Exploring Structure-Function Relationships in Scaffold Design

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Introduction

Structure-Function Relationships in Tissue Engineering

- Material properties and architecture dictate mechanical properties
- Native and regenerated tissue must have similar mechanical properties
- **Adjusting scaffold design to alter mechanical properties is a crucial aspect of tissue engineering**

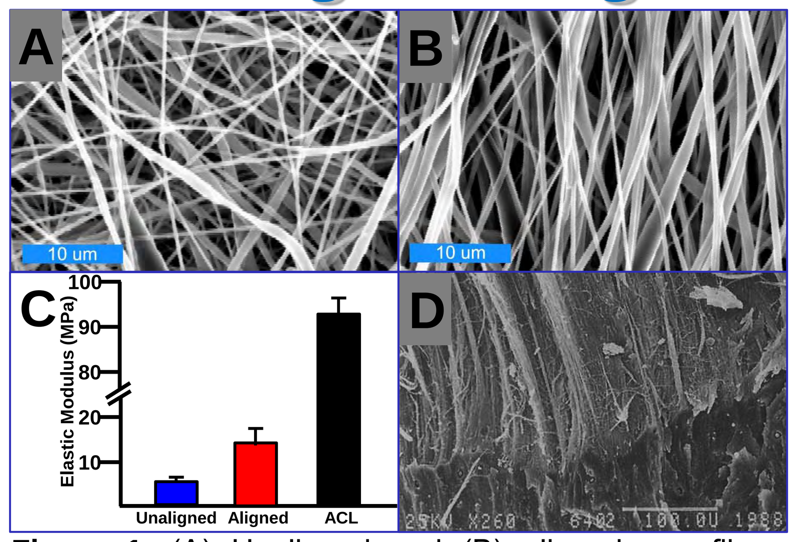

Figure 1. (A) Unaligned and (B) aligned nanofibers exhibit different (C) mechanical properties[1]. (D) The aligned architecture mimics the structure of the ACL[2,3]

Example: Engineering the Anterior Cruciate Ligament (ACL)

- The ACL is the most frequently injured ligament of the knee
- **Synthetic or tissue engineered grafts may help to eliminate problems associated with currently used soft-tissue grafts**

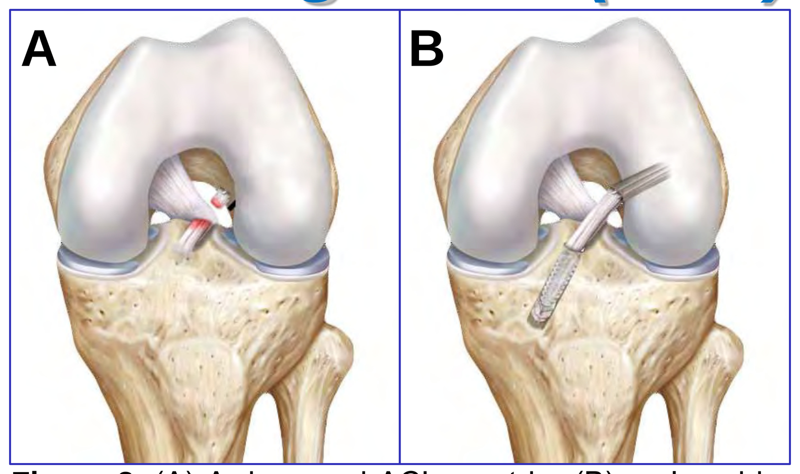

Figure 2. (A) A damaged ACL must be (B) replaced by a soft-tissue or synthetic graft[4]

Objectives

- To teach students about structure-function relationships using accessible materials
- To introduce students to musculoskeletal tissue engineering concepts
- To guide students to use the scientific method to test a design-driven hypothesis

Methods

Materials

- String or rope-like candy (e.g. Fruit-by-the-Foot®, Pull-n'-Peel Twizzlers®
- Small pails
- Weights
- Scale
- Ruler

Methods

1. **Select designs to test**
   - *e,g.* single strand, parallel bundles, twist, braid
2. **Use candy to build each selected design**
   - Observe and record "graft" properties, *e.g.* length, number of strands, number of loops in braid
3. **Test mechanical strength of each design**
   - Use candy "graft" to suspend pail
   - Add weights one at a time until graft breaks
   - Record total weight and compare strengths of different designs

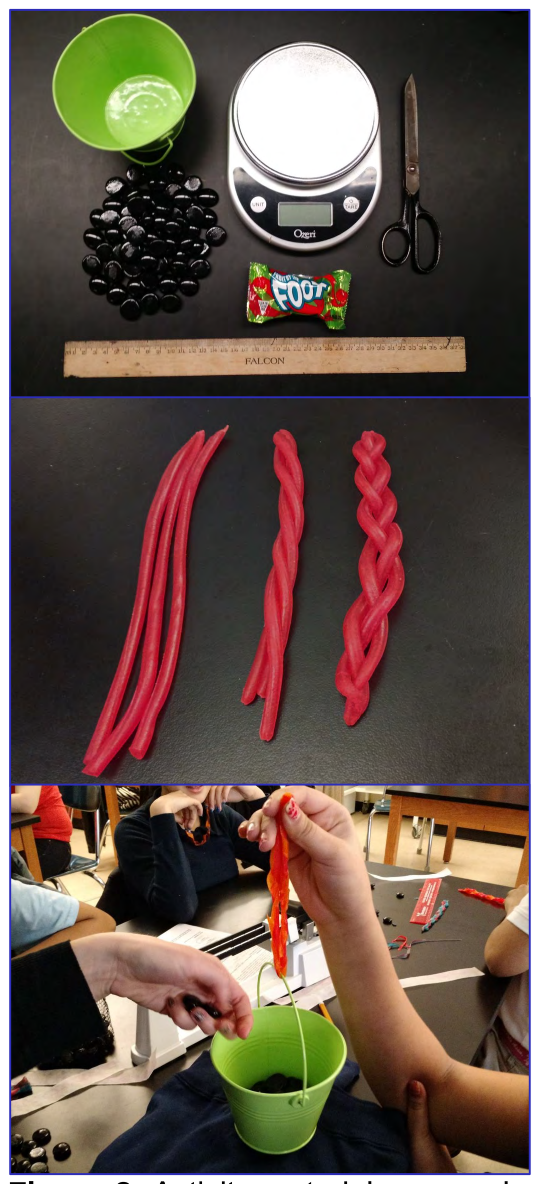

Figure 3. Activity materials, example "graft" designs, and design testing.

Results

- Module presented to local middle and high school students

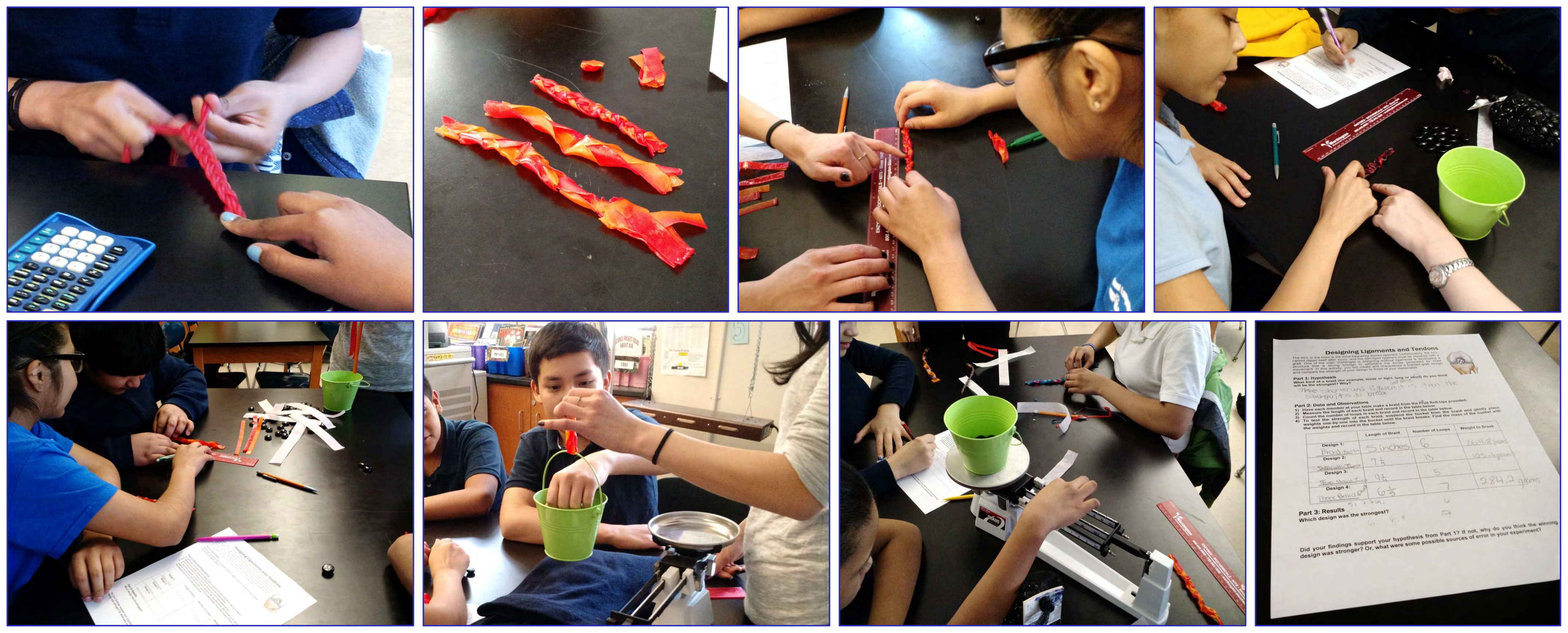

Figure 4. Students at M.S. 247 (New York, NY) test the mechanical properties of different ligament scaffold designs

- Modified module presented to over 300 K-12 students at 2014 USA Science and Engineering Festival

Figure 5. K-12 students at 2014 USA Science and Engineering Festival (Washington, D.C.) explore structure-function relationships

- Multiple regression analysis performed on student-collected results to evaluate effect of various design parameters on graft strength
  - Graft strength is dependent on number of strands (p=0.0144)
  - Graft strength is dependent on number of loops (a quantitative assessment of braid tightness, p=0.076)
- **This activity is able to recapitulate the behaviors of braided and woven grafts observed in the laboratory[5]**

Student Assessment

- Middle and high school students were tested on biomaterial properties and tissue engineering concepts before and after participating in education module
- **Significant improvement in assessment scores regardless of age**

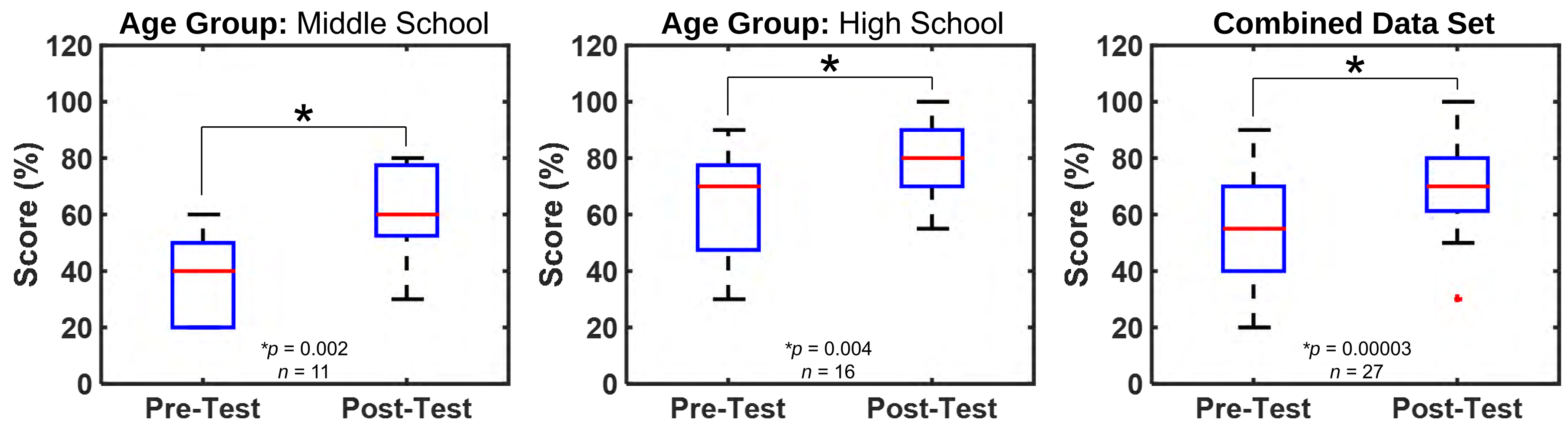

Figure 6. Both middle and high school students showed significant improvement in test scores after participation in the educational module.

References

1) Baker and Mauck, Biomaterials 2007; 2) Clark and Sidles, *J Orthop Res* 1990; 3) Woo *et al.*, *Am J Sport Med* 1991; 4) http://www.prestigesportsmedicine.com; 5) Cooper *et al.*, *Biomaterials* 2005

Acknowledgments

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