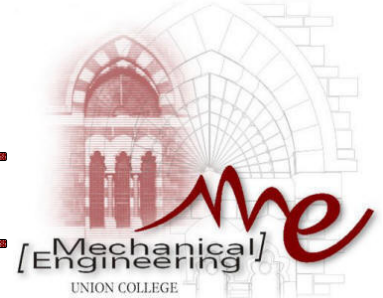


Demonstrating Altered Kinematics from Ligament Injuries with a Three Dimensional Knee Model

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Abstract

A three dimensional physical model of the human knee joint was created in this project. The design enhances previous two dimensional models but its main focus is to simulate altered kinematics from cruciate ligament failure. The model accurately simulates the rolling to sliding ratio within a healthy knee as well as accurate internal rotation simulation as a result of flexion. The model can also be altered to display cruciate ligament injuries ranging from the most severe, Grade III, to slight sprains in the ligament, Grade I. There are several ways in which a physician checks for ligament damage. These injuries can be displayed by implementing common ligament damage tests like the anterior draw test or posterior draw tests. The injurious examples yield increased laxities within the knee which is displayed by an increase in travel of the tibia and femur relative to each other when a force is applied during these tests. The end result is an interactive model that can be altered quickly to display both knee kinematics of a healthy and injurious knee.

Flexion Measuring Aid: The flexion measuring aid offers many advantages. It allows the user to accurately measure flexion angle of the knee. It is also used to measure internal rotation of the knee during flexion.



Anatomical Bone Model: The anatomical representation of the femur and tibia were purchased from a commercial source (Saw Bones Worldwide, Pacific Research Laboratories, Vashon, WA). It is a left knee made of hard white plastic filled with a polyurethane foam.

Cruciate Ligament Design: The cruciate ligaments were designed to be easily altered so that they could function as healthy ligaments as well as various grades of injurious ligaments. The ligament is an elastic material that is held in place using a spring loaded clip. The spring loaded clip is tightened to the first line (1) in order to create healthy knee kinematics. If it is loosened to the second line(2) it simulates a Grade I ligament injury and loosening the clip to the third line(3) simulates a Grade II injury.



The biggest challenge was creating a way in which the ligaments could be totally and easily removed in order to simulate a fully torn ligament. This was done by utilizing current methods in total ligament replacement surgeries.

Tunnels were drilled in both the femur and tibia in order to house both the ACL and PCL. The ligaments can easily be threaded through these holes and be tightened to the necessary length. A visual of how the holes are drilled during surgery is shown on the right.

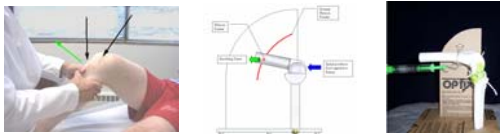


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Testing for Ligament Deficiencies

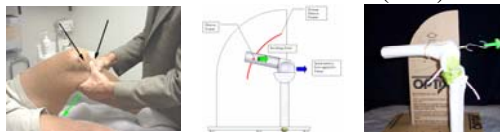
There are several different methods in which physicians check for cruciate ligament injuries in patients. The tests that were chosen to apply to this model are all done when the patient totally relaxes all muscles within the leg because there are no muscles that are active in this model.

Anterior Draw (ADT) and Lachman's Test



- Knee is brought to 90° flexion for anterior draw test and 30° flexion for Lachman's test
- An anterior force is placed on tibia with respect to the femur
- Resulting force creates movement in knee when ACL is damaged

Posterior Draw Test (PDT)



- Knee is brought to 90° flexion
- An posterior force is placed on tibia with respect to the femur
- Resulting force creates movement in knee when PCL is damaged

Severity of Injuries

Grade I

- Ligament is stretched but there is no tear
- The knee does not feel unstable

Grade II

- Ligament is partially torn
- The knee feels unstable

Grade III

- Ligament is fully torn (ruptured)
- The ligament no longer has any effect on joint kinematics and knee becomes largely unstable

Results & Conclusions

The tests were done using a spring scale that produced a maximum of 5 N. The tests were first conducted with both ligaments "healthy". There was no draw in any of the tests and a large force had to be applied to create any type of unnatural movement. Each test was done with a ligament varying from being totally removed (Grade III) to slight laxity in the ligament (Grade I).

Each column below the grade value denotes whether the ACL, PCL or both ligaments were brought to the corresponding injury. The values are millimeters of draw that occur when the knee model is subjected to each specific test. There is immeasurable draw that occurs when the model is subjected to a Grade I injury which is consistent with its medical symptoms but what this test does not show that the model does is the increased internal rotation that can occur during flexion. It is also important to note the value in yellow because the force applied during that particular posterior draw test was only 3N because the extreme laxity in the joint caused the normal applied force of 5 N to pull the femur off of the tibia.

The end result is a model that accurately demonstrates kinematics of a healthy knee as well as displays the resulting effects of ligament damage. The model can be easily altered to simulate several levels of injury. The tests results also display similar results as would be expected by a physician when testing for ligament deficiencies. The results are especially affective in displaying the increase in laxity when both ligaments are damaged. In every case the model with both ligaments injured created the greatest laxity.

Acknowledgements

I would like to extend my gratitude to the members of the Union College Machine Shop for their help in the construction of the model.

	Averages for all Values								
	Grade I			Grade II			Grade III		
	ACL	PCL	Both	ACL	PCL	Both	ACL	PCL	Both
ADT	0.0	1.0	0.0	3.1	2.0	5.8	6.7	2.4	6.9
Lachman	0.0	0.0	0.0	0.0	0.0	3.4	2.0	0.0	4.7
PDT	0.0	0.0	0.0	0.0	3.8	3.3	0.1	4.8	9.6