Modified Spider Silk for Ligament Repair

Group 3
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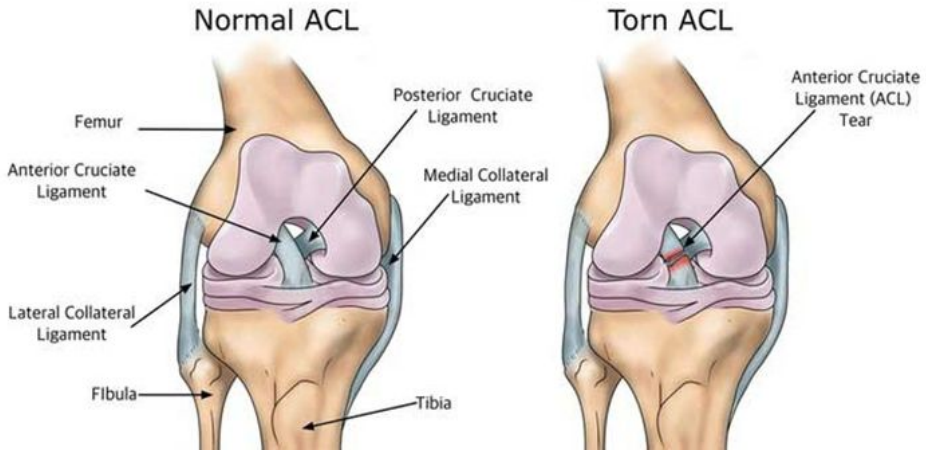
ACL Tear



- Occur commonly in sport injuries
- 350,000 reconstructive surgeries
- Solution
  - Use of autografts/allografts
- Complications

ACL - Mechanical Properties

- Nonlinear and viscoelastic
- Properties dependent on ligament geometry and relationship between ligament length and ligament tension
- ACL differs for different sexes and eventually degrades over age

	Unit	Anteromedial bundle	Anterolateral bundle	Posterior bundle
Modulus	MPa	283.1 ± 114.1	285.9 ± 140.6	154.9 ± 119.5
Strength	MPa	45.7 ± 19.5	30.6 ± 11.0	15.4 ± 9.5
Strain at failure		19.1 ± 2.8	16.1 ± 3.9	15.2 ± 5.2

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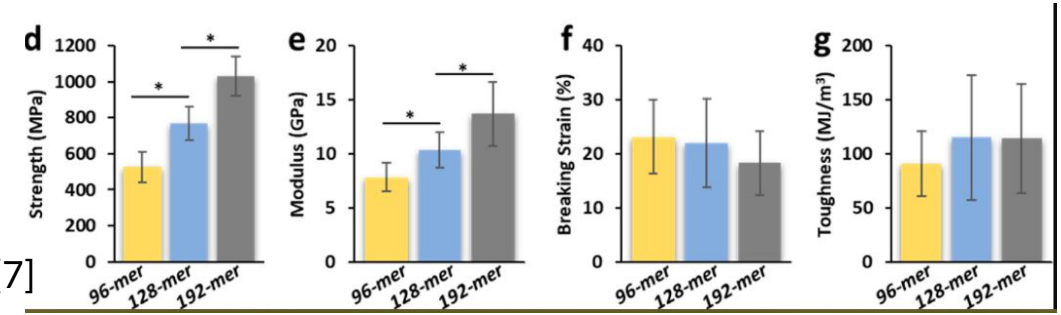
Spider Silk

- Stronger naturally-occurring fiber known
- Difficult to dissolve
- Ideal for for pursuit of biomaterials
  - Biodegradable
  - Biocompatible
  - Good for cell adhesion
  - Non immunogenic
- Dragline Silk
  - Major ampullate silk
- Spidroin
  - Major protein in dragline silk

Spider Silk - Mechanical Properties

- Tensile strength (1.03 ± 0.11 GPa)
  - Greater than steel
- Modulus (13.7 ± 3.0 GPa) vs ACL: 0.275 GPa
- Extensibility (18 ± 6%)
- Toughness (114 ± 51 MJ/m3)
- Nominal fracture strength: 1100 MPa; True fracture strength: 1500 MPa
- Elasticity: More elastic than nylon



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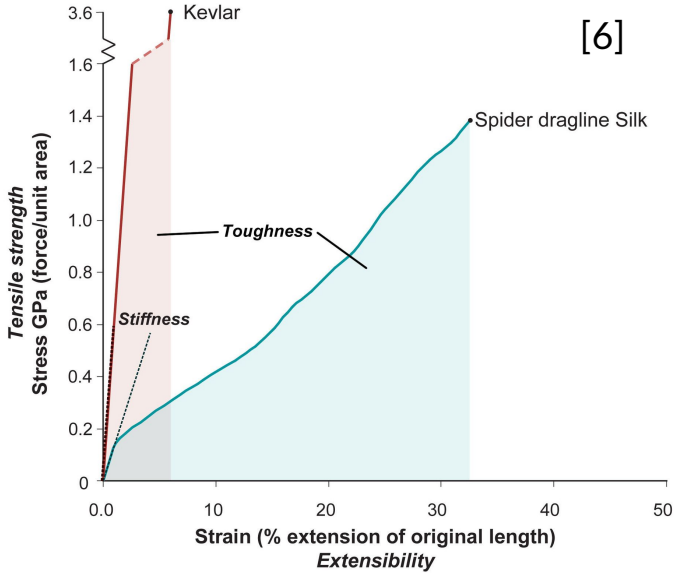

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Current Problems with Spider Silk Use

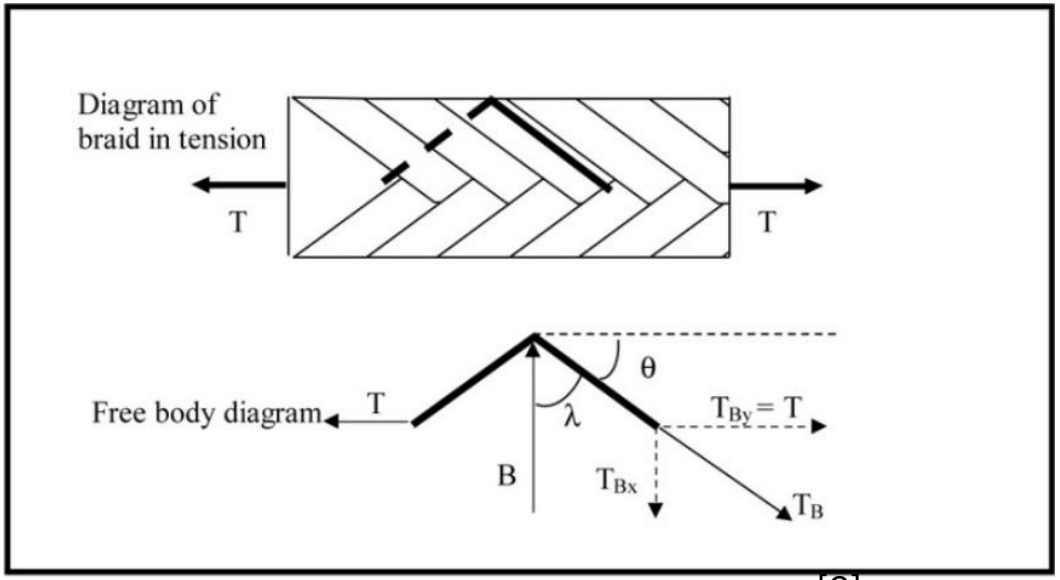
- Spiders cannot be farmed for their silk
  - Production of recombinant spidroins
    - Proteins are too big
- Braiding or twisting limits internal space in scaffold
  - Combination of braiding and twisting can cause premature scaffold failure
  - Less internal space reduces ingrowth of connective tissues

Our Design

- Parts of design
  - Shape
  - MSC differentiation
  - Temperature
  - Extracellular matrix production

Shape

- 4 Braid Scaffold
  - ~50 MPa UTS
  - ~700 MPa elastic modulus
  - 18% UTS strain



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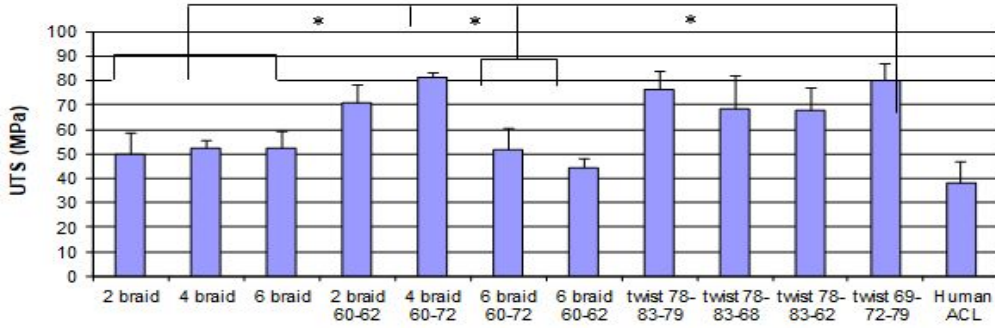
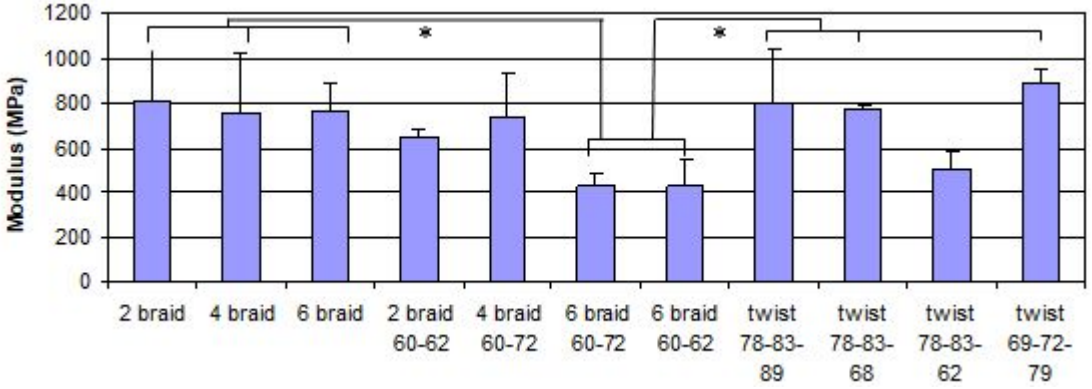

UTS (MPa)
100
90
80
70
60
50
40
30
20
10
0
*
*
*
2 braid
4 braid
6 braid
2 braid 60-62
4 braid 60-72
6 braid 60-72
6 braid 60-62
twist 78-83-79
twist 78-83-68
twist 78-83-62
twist 69-72-79
Human ACL

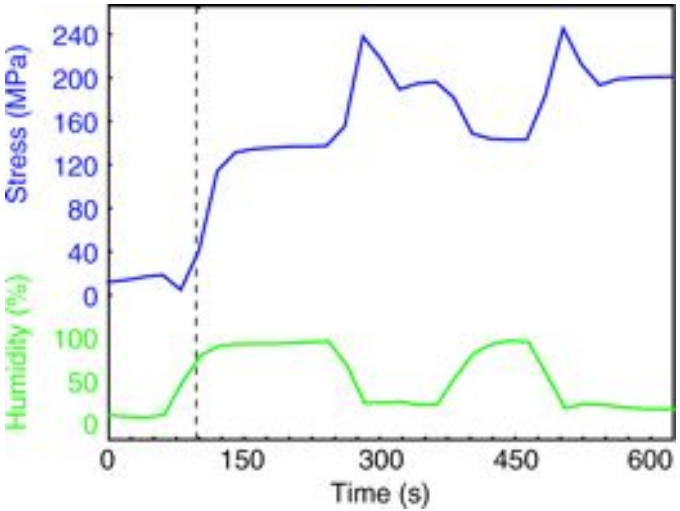

Modulus (MPa)
1200
1000
800
600
400
200
0
*
*
2 braid
4 braid
6 braid
2 braid 60-62
4 braid 60-72
6 braid 60-72
6 braid 60-62
twist 78-83-89
twist 78-83-68
twist 78-83-62
twist 69-72-79

[2]

Temperature

- Structural origin of torsional behavior of spider silk
- Influence of moisture content
- Spider silk property: supercontraction

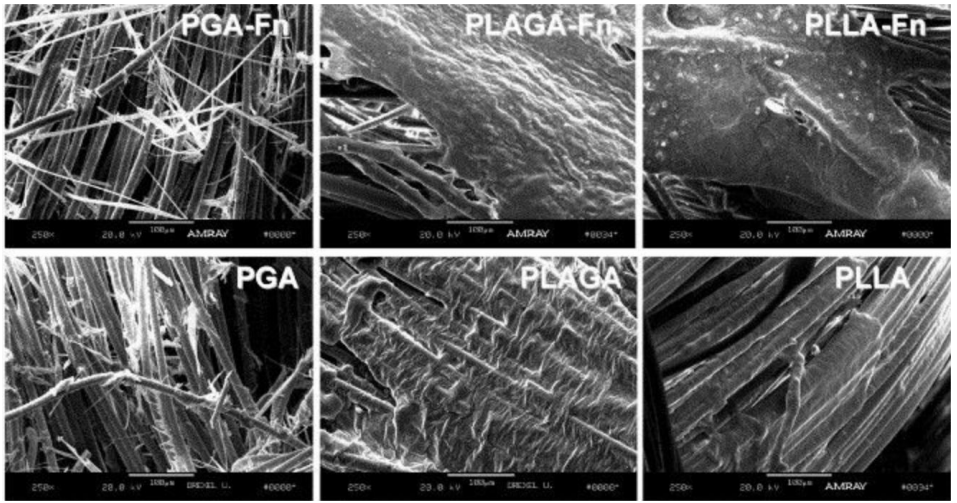
Tissue	% of dry weight			Weight % water in wet sample
	Collagen	Elastin	Proteoglycans	
Tendon	75–85	< 3	1–2	65–70
Ligament (extremity)	75–80	< 5	1–3	55–65



Graph shows response of spider silk to rapid cyclical changes in humidity

Stem Cell Differentiation

- Mesenchymal stem cells (MSCs) cultured onto spider silk fibers
- Applying mechanical signals
- Spider silk enhance differentiation of stem cells



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Collagen Microsponge

- Production
  - Freeze drying silk solution
  - Soak in collagen and hyaluronan
- ECM
  - Increased gene expression

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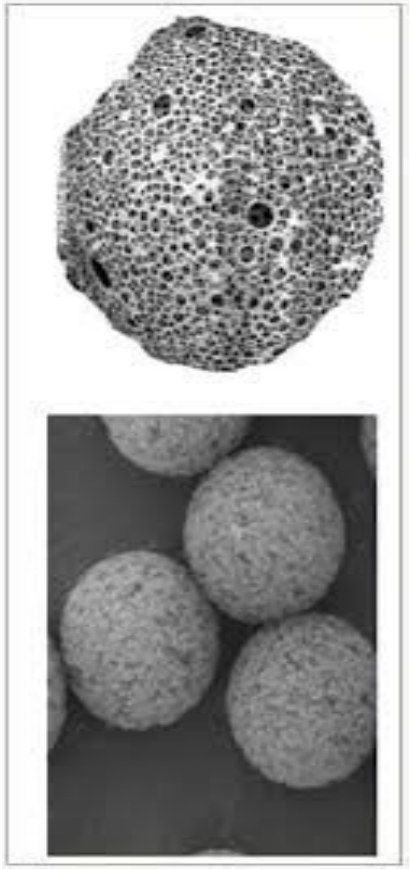

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Today's Wrap Up

- ACL
  - Mechanical Properties
- Spider Silk
  - **Properties**
  - Spidroins
- Main Design
  - **Shape**
  - Stem Cells
  - **ECM Production**
  - Water Content

References

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