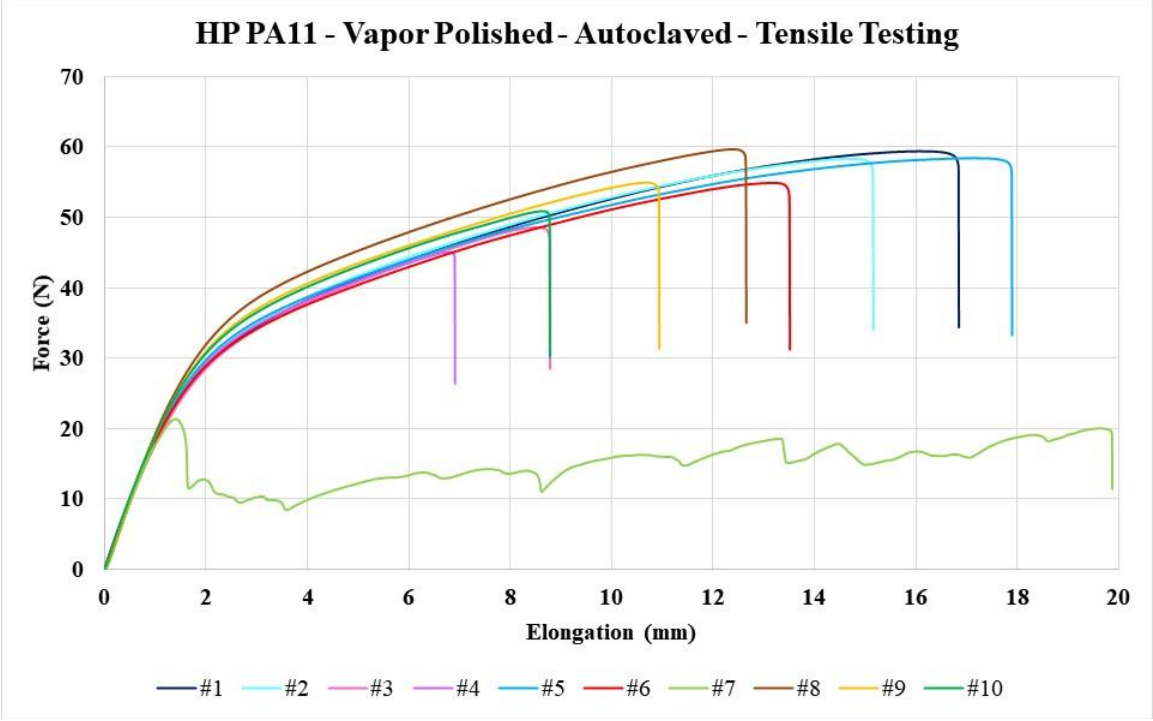


Figure 12. Force versus elongation data collected during the tensile tests for the Autoclaved HP PA11 – Vapor Polished samples.

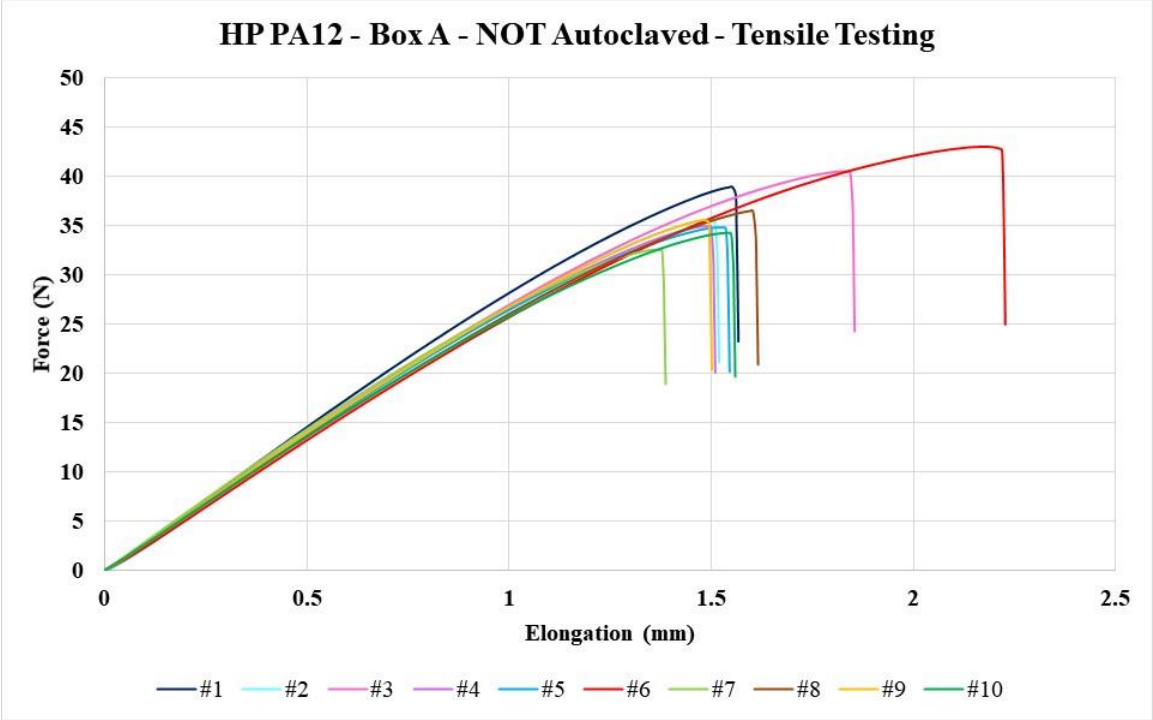


Figure 13. Force versus elongation data collected during the tensile tests for the Not Autoclaved HP PA12 – Box A samples.

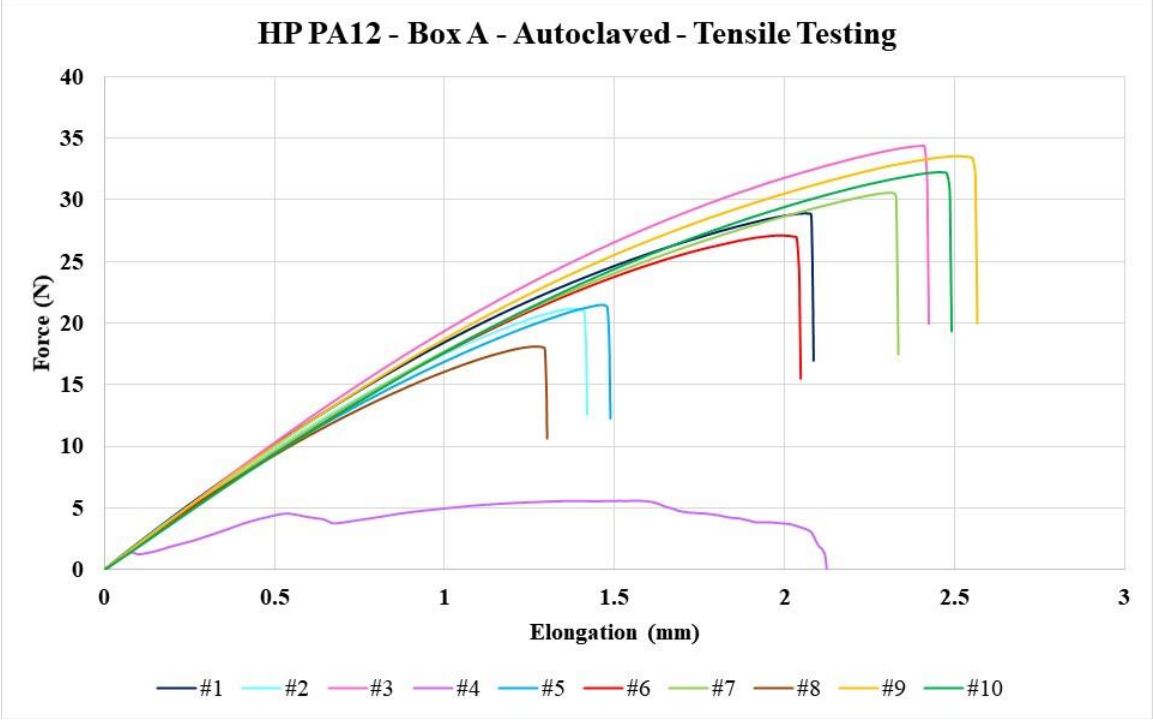


Figure 14. Force versus elongation data collected during the tensile tests for the Autoclaved HP PA12 – Box A samples. For Sample #4, the test did not end cleanly (the sample broke, but the 40% change in force was not detected); for this sample, the break point was manually estimated.

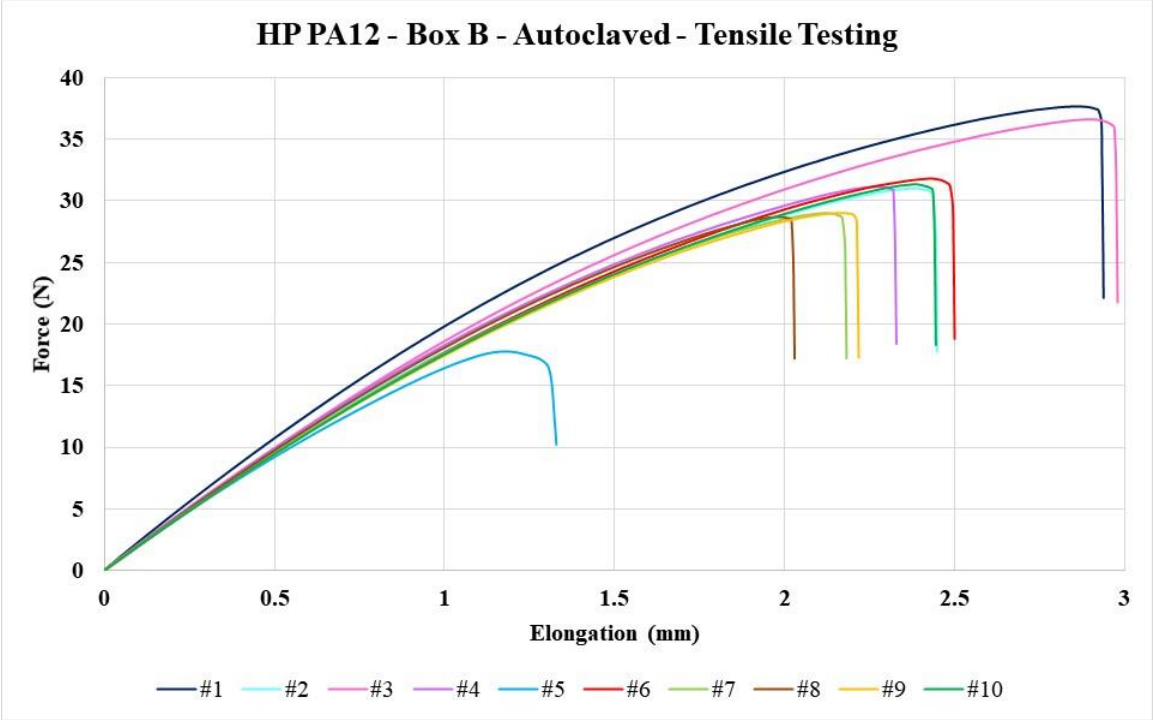


Figure 15. Force versus elongation data collected during the tensile tests for the Autoclaved HP PA12 – Box B samples.

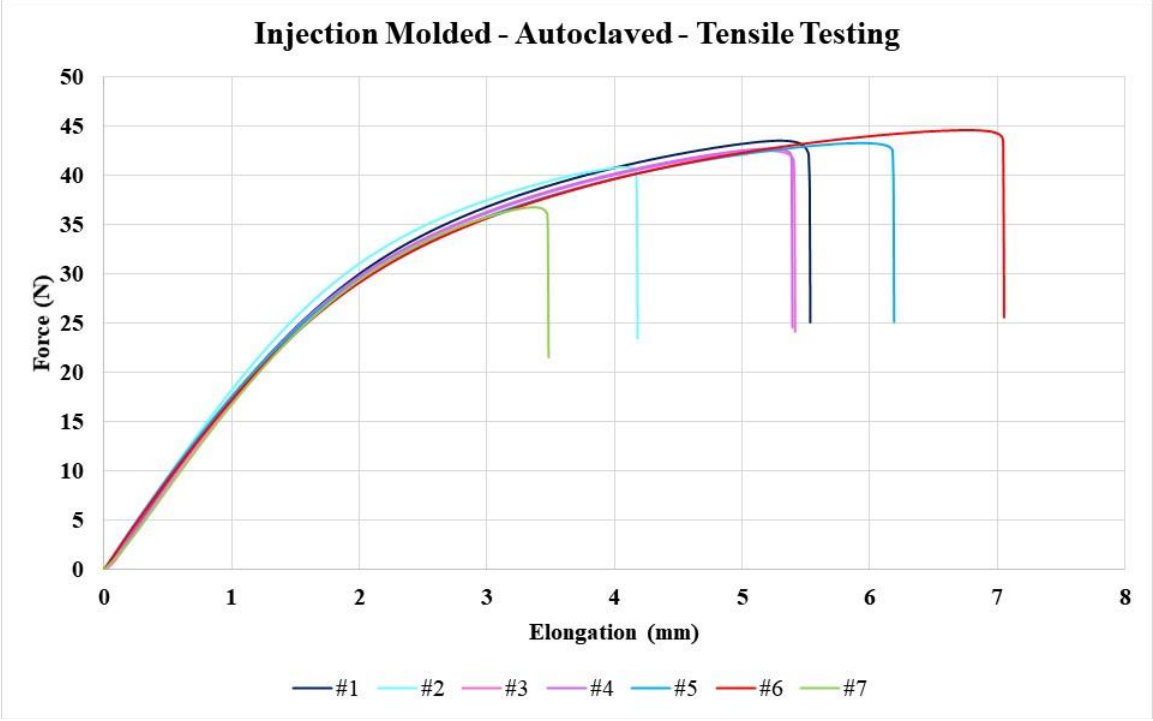


Figure 16. Force versus elongation data collected during the tensile tests for the Autoclaved Injection Molded samples.

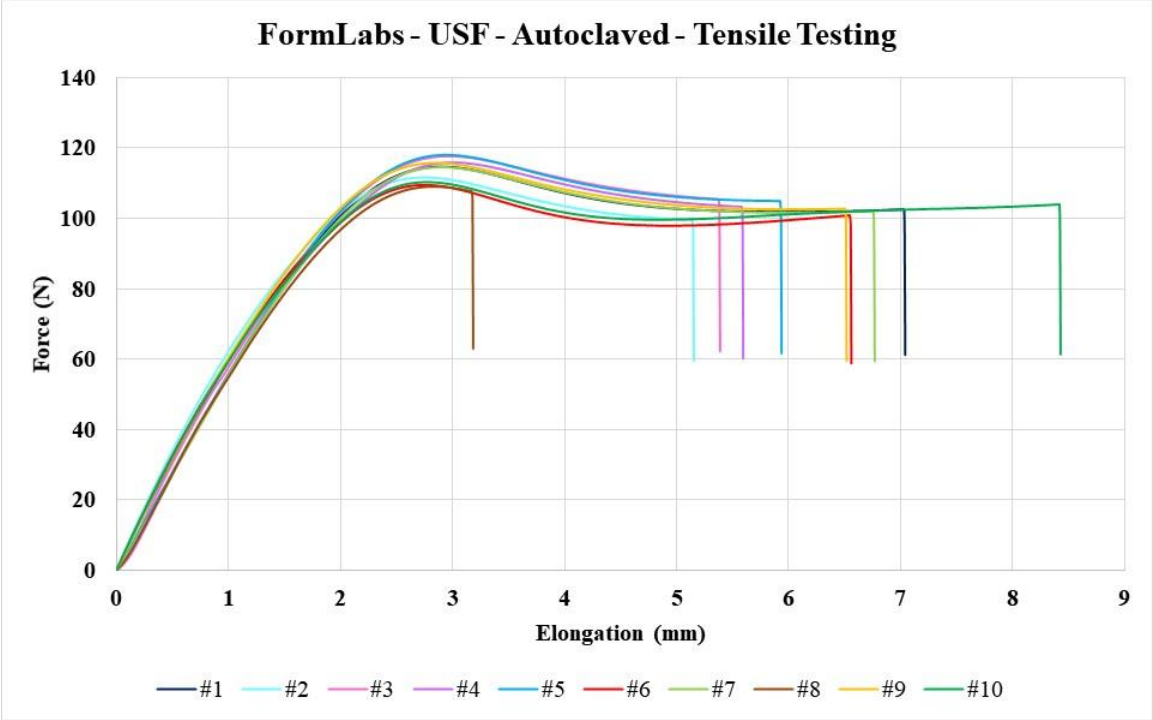


Figure 17. Force versus elongation data collected during the tensile tests for the Autoclaved FormLabs – USF samples.

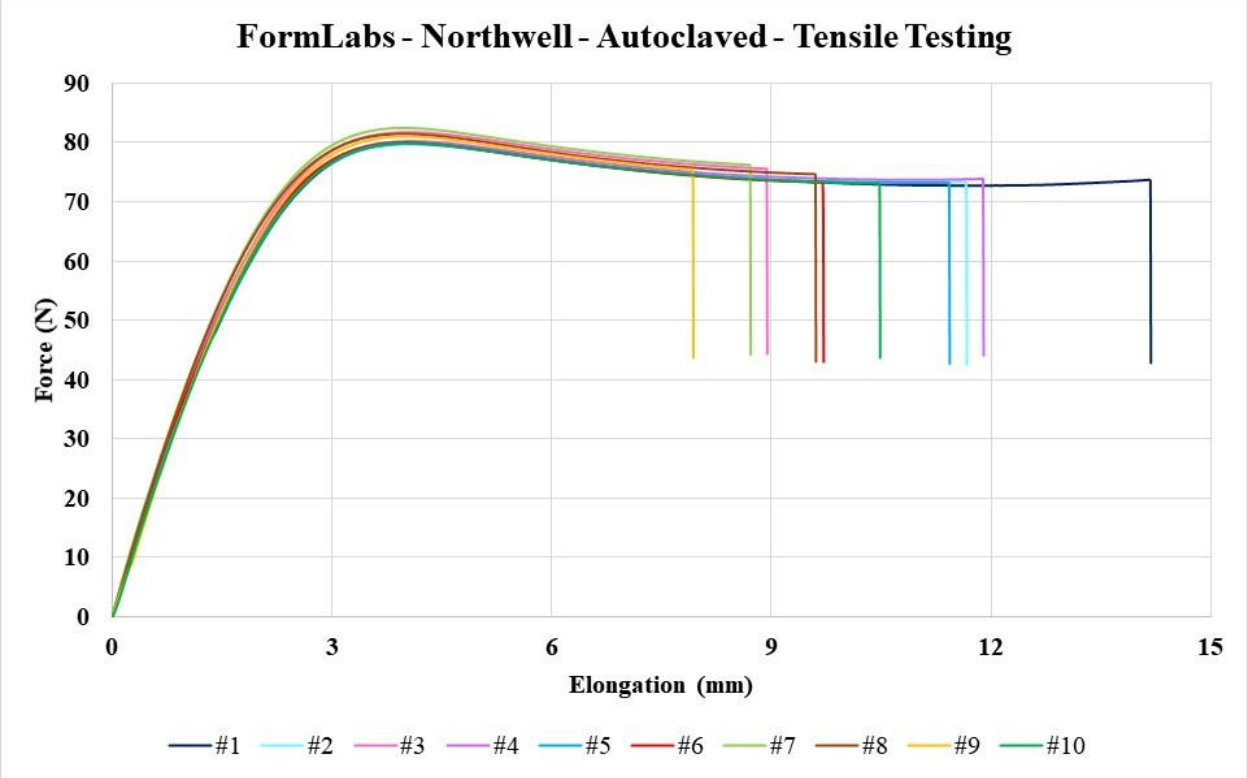


Figure 18. Force versus elongation data collected during the tensile tests for the Autoclaved FormLabs – Northwell samples.

2. Tensile Testing Procedure

1. Pre-Treatment – Autoclave
    a. Note: Pre-treatment was performed on only a subset of the swabs tested.
    b. Equipment
        i. Tuttnauer EZ10 Automatic Autoclave (Figure 19)

Figure 19. Autoclave used for pre-treatment of swabs.

    c. Materials
        i. VWR Cat. NO. 89140-800 Self Sealing Sterilization Pouch (5.25in x 10in) (Figure 20)
    d. Procedure
        i. Swabs were placed inside the sterilization pouch. 10 swabs were placed in a single pouch (Figure 20).

Figure 20. Swabs were placed inside a self-sealing sterilization pouch.

ii. Pouches were then placed inside the autoclave. Up to 4 pouches of swabs were autoclaved simultaneously.
iii. Swabs were autoclaved with the following settings:
    1. Temperature: 250°F
    2. Sterilization Time: 30 minutes
    3. Dry Time: 15 minutes
    4. (Note: The pressure during sterilization was 17psi.)

2. Tensile Testing
    a. Equipment
        i. Instron Model 5966 (Figure 21) running Bluehill Universal Software
        ii. 1kN Load Cell (Instron Model 2580-1KN) (Figure 21)
        iii. Pneumatic Grips (Instron Model 2712-019) with serrated plates (0.5in height), controlled with 60psi of pressure (Figure 21)

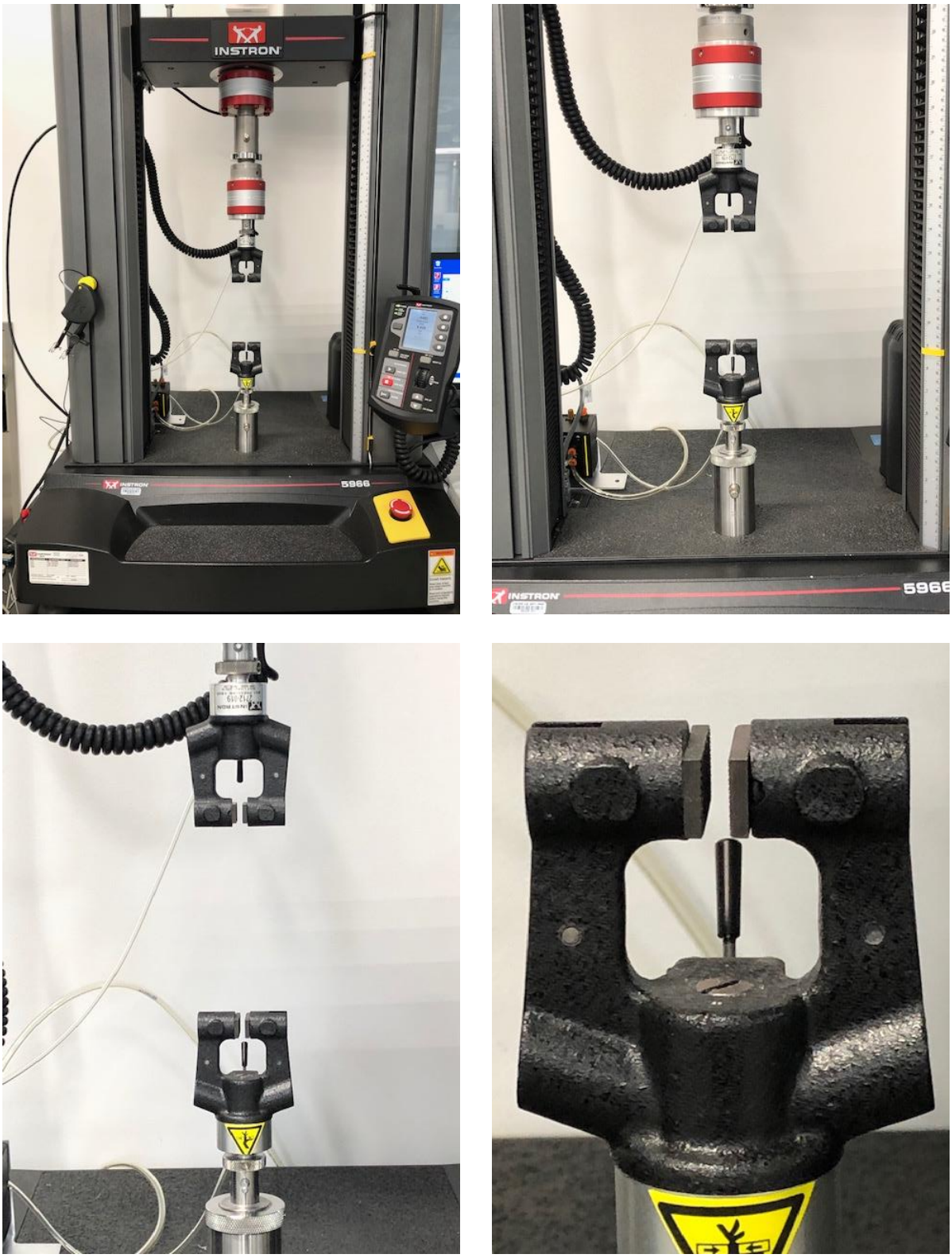


Figure 21. Test setup for the tensile tests.

b. Procedure
    i. Place the handle of the swab in the upper grips and close. The swab should not protrude above the height of the plates (Figure 22).

Figure 22. Image of the swab position inside the upper grips. The tip of the swab handle should be flush with the top of the grips.

ii. Secure the tip of the swab in the lower grips and close. The tip of the swab will protrude slightly below the height of the plates. The swab head should be at the top of the plates (Figure 23).

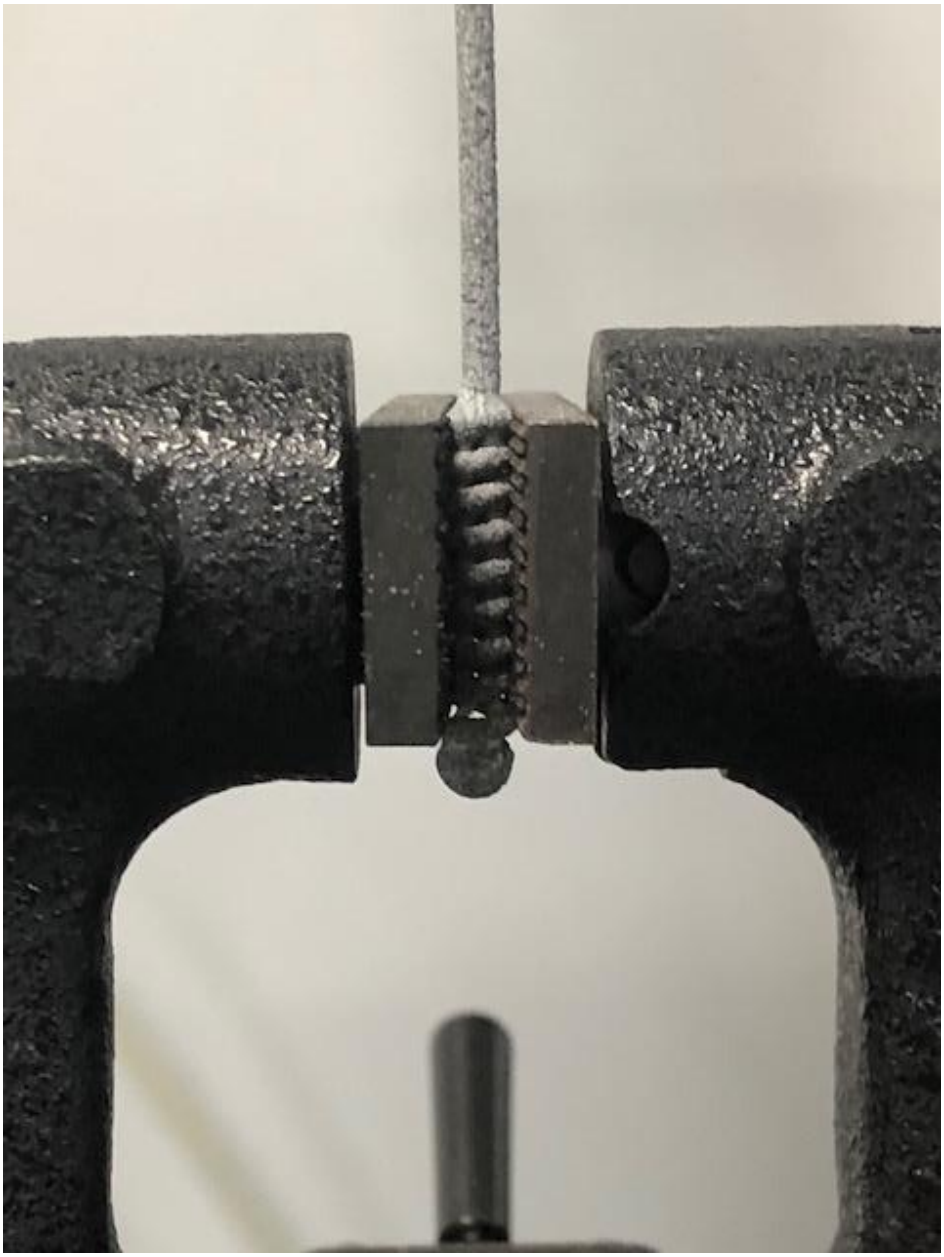


Figure 23. Image of the swab inside the lower grips. The top of the swab head should be flush with the top of the grips. The tip of the swab head will protrude below the grips.

iii. Adjust the height of the upper grip to remove any slack (Figure 24). Make sure not to pre-load the swab.

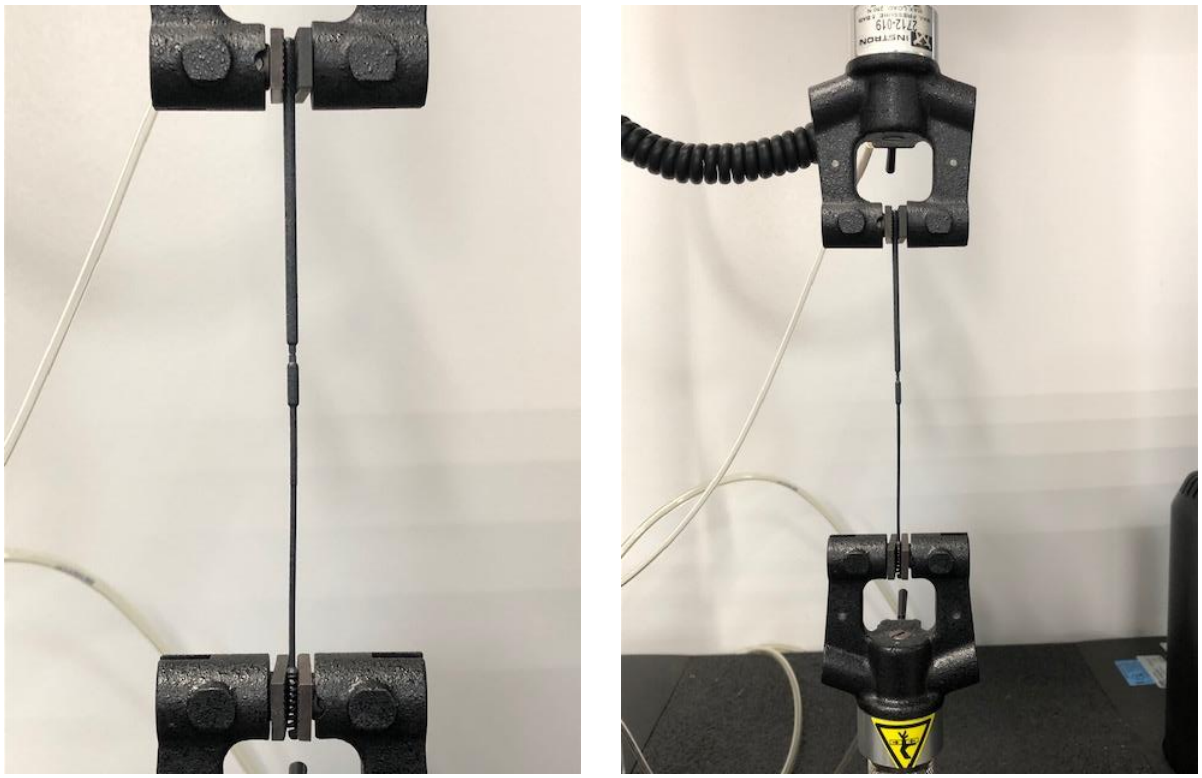


Figure 24. Image of the swab positioned in the grips. Prior to testing, any slack in the specimen should be removed by adjusting the height of the upper grips. Ensure that this slack-removal process does not pre-load the swab.

iv. Balance both the force and displacement.
v. Start the tensile test procedure:
    1. Rate of Test: 25mm/min
    2. Test End: 40% change in Force
vi. The data is automatically collected for Time, Force, and Displacement. The test should automatically conclude when a 40% change in Force is detected (i.e. when the swab breaks). This data point is recorded as the "Break Point."
vii. The physical location of the break point was classified as:
    1. "Neck" (for swabs breaking in the neck region – Figures 25 and 26),
    2. "Head-Neck" (for swabs breaking at the joint between the head and the neck – Figure 27), or
    3. "Breakpoint" (for swabs that broke at the desired breakpoint on the handle – Figure 28).

Figure 25. Representative images of the swabs classified as breaking at the "Neck."

Figure 26. Representative image of a swab classified as breaking at the "Head-Neck."

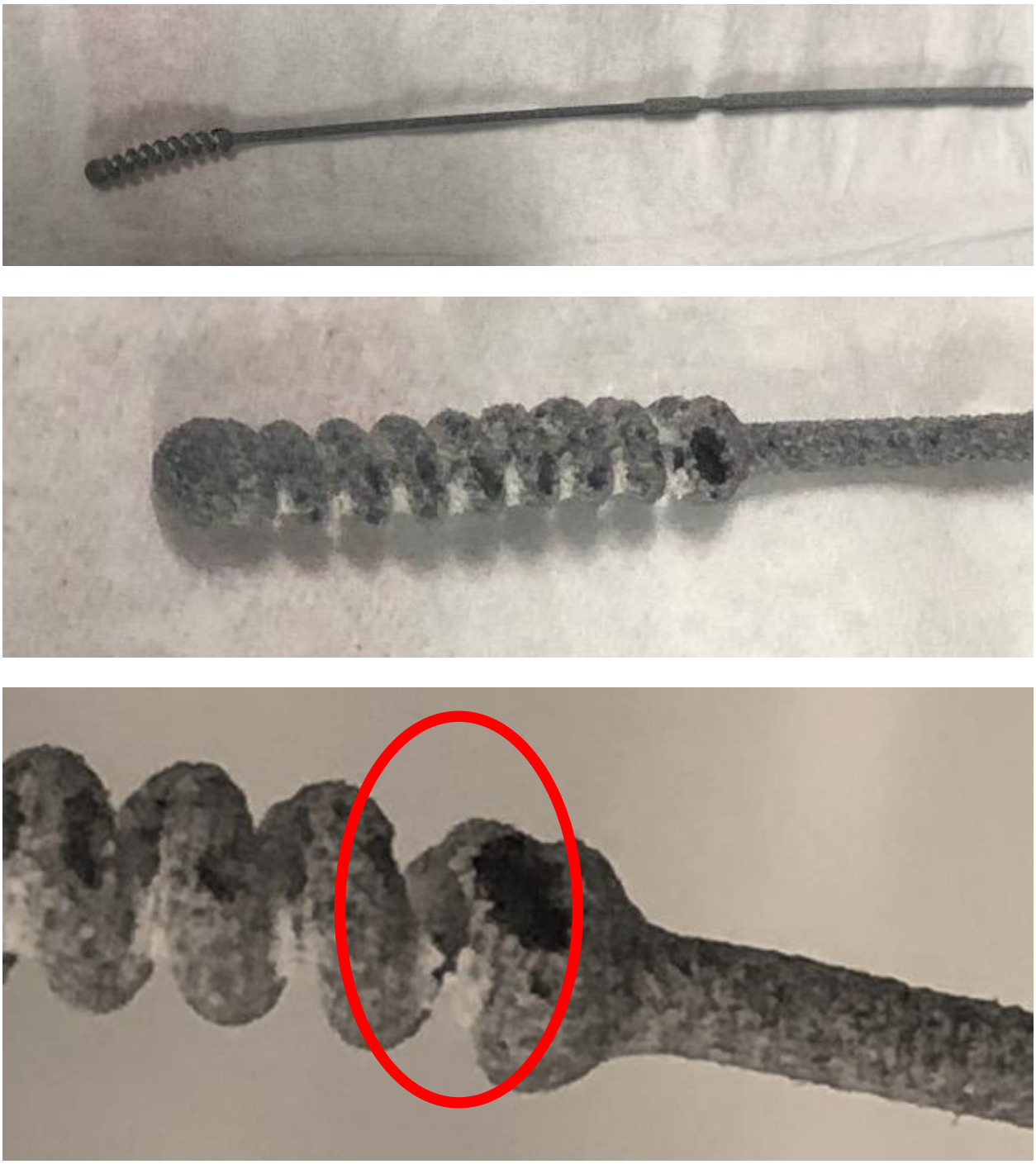


Figure 27. Representative image of a swab classified as breaking at the "Head." The break location is shown circled in red in the bottom image. In many cases, though, the actual break location was not visually observable and the swabs were classified as having broken based on the force-elongation data.

Figure 28. Representative image of a swab classified as breaking at the "Breakpoint."

3. Sample Details

The remaining figures below show images of the samples tested in the testing setup as well as images of the swabs after the test.

HP PA11 – Box A – #1 (NOT Autoclaved)

Setup

Post-Test

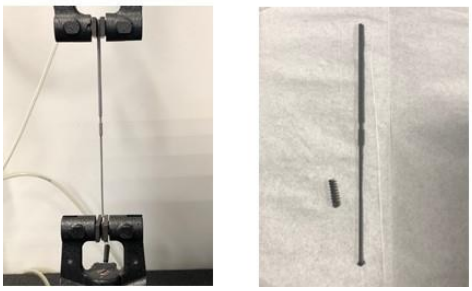


Figure 29. Images of the Not Autoclaved HP PA11 – Box A – Sample #1 in the setup and after testing.

HP PA11 – Box A – #2 (NOT Autoclaved)

Setup

Post-Test

Figure 30. Images of the Not Autoclaved HP PA11 – Box A – Sample #2 in the setup and after testing.

HP PA11 – Box A – #3 (NOT Autoclaved)

Setup

Post-Test

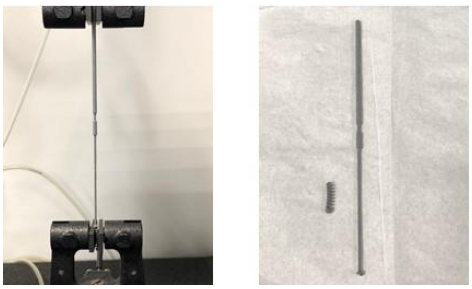


Figure 31. Images of the Not Autoclaved HP PA11 – Box A – Sample #3 in the setup and after testing.

HP PA11 – Box A – #4 (NOT Autoclaved)

Setup

Post-Test

Figure 32. Images of the Not Autoclaved HP PA11 – Box A – Sample #4 in the setup and after testing.

HP PA11 – Box A – #5 (NOT Autoclaved)

Setup

Post-Test

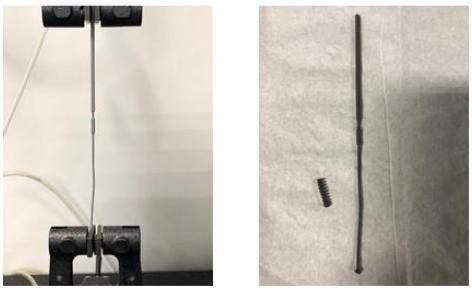


Figure 33. Images of the Not Autoclaved HP PA11 – Box A – Sample #5 in the setup and after testing.

HP PA11 – Box A – #6 (NOT Autoclaved)

Setup

Post-Test

Figure 34. Images of the Not Autoclaved HP PA11 – Box A – Sample #6 in the setup and after testing.

HP PA11 – Box A – #7 (NOT Autoclaved)

Setup

Post-Test

Figure 35. Images of the Not Autoclaved HP PA11 – Box A – Sample #7 in the setup and after testing.

HP PA11 – Box A – #8 (NOT Autoclaved)

Setup

Post-Test

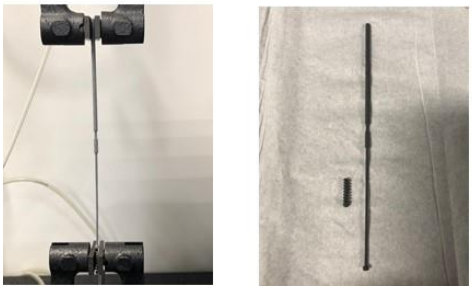


Figure 36. Images of the Not Autoclaved HP PA11 – Box A – Sample #8 in the setup and after testing.

HP PA11 – Box A – #9 (NOT Autoclaved)

Setup

Post-Test

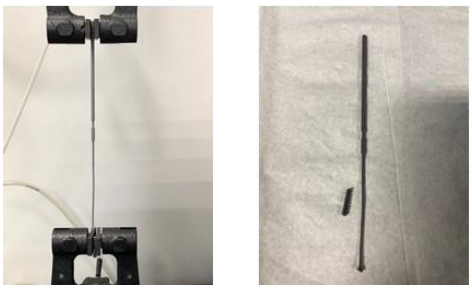


Figure 37. Images of the Not Autoclaved HP PA11 – Box A – Sample #9 in the setup and after testing.

HP PA11 – Box A – #10 (NOT Autoclaved)

Setup

Post-Test

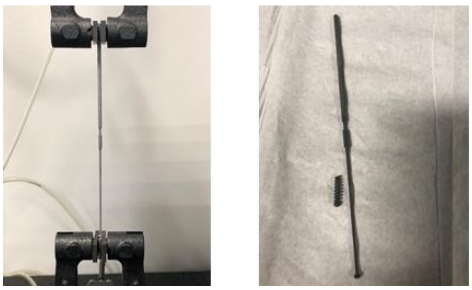


Figure 38. Images of the Not Autoclaved HP PA11 – Box A – Sample #10 in the setup and after testing.

HP PA11 – Box A – #1 (Autoclaved)

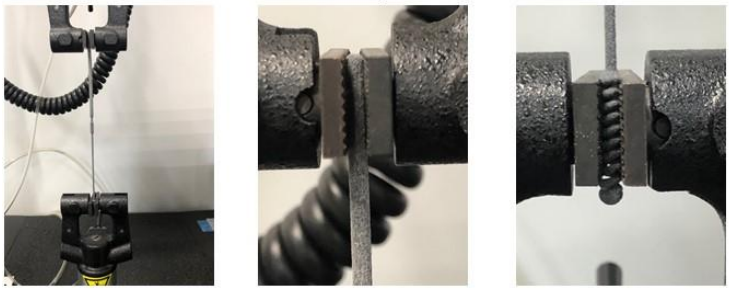
Setup

Post-Test

Figure 39. Images of the Autoclaved HP PA11 – Box A – Sample #1 in the setup and after testing.

HP PA11 – Box A – #2 (Autoclaved)

Setup



Post-Test

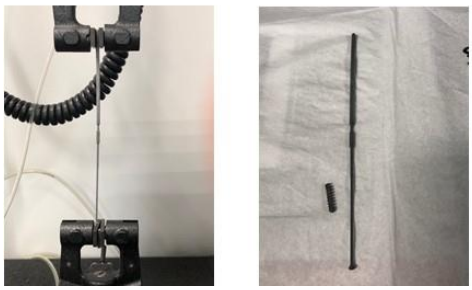


Figure 40. Images of the Autoclaved HP PA11 – Box A – Sample #2 in the setup and after testing.

HP PA11 – Box A – #3 (Autoclaved)

Setup

Post-Test

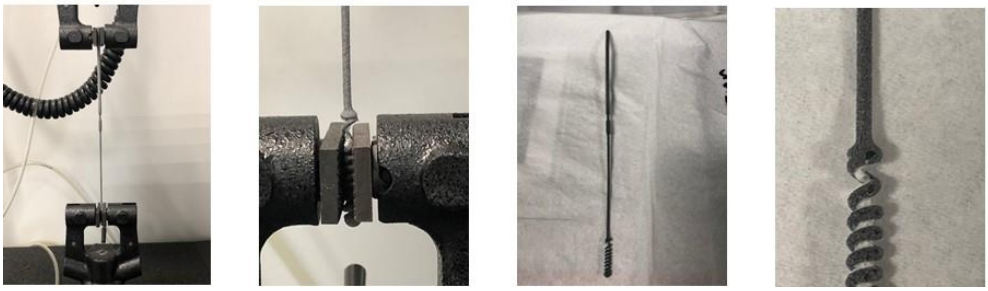


Figure 41. Images of the Autoclaved HP PA11 – Box A – Sample #3 in the setup and after testing.

HP PA11 – Box A – #4 (Autoclaved)

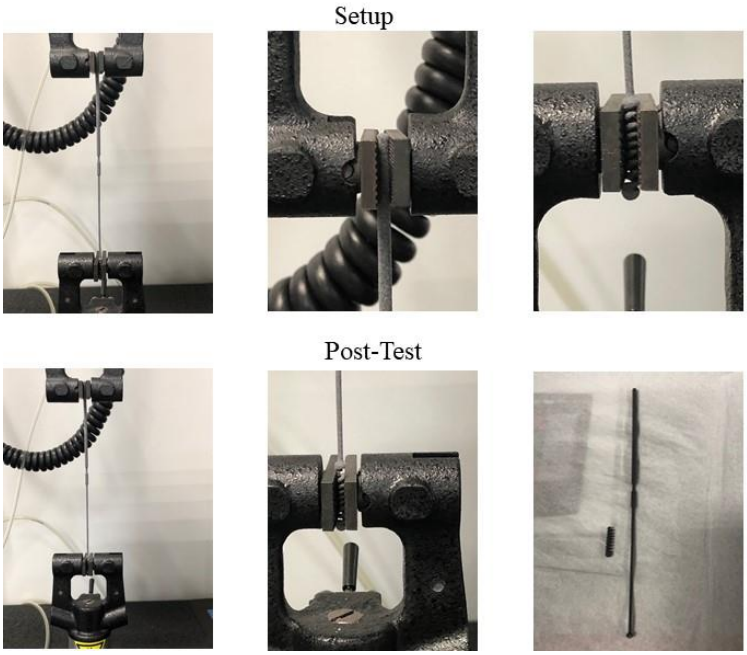


Figure 42. Images of the Autoclaved HP PA11 – Box A – Sample #4 in the setup and after testing.

HP PA11 – Box A – #5 (Autoclaved)

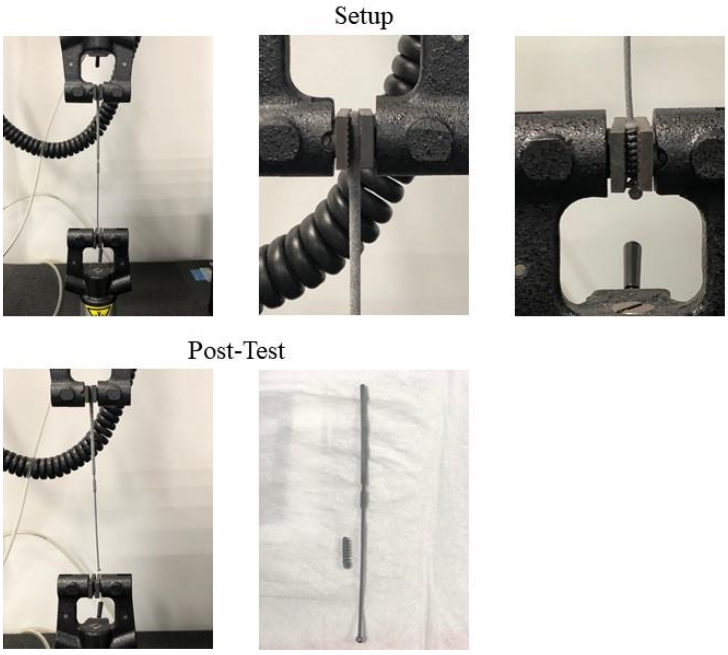


Figure 43. Images of the Autoclaved HP PA11 – Box A – Sample #5 in the setup and after testing.

HP PA11 – Box A – #6 (Autoclaved)

Setup

Post-Test

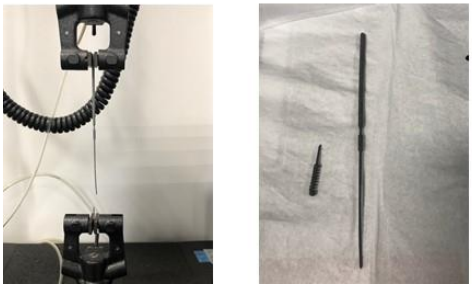


Figure 44. Images of the Autoclaved HP PA11 – Box A – Sample #6 in the setup and after testing.

HP PA11 – Box A – #7 (Autoclaved)

Setup

Post-Test

Figure 45. Images of the Autoclaved HP PA11 – Box A – Sample #7 in the setup and after testing.

HP PA11 – Box A – #8 (Autoclaved)

Setup

Post-Test

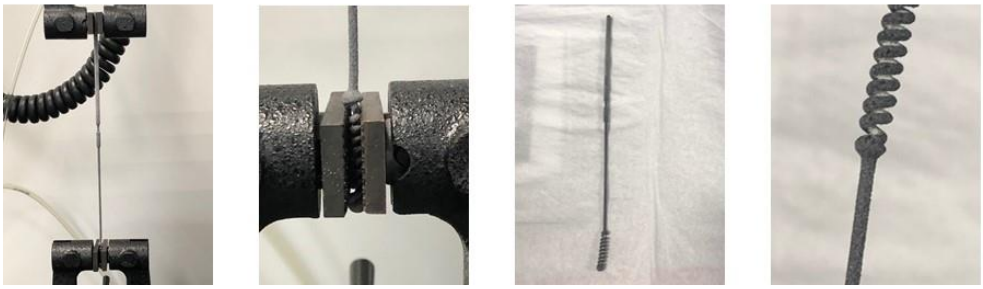


Figure 46. Images of the Autoclaved HP PA11 – Box A – Sample #8 in the setup and after testing.

HP PA11 – Box A – #9 (Autoclaved)

Setup

Post-Test

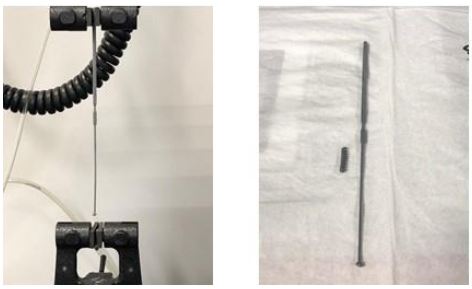


Figure 47. Images of the Autoclaved HP PA11 – Box A – Sample #9 in the setup and after testing.

HP PA11 – Box A – #10 (Autoclaved)

Setup

Post-Test

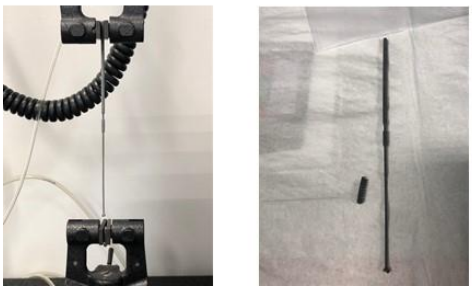


Figure 48. Images of the Autoclaved HP PA11 – Box A – Sample #10 in the setup and after testing.

HP PA11 – Box B – #1 (Autoclaved)

Setup

Post-Test

Figure 49. Images of the Autoclaved HP PA11 – Box B – Sample #1 in the setup and after testing.

HP PA11 – Box B – #2 (Autoclaved)

Setup

Post-Test

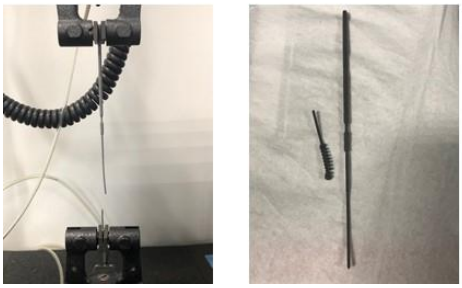
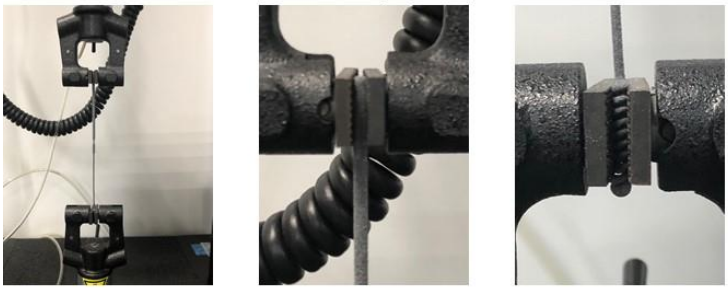


Figure 50. Images of the Autoclaved HP PA11 – Box B – Sample #2 in the setup and after testing.

HP PA11 – Box B – #3 (Autoclaved)

Setup

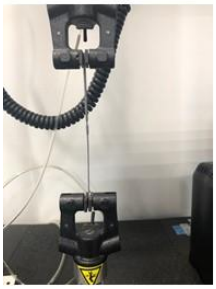


Post-Test

Figure 51. Images of the Autoclaved HP PA11 – Box B – Sample #3 in the setup and after testing.

HP PA11 – Box B – #4 (Autoclaved)

Setup

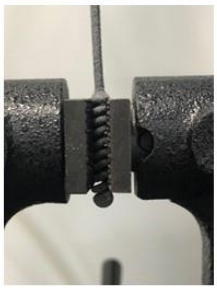


Post-Test

Figure 52. Images of the Autoclaved HP PA11 – Box B – Sample #4 in the setup and after testing.

HP PA11 – Box B – #5 (Autoclaved)

Setup



Post-Test

Figure 53. Images of the Autoclaved HP PA11 – Box B – Sample #5 in the setup and after testing.

HP PA11 – Box B – #6 (Autoclaved)

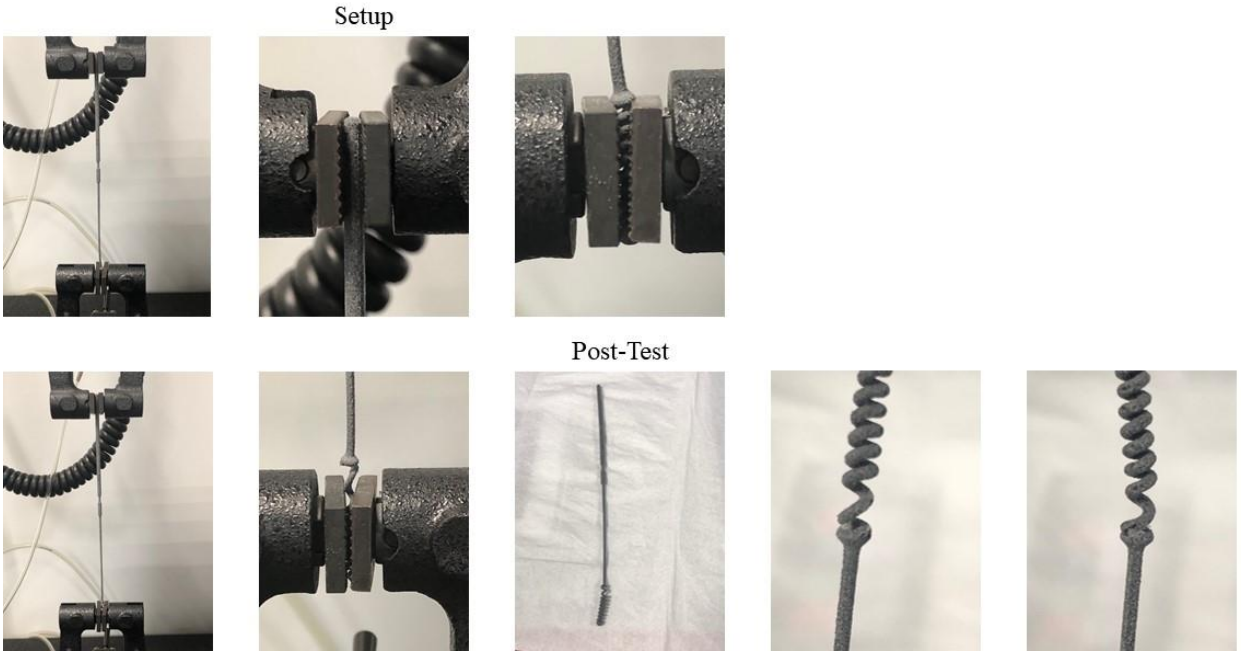


Figure 54. Images of the Autoclaved HP PA11 – Box B – Sample #6 in the setup and after testing.

HP PA11 – Box B – #7 (Autoclaved)

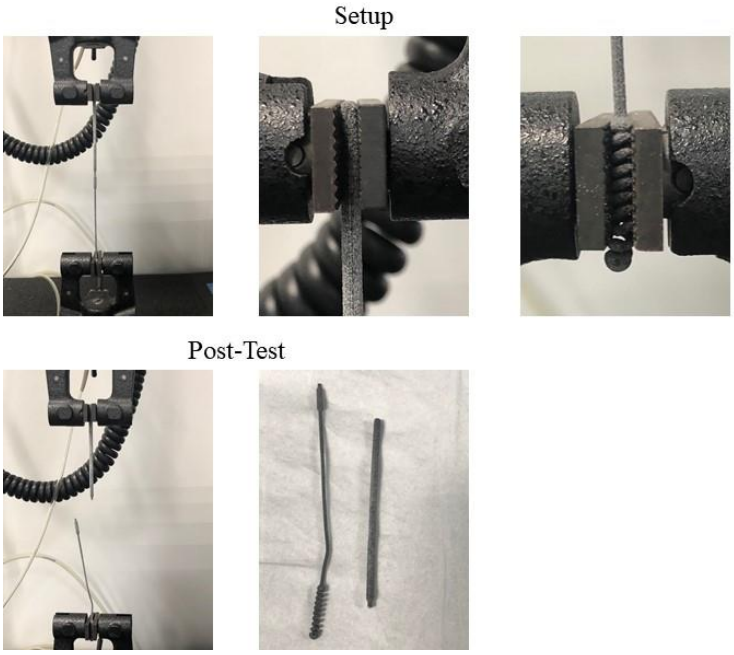


Figure 55. Images of the Autoclaved HP PA11 – Box B – Sample #7 in the setup and after testing.

HP PA11 – Box B – #8 (Autoclaved)

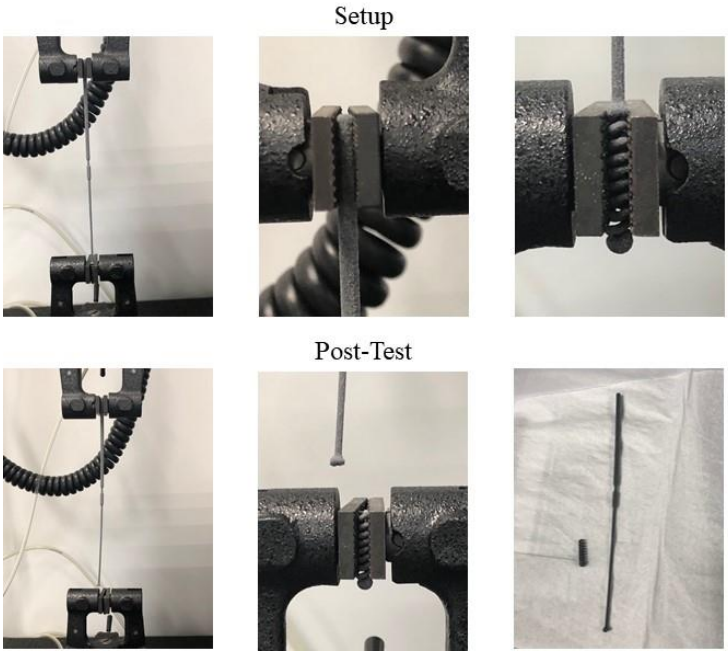


Figure 56. Images of the Autoclaved HP PA11 – Box B – Sample #8 in the setup and after testing.

HP PA11 – Box B – #9 (Autoclaved)

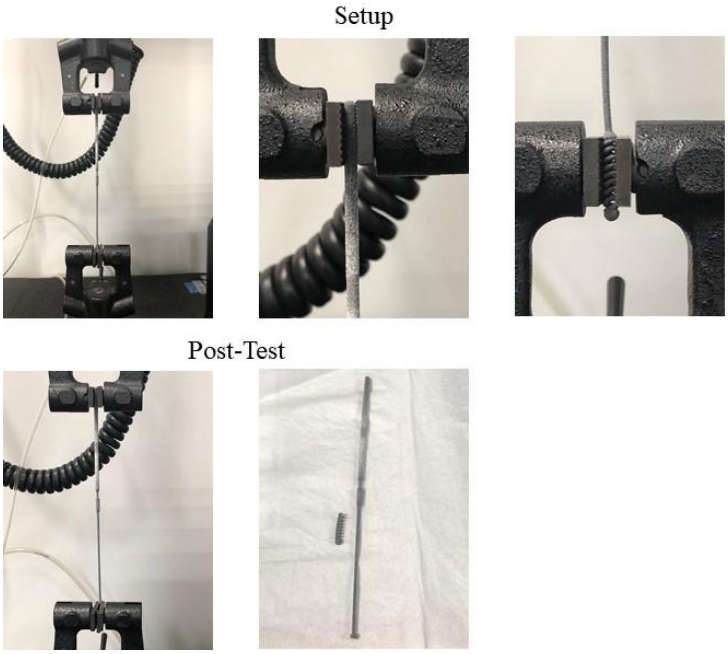


Figure 57. Images of the Autoclaved HP PA11 – Box B – Sample #9 in the setup and after testing.

HP PA11 – Box B – #10 (Autoclaved)

Setup

Post-Test

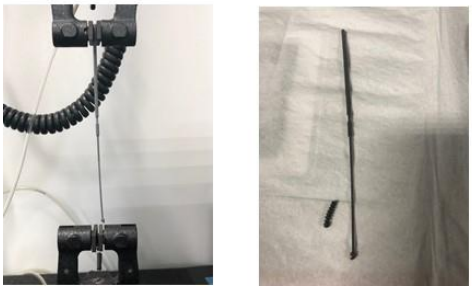


Figure 58. Images of the Autoclaved HP PA11 – Box B – Sample #10 in the setup and after testing.

HP PA11 Vapor Polished – #1 (Autoclaved)

Setup

Post-Test

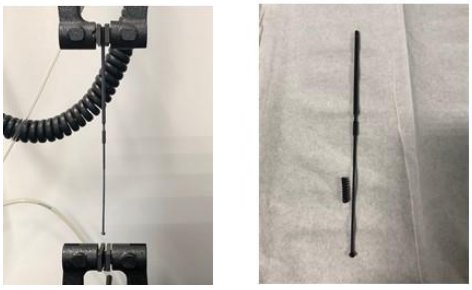


Figure 59. Images of the Autoclaved HP PA11 Vapor Polished – Sample #1 in the setup and after testing.

HP PA11 Vapor Polished – #2 (Autoclaved)

Setup

Post-Test

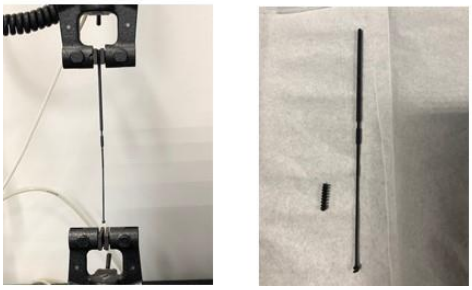


Figure 60. Images of the Autoclaved HP PA11 Vapor Polished – Sample #2 in the setup and after testing.

HP PA11 Vapor Polished – #3 (Autoclaved)

Setup

Post-Test

Figure 61. Images of the Autoclaved HP PA11 Vapor Polished – Sample #3 in the setup and after testing.

HP PA11 Vapor Polished – #4 (Autoclaved)

Setup

Post-Test

Figure 62. Images of the Autoclaved HP PA11 Vapor Polished – Sample #4 in the setup and after testing.

HP PA11 Vapor Polished – #5 (Autoclaved)

Setup

Post-Test

Figure 63. Images of the Autoclaved HP PA11 Vapor Polished – Sample #5 in the setup and after testing.

HP PA11 Vapor Polished – #6 (Autoclaved)

Setup

Post-Test

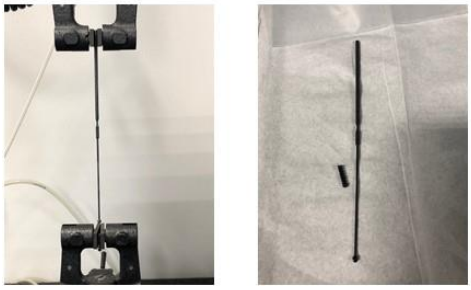


Figure 64. Images of the Autoclaved HP PA11 Vapor Polished – Sample #6 in the setup and after testing.

HP PA11 Vapor Polished – #7 (Autoclaved)

Setup

Post-Test

Figure 65. Images of the Autoclaved HP PA11 Vapor Polished – Sample #7 in the setup and after testing.

HP PA11 Vapor Polished – #8 (Autoclaved)

Setup

Post-Test

Figure 66. Images of the Autoclaved HP PA11 Vapor Polished – Sample #8 in the setup and after testing.

HP PA11 Vapor Polished – #9 (Autoclaved)

Setup

Post-Test

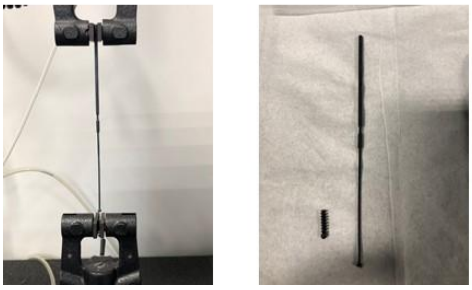


Figure 67. Images of the Autoclaved HP PA11 Vapor Polished – Sample #9 in the setup and after testing.

HP PA11 Vapor Polished – #10 (Autoclaved)

Setup

Post-Test

Figure 68. Images of the Autoclaved HP PA11 Vapor Polished – Sample #10 in the setup and after testing.

HP PA12 – Box A – #1 (NOT Autoclaved)

Setup

Post-Test

Figure 69. Images of the Not Autoclaved HP PA12 – Box A – Sample #1 in the setup and after testing.

HP PA12 – Box A – #2 (NOT Autoclaved)

Setup

Post-Test

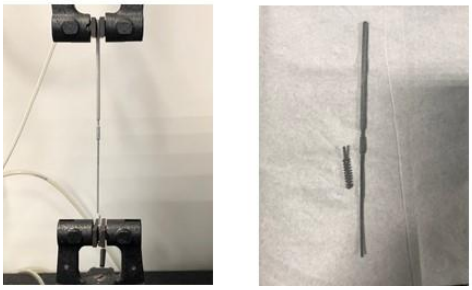


Figure 70. Images of the Not Autoclaved HP PA12 – Box A – Sample #2 in the setup and after testing.

HP PA12 – Box A – #3 (NOT Autoclaved)

Setup

Post-Test

Figure 71. Images of the Not Autoclaved HP PA12 – Box A – Sample #3 in the setup and after testing.

HP PA12 – Box A – #4 (NOT Autoclaved)

Setup

Post-Test

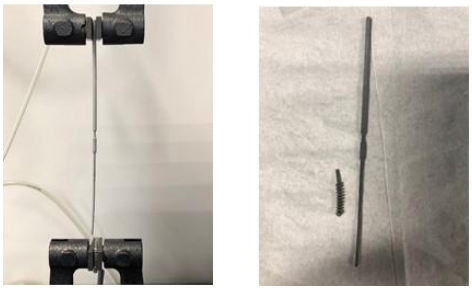
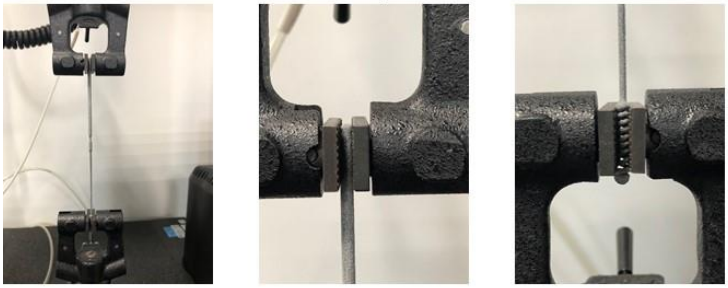


Figure 72. Images of the Not Autoclaved HP PA12 – Box A – Sample #4 in the setup and after testing.

HP PA12 – Box A – #5 (NOT Autoclaved)

Setup



Post-Test

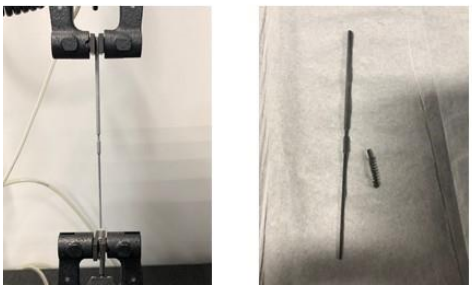


Figure 73. Images of the Not Autoclaved HP PA12 – Box A – Sample #5 in the setup and after testing.

HP PA12 – Box A – #6 (NOT Autoclaved)

Setup

Post-Test

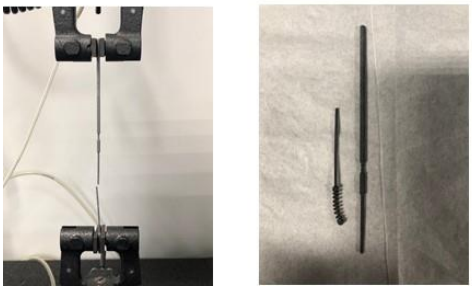
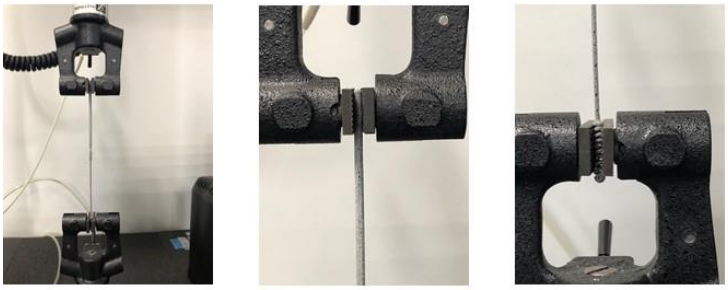


Figure 74. Images of the Not Autoclaved HP PA12 – Box A – Sample #6 in the setup and after testing.

HPPA12 – Box A – #7 (NOT Autoclaved)

Setup



Post-Test

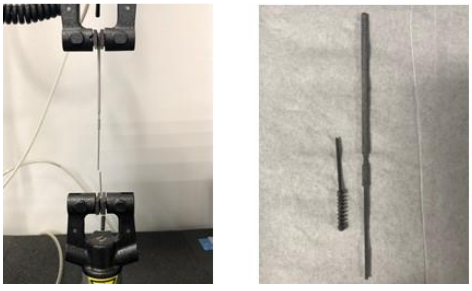


Figure 75. Images of the Not Autoclaved HP PA12 – Box A – Sample #7 in the setup and after testing.

HP PA12 – Box A – #8 (NOT Autoclaved)

Setup

Post-Test

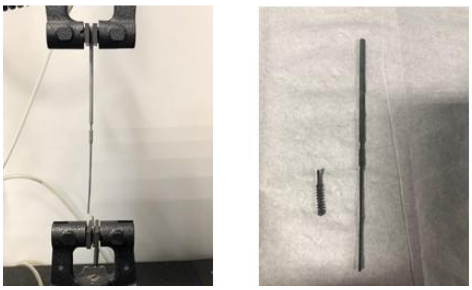


Figure 76. Images of the Not Autoclaved HP PA12 – Box A – Sample #8 in the setup and after testing.

HP PA12 – Box A – #9 (NOT Autoclaved)

Setup

Post-Test

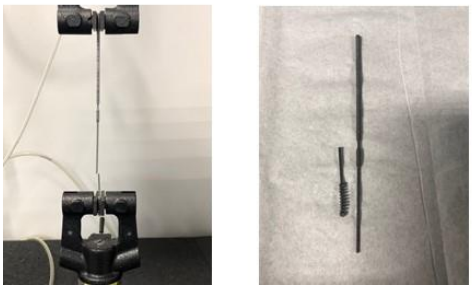


Figure 77. Images of the Not Autoclaved HP PA12 – Box A – Sample #9 in the setup and after testing.

HP PA12 – Box A – #10 (NOT Autoclaved)

Setup

Post-Test

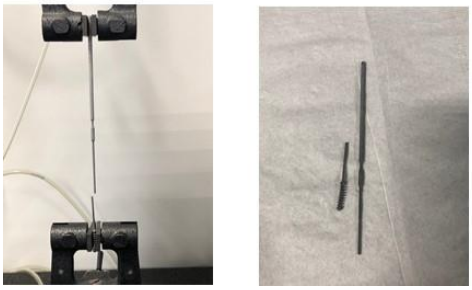


Figure 78. Images of the Not Autoclaved HP PA12 – Box A – Sample #10 in the setup and after testing.

HP PA12 – Box A – #1 (Autoclaved)

Setup

Post-Test

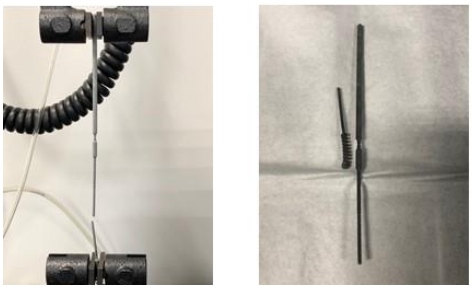


Figure 79. Images of the Autoclaved HP PA12 – Box A – Sample #1 in the setup and after testing.

HP PA12 – Box A – #2 (Autoclaved)

Setup

Post-Test

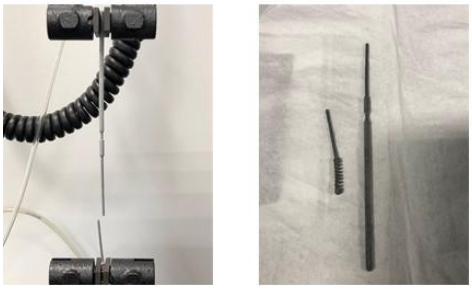


Figure 80. Images of the Autoclaved HP PA12 – Box A – Sample #2 in the setup and after testing.

HP PA12 – Box A – #3 (Autoclaved)

Setup

Post-Test

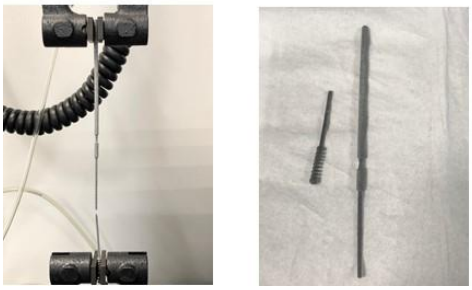


Figure 81. Images of the Autoclaved HP PA12 – Box A – Sample #3 in the setup and after testing.

HP PA12 – Box A – #4 (Autoclaved)

Setup

Post-Test

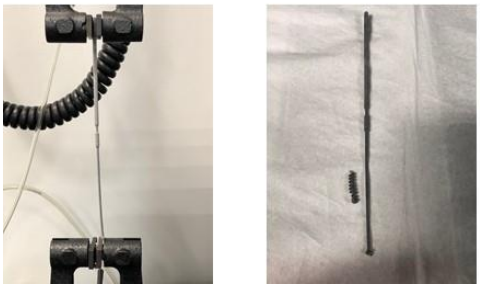


Figure 82. Images of the Autoclaved HP PA12 – Box A – Sample #4 in the setup and after testing.

HP PA12 – Box A – #5 (Autoclaved)

Setup

Post-Test

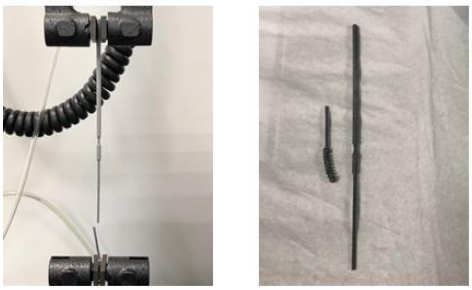
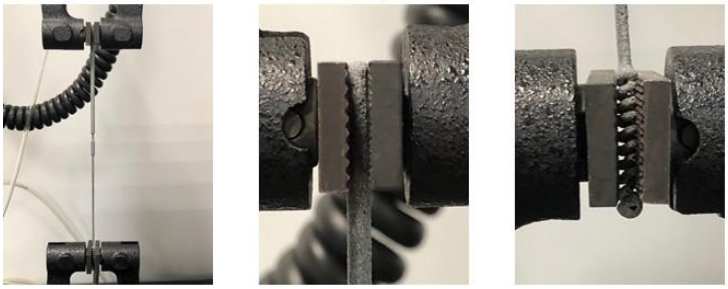


Figure 83. Images of the Autoclaved HP PA12 – Box A – Sample #5 in the setup and after testing.

HP PA12 – Box A – #6 (Autoclaved)

Setup



Post-Test

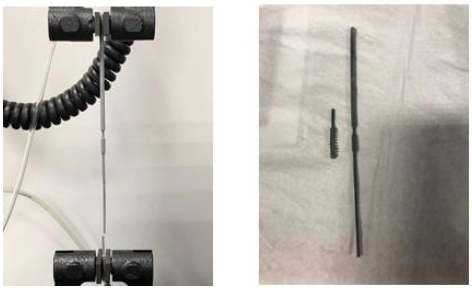


Figure 84. Images of the Autoclaved HP PA12 – Box A – Sample #6 in the setup and after testing.

HP PA12 – Box A – #7 (Autoclaved)

Setup

Post-Test

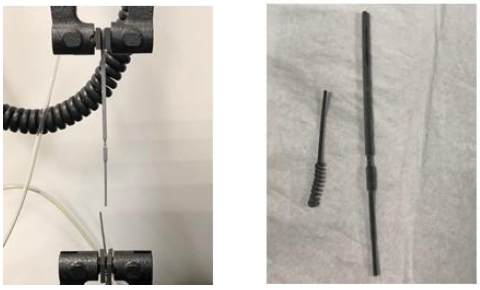


Figure 85. Images of the Autoclaved HP PA12 – Box A – Sample #7 in the setup and after testing.

HP PA12 – Box A – #8 (Autoclaved)

Setup

Post-Test

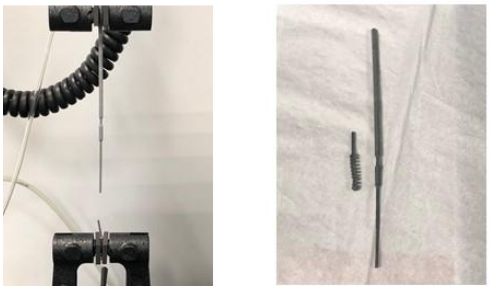


Figure 86. Images of the Autoclaved HP PA12 – Box A – Sample #8 in the setup and after testing.

HP PA12 – Box A – #9 (Autoclaved)

Setup

Post-Test

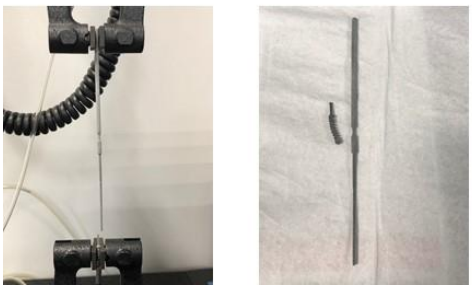


Figure 87. Images of the Autoclaved HP PA12 – Box A – Sample #9 in the setup and after testing.

HP PA12 – Box A – #10 (Autoclaved)

Setup

Post-Test

Figure 88. Images of the Autoclaved HP PA12 – Box A – Sample #10 in the setup and after testing.

HP PA12 – Box B – #1 (Autoclaved)

Setup

Post-Test

Figure 89. Images of the Autoclaved HP PA12 – Box B – Sample #1 in the setup and after testing.

HP PA12 – Box B – #2 (Autoclaved)

Setup

Post-Test

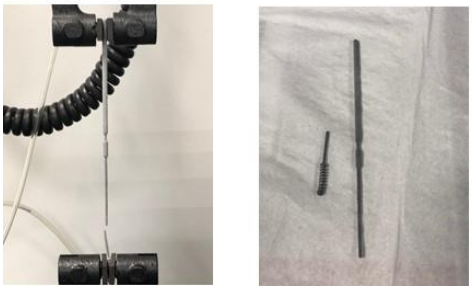


Figure 90. Images of the Autoclaved HP PA12 – Box B – Sample #2 in the setup and after testing.

HP PA12 – Box B – #3 (Autoclaved)

Setup

Post-Test

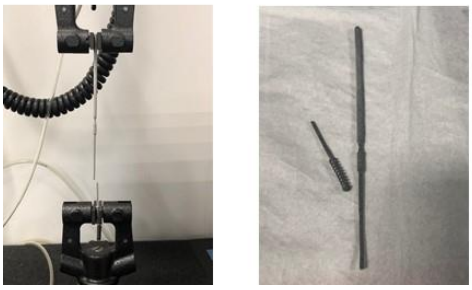


Figure 91. Images of the Autoclaved HP PA12 – Box B – Sample #3 in the setup and after testing.

HP PA12 – Box B – #4 (Autoclaved)

Setup

Post-Test

Figure 92. Images of the Autoclaved HP PA12 – Box B – Sample #4 in the setup and after testing.

HP PA12 – Box B – #5 (Autoclaved)

Setup

Post-Test

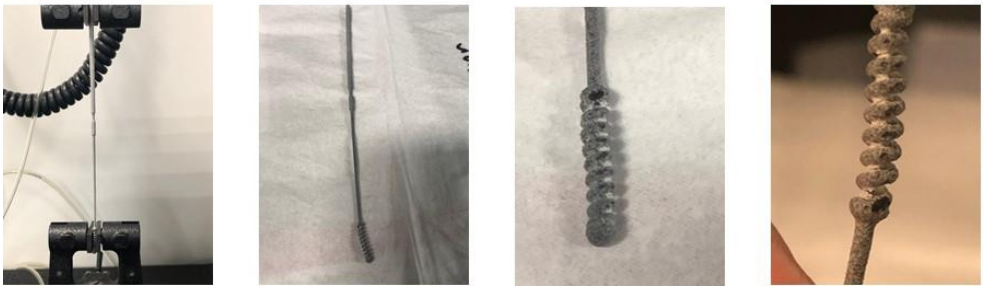


Figure 93. Images of the Autoclaved HP PA12 – Box B – Sample #5 in the setup and after testing.

HP PA12 – Box B – #6 (Autoclaved)

Setup

Post-Test

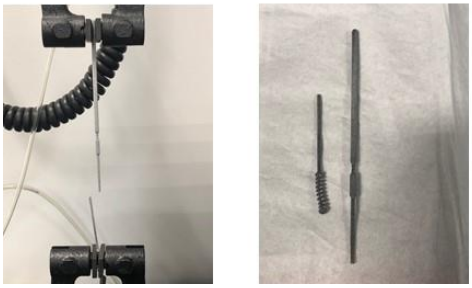


Figure 94. Images of the Autoclaved HP PA12 – Box B – Sample #6 in the setup and after testing.

HP PA12 – Box B – #7 (Autoclaved)

Setup

Post-Test

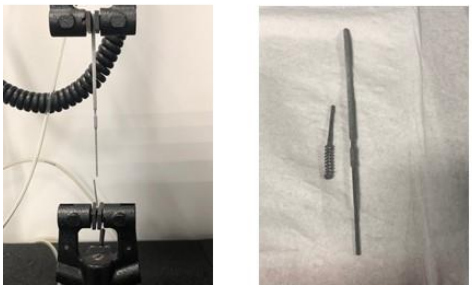
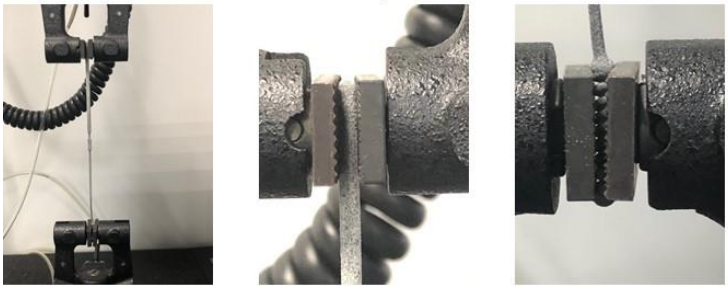


Figure 95. Images of the Autoclaved HP PA12 – Box B – Sample #7 in the setup and after testing.

HP PA12 – Box B – #8 (Autoclaved)

Setup



Post-Test

Figure 96. Images of the Autoclaved HP PA12 – Box B – Sample #8 in the setup and after testing.

HP PA12 – Box B – #9 (Autoclaved)

Setup

Post-Test

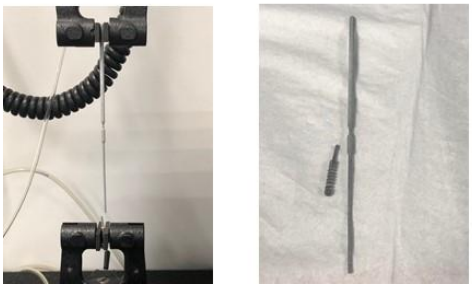


Figure 97. Images of the Autoclaved HP PA12 – Box B – Sample #9 in the setup and after testing.

HP PA12 – Box B – #10 (Autoclaved)

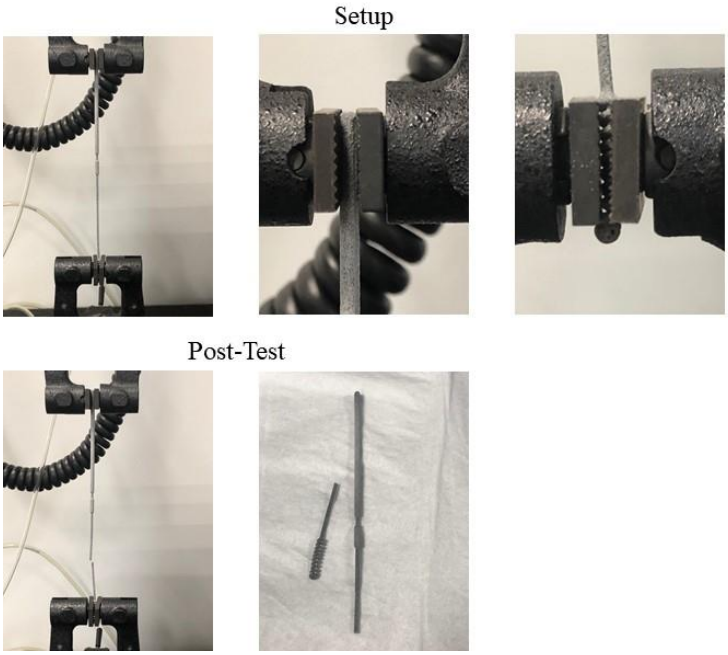


Figure 98. Images of the Autoclaved HP PA12 – Box B – Sample #10 in the setup and after testing.

Injection Molded – #1 (Autoclaved)

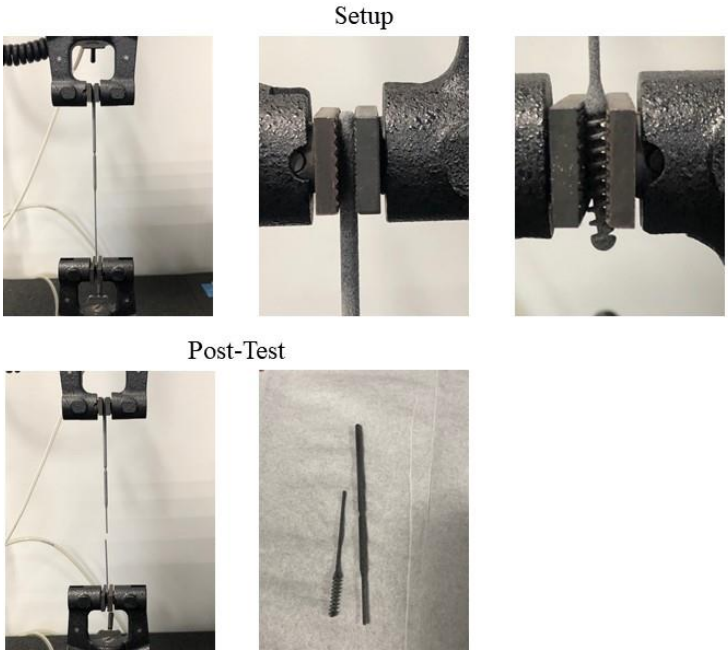


Figure 99. Images of the Autoclaved Injection Molded – Sample #1 in the setup and after testing.

Injection Molded – #2 (Autoclaved)

Setup

Post-Test

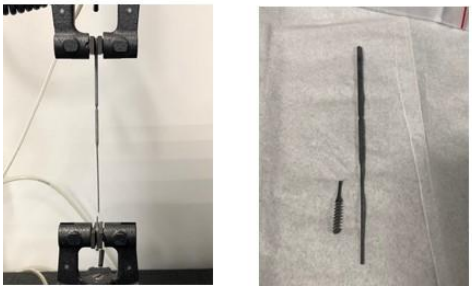


Figure 100. Images of the Autoclaved Injection Molded – Sample #2 in the setup and after testing.

Injection Molded – #3 (Autoclaved)

Setup

Post-Test

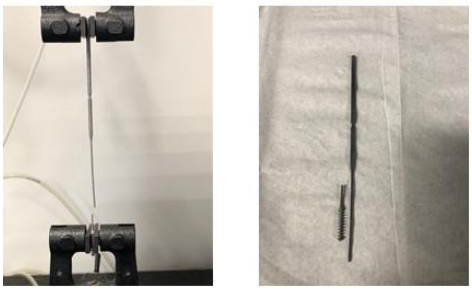


Figure 101. Images of the Autoclaved Injection Molded – Sample #3 in the setup and after testing.

Injection Molded – #4 (Autoclaved)

Setup

Post-Test

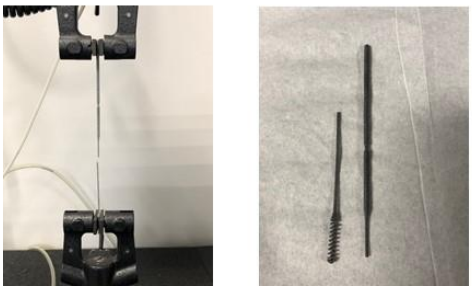
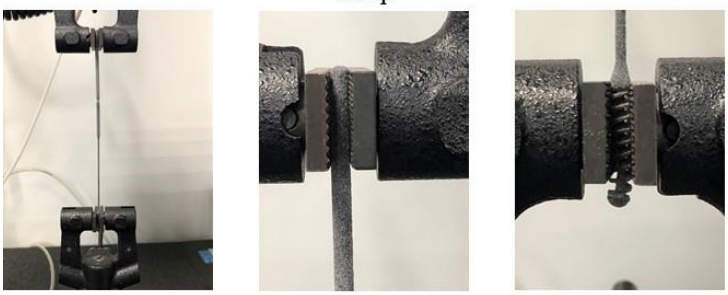


Figure 102. Images of the Autoclaved Injection Molded – Sample #4 in the setup and after testing.

Injection Molded – #5 (Autoclaved)

Setup



Post-Test

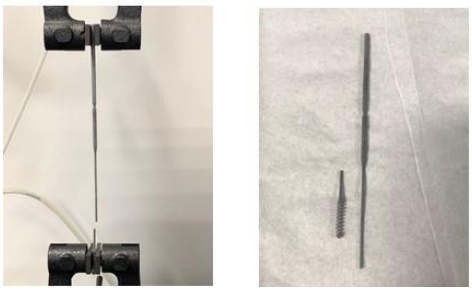


Figure 103. Images of the Autoclaved Injection Molded – Sample #5 in the setup and after testing.

Injection Molded – #6 (Autoclaved)

Setup

Post-Test

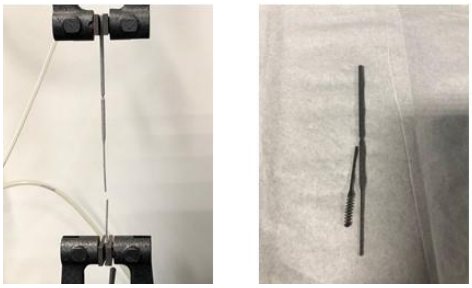


Figure 104. Images of the Autoclaved Injection Molded – Sample #6 in the setup and after testing.

Injection Molded – #7 (Autoclaved)

Setup

Post-Test

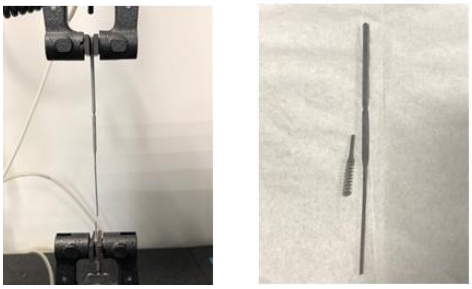


Figure 105. Images of the Autoclaved Injection Molded – Sample #7 in the setup and after testing.

FormLabs – USF – #1 (Autoclaved)

Setup

Post-Test

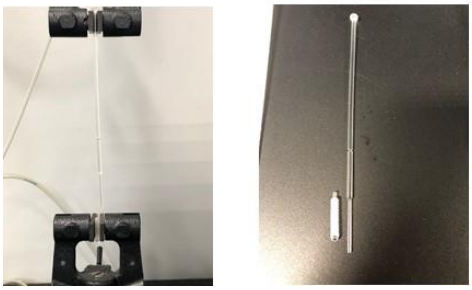


Figure 106. Images of the Autoclaved FormLabs – USF – Sample #1 in the setup and after testing.

FormLabs – USF – #2 (Autoclaved)

Setup

Post-Test

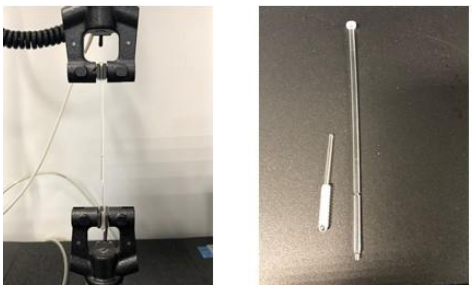


Figure 107. Images of the Autoclaved FormLabs – USF – Sample #2 in the setup and after testing.

FormLabs – USF – #3 (Autoclaved)

Setup

Post-Test

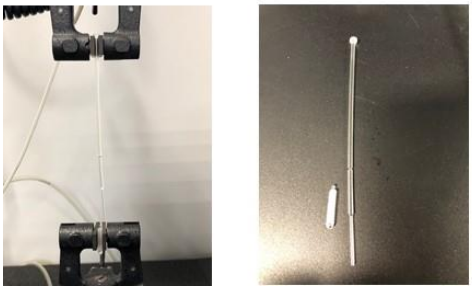
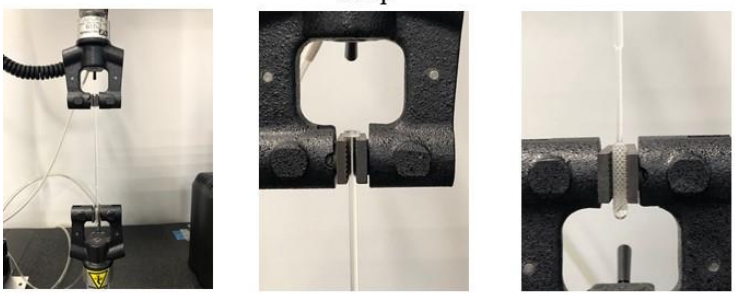


Figure 108. Images of the Autoclaved FormLabs – USF – Sample #3 in the setup and after testing.

FormLabs – USF – #4 (Autoclaved)

Setup



Post-Test

Figure 109. Images of the Autoclaved FormLabs – USF – Sample #4 in the setup and after testing.

FormLabs – USF – #5 (Autoclaved)

Setup

Post-Test

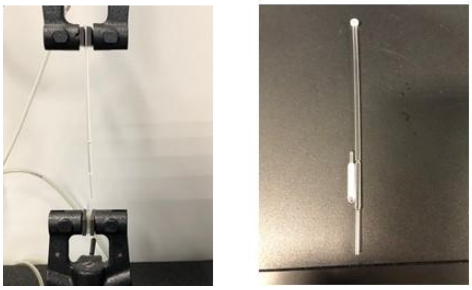


Figure 110. Images of the Autoclaved FormLabs – USF – Sample #5 in the setup and after testing.

FormLabs – USF – #6 (Autoclaved)

Setup

Post-Test

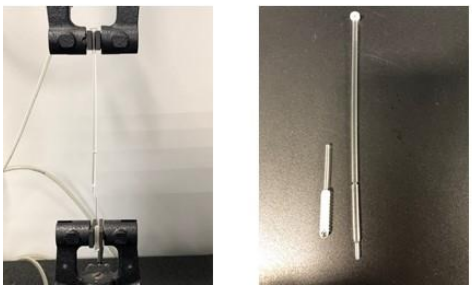


Figure 111. Images of the Autoclaved FormLabs – USF – Sample #6 in the setup and after testing.

FormLabs – USF – #7 (Autoclaved)

Setup

Post-Test

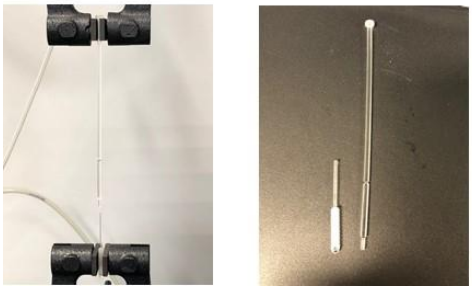


Figure 112. Images of the Autoclaved FormLabs – USF – Sample #7 in the setup and after testing.

FormLabs – USF – #8 (Autoclaved)

Setup

Post-Test

Figure 113. Images of the Autoclaved FormLabs – USF – Sample #8 in the setup and after testing.

FormLabs – USF – #9 (Autoclaved)

Setup

Post-Test

Figure 114. Images of the Autoclaved FormLabs – USF – Sample #9 in the setup and after testing.

FormLabs – USF – #10 (Autoclaved)

Setup

Post-Test

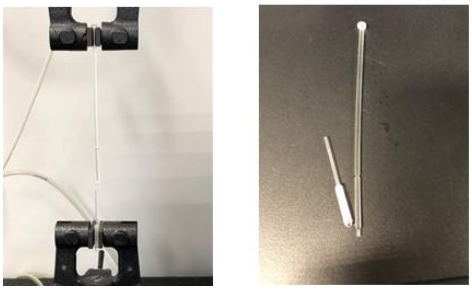


Figure 115. Images of the Autoclaved FormLabs – USF – Sample #10 in the setup and after testing.

FormLabs – Northwell – #1 (Autoclaved)

Setup

Post-Test

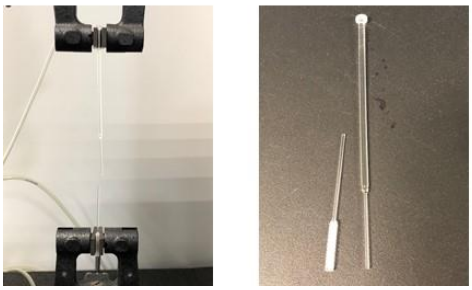


Figure 116. Images of the Autoclaved FormLabs – Northwell – Sample #1 in the setup and after testing.

FormLabs – Northwell – #2 (Autoclaved)

Setup

Post-Test

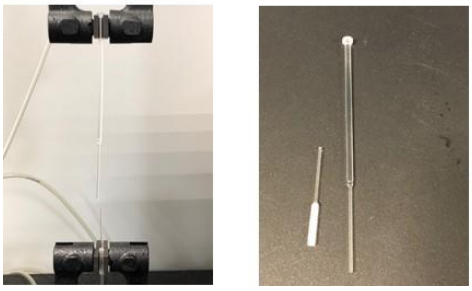
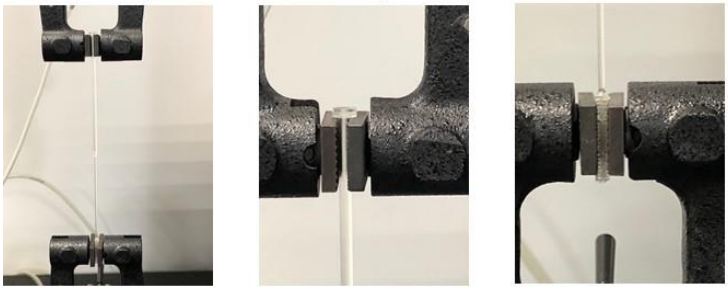


Figure 117. Images of the Autoclaved FormLabs – Northwell – Sample #2 in the setup and after testing.

FormLabs – Northwell – #3 (Autoclaved)

Setup



Post-Test

Figure 118. Images of the Autoclaved FormLabs – Northwell – Sample #3 in the setup and after testing.

FormLabs – Northwell – #4 (Autoclaved)

Setup

Post-Test

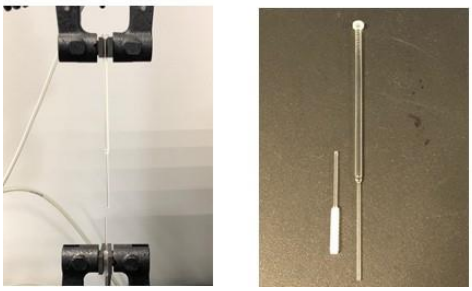


Figure 119. Images of the Autoclaved FormLabs – Northwell – Sample #4 in the setup and after testing.

FormLabs – Northwell – #5 (Autoclaved)

Setup

Post-Test

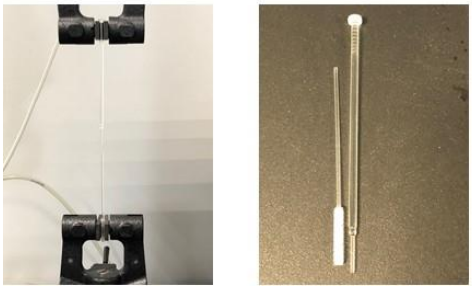


Figure 120. Images of the Autoclaved FormLabs – Northwell – Sample #5 in the setup and after testing.

FormLabs – Northwell – #6 (Autoclaved)

Setup

Post-Test

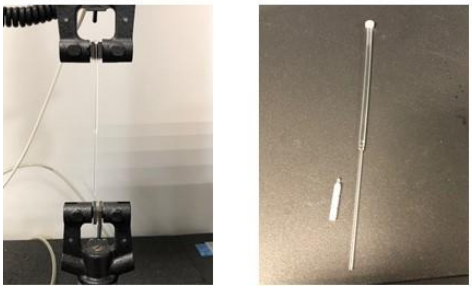


Figure 121. Images of the Autoclaved FormLabs – Northwell – Sample #6 in the setup and after testing.

FormLabs – Northwell – #7 (Autoclaved)

Setup

Post-Test

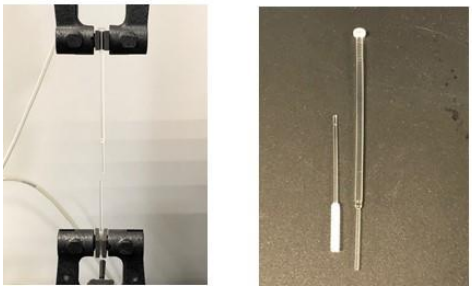


Figure 122. Images of the Autoclaved FormLabs – Northwell – Sample #7 in the setup and after testing.

FormLabs – Northwell – #8 (Autoclaved)

Setup

Post-Test

Figure 123. Images of the Autoclaved FormLabs – Northwell – Sample #8 in the setup and after testing.

FormLabs – Northwell – #9 (Autoclaved)

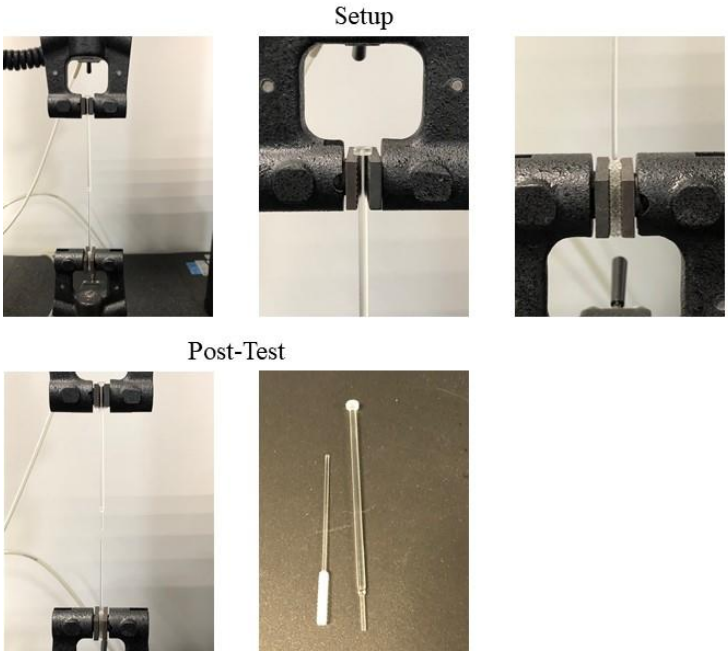


Figure 124. Images of the Autoclaved FormLabs – Northwell – Sample #9 in the setup and after testing.

FormLabs – Northwell – #10 (Autoclaved)

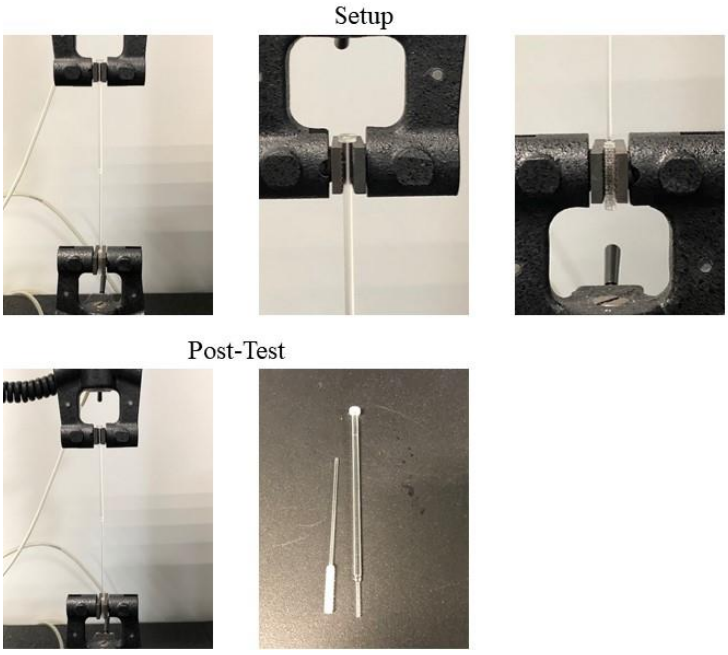


Figure 125. Images of the Autoclaved FormLabs – Northwell – Sample #10 in the setup and after testing.