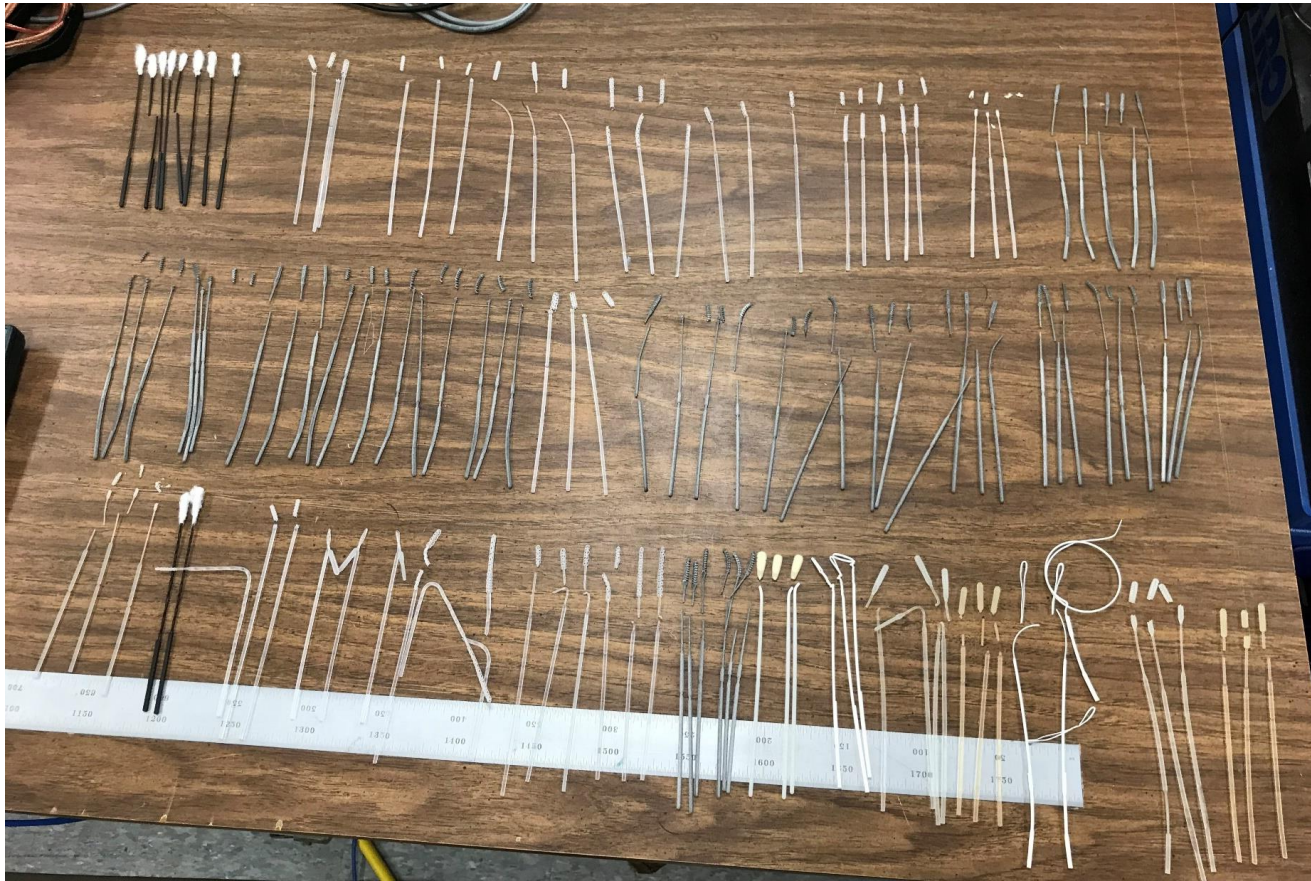

Mechanical Testing of 3D Printed COVID-19 Swabs



Harvard-Army Team

Point of Contact: Prof. Kevin Kit Parker: kkparker@g.harvard.edu

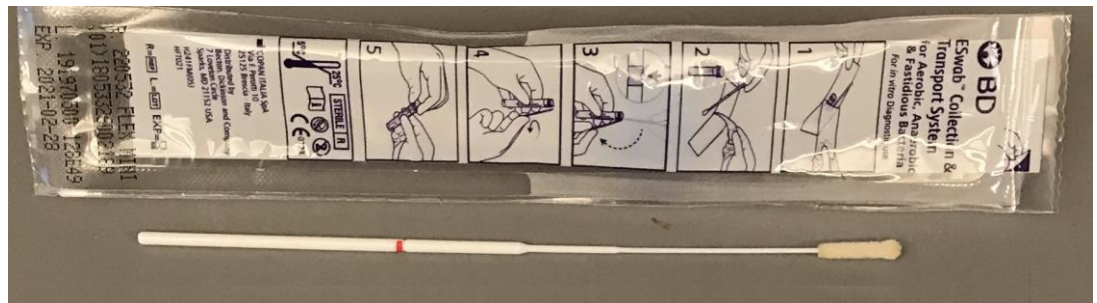
Problem Statement: Swabs for COVID Testing

- Testing for COVID is limited due to supply shortage
- Commercial COPAN and PURITAN swabs are in short supply and testing of patients is limited to ration the supplies
- The swabs needs:
 - To flex through the passages nose to the back of the throat
 - Survive being twisted 10 times in the patient
- To quantify these criteria, testing of 3D printed swabs compared to commercial swabs will occur by
 - Tensile Testing
 - Torsional Testing

Clinical Testing



Commercial Swab



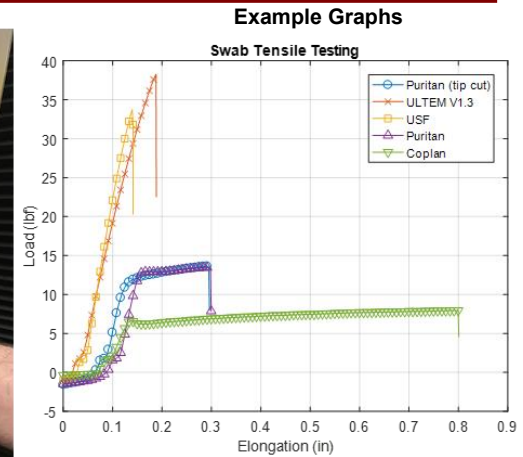
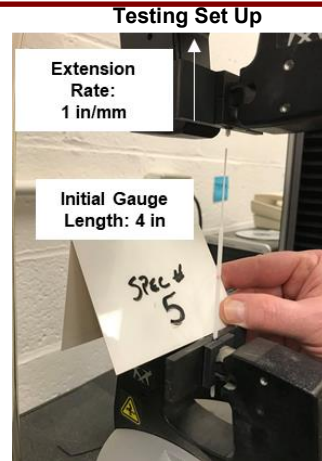
3D Printed Alternative



→ 3D printed alternative swabs need to meet the mechanical demands of clinical use based on the mechanical performance of commercial swabs

Tensile Testing of 3D Printed Swabs

- **Tensile Testing (Adapted from ASTM D638):**
 - Gauge Length: 4 in
 - Extension Rate: 1 in/min
 - Specimen Diameter: Varied per sample but near the 1 mm neck dimension of Copan swabs
 - Sample Geometry: Swab replicate with circular cross section vs traditional “dog bone”
 - Sample Loading: 0.5 in placed within pneumatic grips
 - Note: Data not normalized for cross sectional area
- Copan is the best performing commercial swab
 - Strain at Max Extension: .199
 - Toughness: 5.024 in-lbf
 - Ductile failure
- Puritan is the worst performing commercial swabs
 - Strain at Max Extension: 0.073
 - Toughness: 2.153 in-lbf
 - Ductile failure



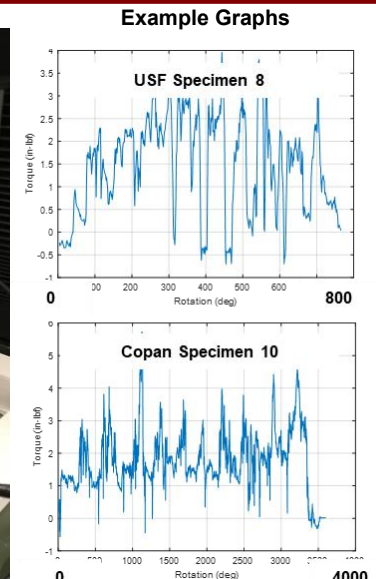
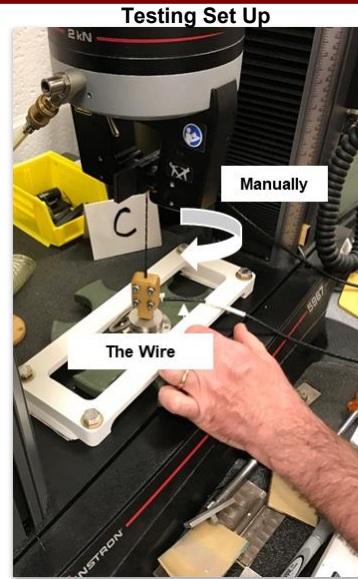
Material	Average of Tensile extension at Maximum Load [in]	Average of Max Extension [in]	Average of Strain at Max Extension [in/in]	Average of Toughness [in-lbf]	Typical Failure mode
MFNylon	4.780	4.803	1.201	62.492	Ductile
Origin	0.528	0.938	0.235	6.304	Brittle/Ductile
Carbon	0.718	0.762	0.221	4.073	Ductile
Copan (Control)	0.795	0.795	0.199	5.024	Ductile
HP	0.298	0.435	0.186	0.617	Brittle/Ductile
MFOnyx	0.342	0.356	0.172	3.593	Brittle/Ductile
Optomec	0.097	0.169	0.152	0.157	Ductile
Puritan (Control)	0.290	0.290	0.073	2.153	Ductile
Formlabs	0.149	0.203	0.051	4.131	Brittle
OSI	0.127	0.184	0.046	0.003	Ductile

→ Based on Puritan: Swabs need to have a max strain greater than 0.073, a toughness greater than 2.153 in-lbf, and have ductile mode of failure

N = 1 for controls, n = at least 3 for 3D printed swabs

Torsional Testing of 3D Printed Swabs

- **Torsional Testing:**
 - **Sample Twisting:**
Manual, twist angle estimated not recorded automatically
 - **Sample Loading:** 0.5 in placed within upper pneumatic grip, 0.5 in placed within lower Omega model TQ202-100 torque cell using a custom adapter
 - Testing ended when the sample broke or when the torsional cell wire could no longer continue warping (near 4000 deg)
- Puritan is the worst performing commercial swabs
 - Average Rotation at Failure: 612.0 Deg
 - Partially ductile failure



Material	Average of Rotation (deg)	Typical Failure Mode
MFOnyx	5220.0	None
MF Nylon	4920.0	None
Carbon	3481.2	None/ductile
Origin	3204.0	Partially Ductile
Optomec	1890.0	Partially Ductile
Formlabs	1620.0	Brittle
HP	884.7	Partially Ductile
Puritan	612.0	Partially Ductile

N = 1 for controls; n = at least 3 for 3D printed swabs

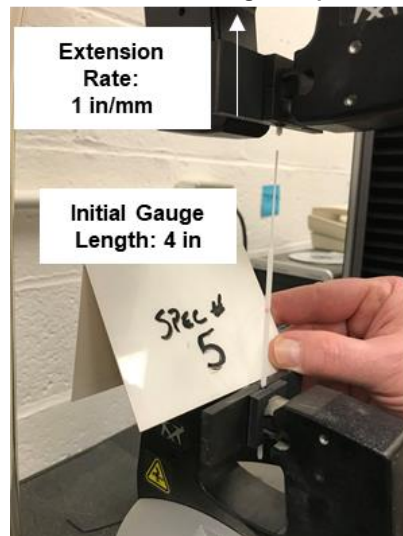
→ Based on Puritan: Average rotation at failure needs to be greater than 612 degrees and have a ductile failure mode

Summary

3D printed swab alternatives need to meet the mechanical demands of clinical use based on the mechanical performance of commercial swabs

- Based on Puritan Performance: Max Strain needs to be better than 0.073 and a toughness greater than 2.153 in-lbf and have ductile failure mode
- Based on Puritan Performance: Average rotation at failure needs to be greater than 612 degrees and have a ductile failure mode
- Meeting these design criteria aims to achieve a large safety factor based on the mechanical performance of commercial swabs
- Note: This work does not replace the importance of clinical testing, the value of expert evaluation, or meet any FDA requirements

Tensile Testing Set Up



Torsion Testing Set Up

