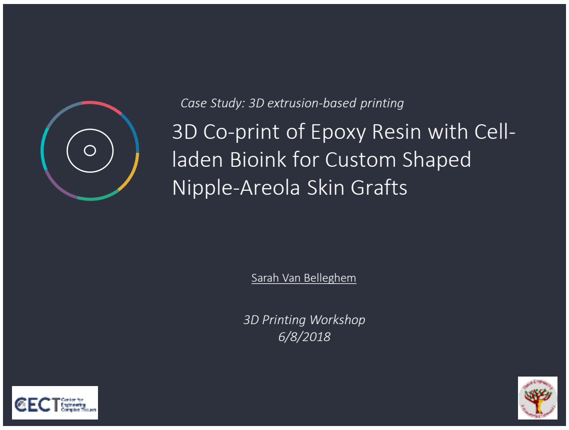
Case Study: 3D extrusion-based printing
3D Co-print of Epoxy Resin with Cell-laden Bioink for Custom Shaped Nipple-Areola Skin Grafts
Sarah Van Belleghem
3D Printing Workshop
6/8/2018


WELCOME 3D PRINTING WORKSHOP
Sarah Van Belleghem/ PhD Pre-candidate
Hello everyone! I am a 3rd year PhD candidate in the University of Maryland's Bioengineering Department. I graduated from MIT in mechanical engineering back in 2015, and am very interested in progressing advances pertaining to the women's health world.
PRESENTATION MAP
Project Development
Clinical Problem
Current Treatment
Solution
Design Criteria
Implant Design
Print in Action
Mechanical Properties
Cellular Response
Thank you
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Project Development
Pertaining to 3D printing
1
Unique Architecture is Necessary
Must be fabricated only by 3D printing; no other forms of traditional fabrication can create desired object.
2
Fabrication is Feasible
The chosen 3D printing technology should be able to create desired object (materials, size/shape)
3
Central Biological Question
Must be investigated, either cellular mechanism/furthering knowledge of fundamental biology.
4
Apparent Clinical Need
Gives value to your research and a necessary personal connection to drive focused research efforts.
3
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Nipple Areola Skin Grafts for Breast Cancer Survivors
Furthering breast restoration, emotional healing, and women's health advances

Clinical Problem
Mastectomy and Breast Reconstruction
Breast Cancer Stages
25%
35%
58%
Stage 0
Stage I and II
Stage III
~70,000
Breast Reconstruction Cases per Year
40%
5
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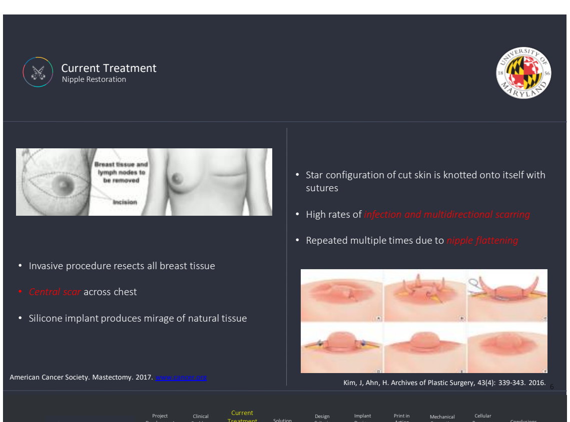

Current Treatment
Nipple Restoration
Breast tissue and lymph nodes to be removed
Incision
Star configuration of cut skin is knotted onto itself with sutures
High rates of infection and multidirectional scarring
Repeated multiple times due to nipple flattening
Invasive procedure resects all breast tissue
Central scar across chest
Silicone implant produces mirage of natural tissue
American Cancer Society. Mastectomy. 2017. www.cancer.org
Kim, J, Ahn, H. Archives of Plastic Surgery, 43(4): 339-343. 2016.
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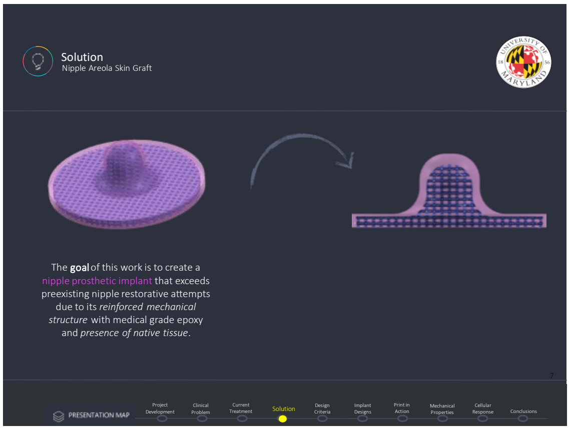
Solution
Nipple Areola Skin Graft
The goal of this work is to create a nipple prosthetic implant that exceeds preexisting nipple restorative attempts due to its reinforced mechanical structure with medical grade epoxy and presence of native tissue.
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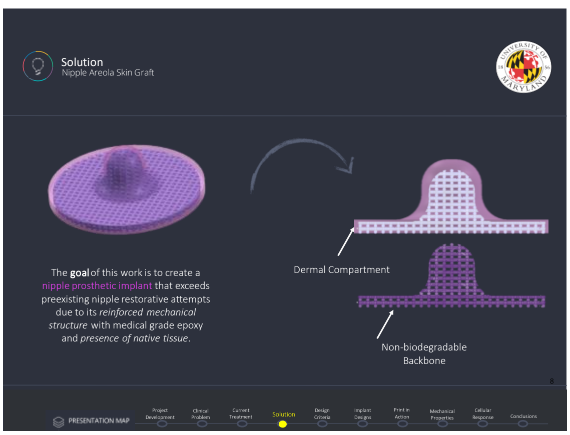
Solution
Nipple Areola Skin Graft
The goal of this work is to create a nipple prosthetic implant that exceeds preexisting nipple restorative attempts due to its reinforced mechanical structure with medical grade epoxy and presence of native tissue.
Dermal Compartment
Non-biodegradable Backbone
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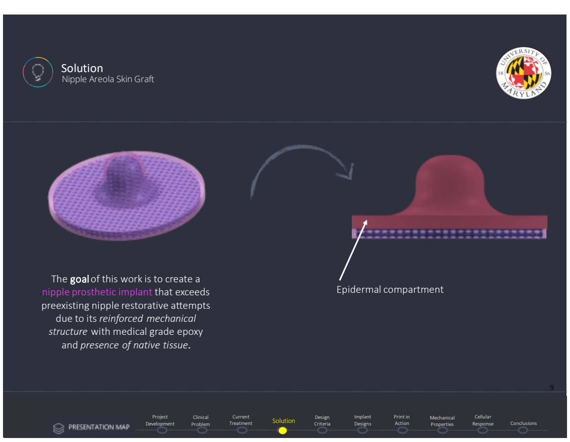
Solution
Nipple Areola Skin Graft
The goal of this work is to create a nipple prosthetic implant that exceeds preexisting nipple restorative attempts due to its reinforced mechanical structure with medical grade epoxy and presence of native tissue.
Epidermal compartment
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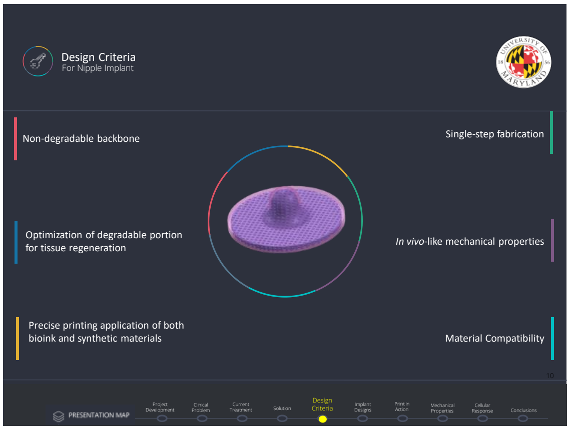
Design Criteria
For Nipple Implant
Non-degradable backbone
Single-step fabrication
Optimization of degradable portion for tissue regeneration
In vivo-like mechanical properties
Precise printing application of both bioink and synthetic materials
Material Compatibility
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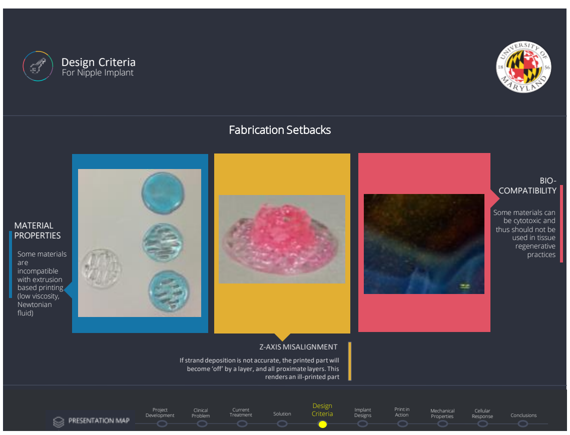
Design Criteria
For Nipple Implant
Fabrication Setbacks
MATERIAL PROPERTIES
Some materials are incompatible with extrusion based printing (low viscosity, Newtonian fluid)
BIO-COMPATIBILITY
Some materials can be cytotoxic and thus should not be used in tissue regenerative practices
Z-AXIS MISALIGNMENT
If strand deposition is not accurate, the printed part will become 'off' by a layer, and all proximate layers. This renders an ill-printed part
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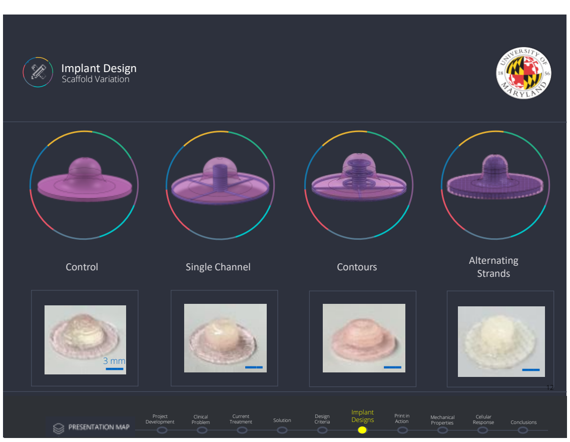
Implant Design
Scaffold Variation
Control
Single Channel
Contours
Alternating Strands
3 mm
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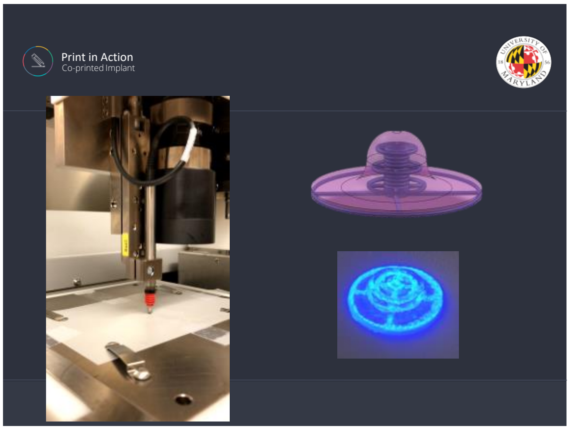
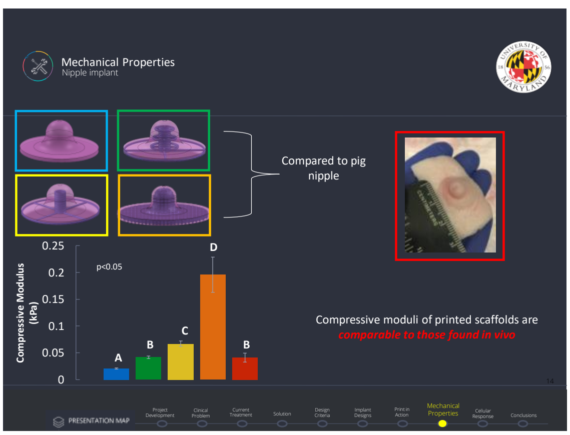

Print in Action
Co-printed Implant


Mechanical Properties
Nipple implant
Compared to pig nipple
Compressive Modulus (kPa)
0.25
0.2
0.15
0.1
0.05
0
p<0.05
A
B
C
D
B
Compressive moduli of printed scaffolds are comparable to those found in vivo
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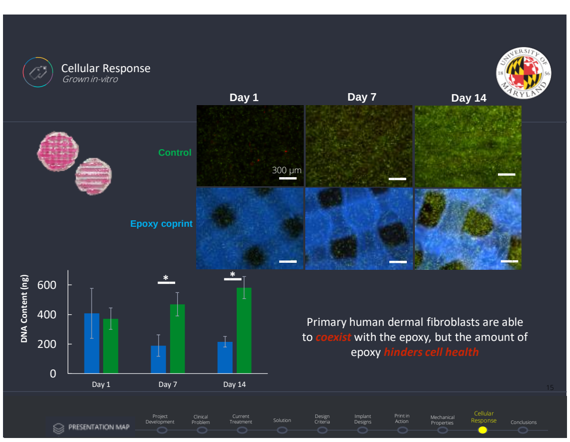
Cellular Response
Grown in-vitro
Day 1
Day 7
Day 14
Control
Epoxy coprint
300 µm
DNA Content (ng)
600
400
200
0
Day 1
Day 7
Day 14
Primary human dermal fibroblasts are able to coexist with the epoxy, but the amount of epoxy hinders cell health
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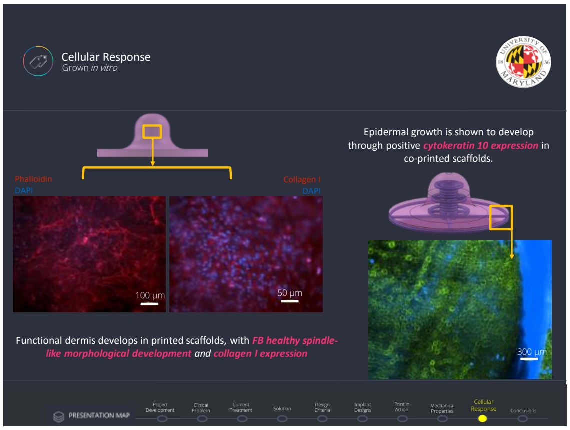
Cellular Response
Grown in vitro
Epidermal growth is shown to develop through positive cytokeratin 10 expression in co-printed scaffolds.
Phalloidin
DAPI
Collagen I
DAPI
100 μm
50 μm
300 μm
Functional dermis develops in printed scaffolds, with FB healthy spindle-like morphological development and collagen I expression
PRESENTATION MAP


Conclusion
Nipple Areola Skin Graft
A co-printed nipple areola skin graft construct composed of biodegradable cell-laden bioink and synthetic medical-grade epoxy
Material compatibility with human dermal fibroblasts and medical grade epoxy allowed for sustained cell proliferation and physiological skin protein expression
Robust mechanical properties comparable to those seen in vivo
PRESENTATION MAP


Thank You.
Principal Investigators: John P. Fisher, Peter Kim
Lab Members:
Hannah Baker
Marco Santoro
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Charlotte Piard
Javier Navarro Rueda
Max Lerman
Ting Guo
Navein Arumugasaamy
Megan Kimicata
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