Measurement of Mechanical Properties of Male Cervidae Anterior Cruciate Ligament, Patella Tendon, and Achilles Tendon

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Introduction

The human anterior cruciate ligament (ACL) is in the knee joint and prevents the tibia (shin bone) from sliding in front of the femur (thigh bone). When the ACL is ruptured, the injury can be repaired using a replacement ligament in the form of an autograph, allograph, xenograft, or synthetic material. When replacement tissue is used it is important to understand and match the mechanical properties of the tissue to that of a human. In this study, deer tendons were tested to determine their maximum force at fracture, ultimate strength, strain at fracture, and elastic modulus. These properties were compared across each tendon and with the physical properties of a human ACL.

Methods

Cervidae (deer) tendons, including the ACL, patellar tendon, and Achilles tendon, were harvested with the help of a local deer meat processor. The tendons were then frozen and tested later. To preserve the tendons after thawing, they were sprayed with a saline solution, and were tested for their tensile strength. The tensile test was conducted using two Instron universal testing machines. The testing started on a machine with clamps that were mechanically tightened, but the tendons kept slipping. The researcher then moved to an Instron machine that had pneumatic (closing by a constant air pressure) clamps. The samples continued to slip because when the tendons were squeezed by the clamps the moisture excreted and became too slippery for the clamps to hold it. In order to stop the slipping, the tendons were wrapped in paper towels to assure a firm dry hold. The machine recorded the force vs. displacement graph, which was used to determine the ultimate strength, strain at fracture, and elastic modulus of the tendons.

Harvesting

Patella

Figure 1: Image of the Patella Tendon Harvesting.

Achilles

Figure 2: Image of Achilles harvesting.

ACL

Figure 3: Image of ACL harvesting.

Student Researcher
LinkedIn:

Figure 4 a

Figure 4 b

Figure 4 a & b: QR codes for videos of the harvesting of the ACL and Achilles.

Testing

Achilles 1

Figure 5 a

Achilles 2

Figure 5 b

Patella

Figure 5 c

ACL

Figure 5 d

Figure 6: Photographs and videos were taken during testing

Figure 5 a, b, c, & d: QR codes for videos of slow motion videos of the test being run for both Achilles, the patella, and the ACL.

Achilles 1

Figure 7 a

Achilles 2

Figure 7 b

Patella

Figure 7 c

ACL

Figure 7 d

Figure 7 a, b, c, & d: Images of the tendons before testing while clamped.

Results

Two Achilles tendons were tested and the results were averaged. They had an ultimate strength of 34.48 MPa, a strain at fracture of 0.52, an elastic modulus of 65.9 MPa, and an ultimate tensile force of 1693.8 N. The Patellar tendon had an ultimate strength of 15.7 MPa, a strain at fracture of 0.43, an elastic modulus of 36.5 MPa, and an ultimate tensile force of 1010.7 N. The ACL had an ultimate strength of 9.2 MPa, a strain at fracture of 0.18, an elastic modulus of 51.1 MPa, and an ultimate tensile force of 670.4 N. In a study, it was found that the human ACL has an ultimate strength of 35 MPa.

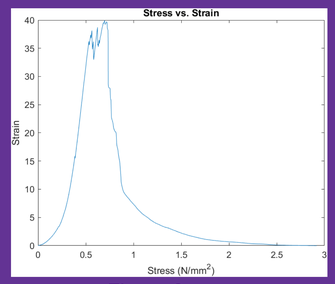

Figure 8 a

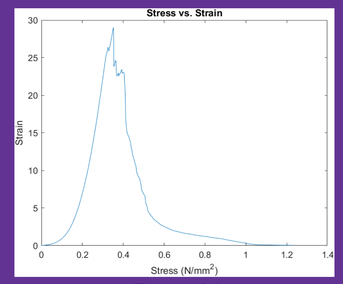

Figure 8 b

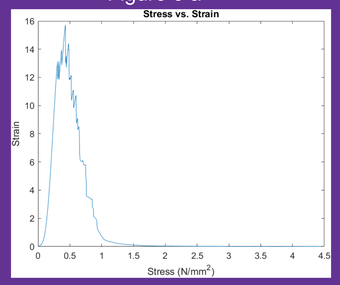

Figure 8 c

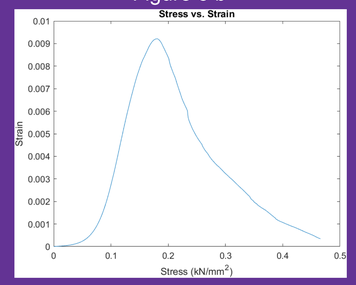

Figure 8 d

Figure 8 a, b, c, & d: Stress-Strain graphs from calculations with the first and second Achilles, patella, and ACL tested.

Conclusions

It was determined that the ultimate strength for a human ACL was comparable to that of the cervidae Achilles tendons, but not for the patellar tendon or the ACL. The methods developed here can be used to test other biological tissue, including human to determine mechanical properties and it can also be used to test the performance of engineered tissues (either biological or synthetic).

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