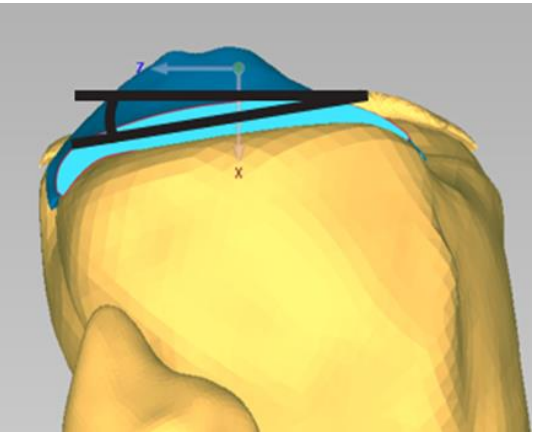
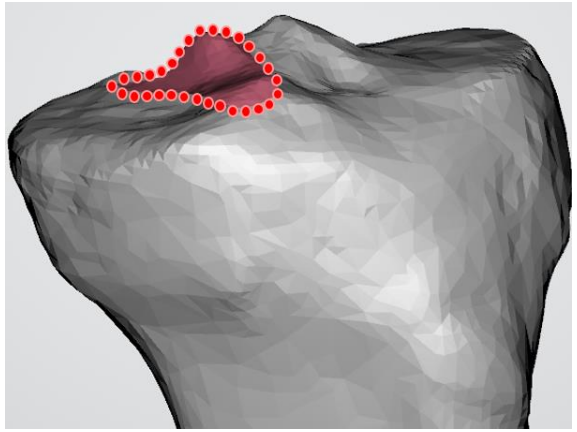
UPDATE ON HSS DIGITAL TWIN PLATFORM

&

Use of Digital Twin to Determine the Effect of Tibial Geometries on ACL Force during Pivoting Loads





Andrew D. Pearle, MD

Chief Emeritus, Sports Medicine Institute

Hospital for Special Surgery

Professor of Orthopedic Surgery

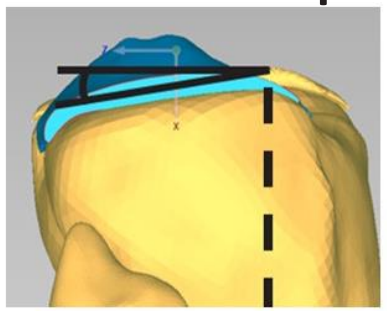
Weill Cornell Medical College

Three Digital Twin Talks from the HSS Team

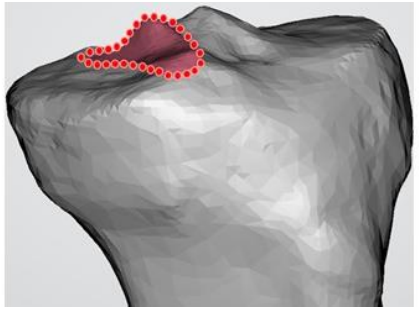
1. Shape – Function Relationships

Andy Pearle

Tibial Slope



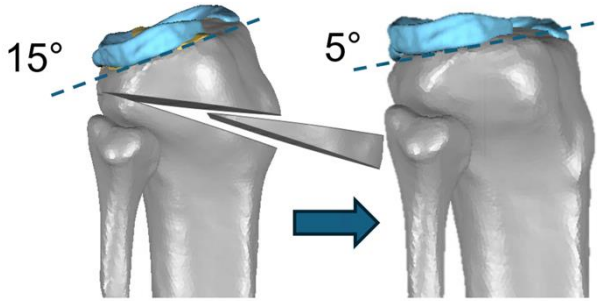
Tibial Eminences



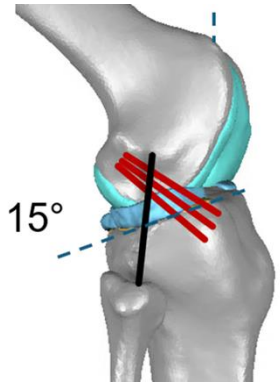
2. Surgical Simulations

Danyal Nawabi

Osteotomy

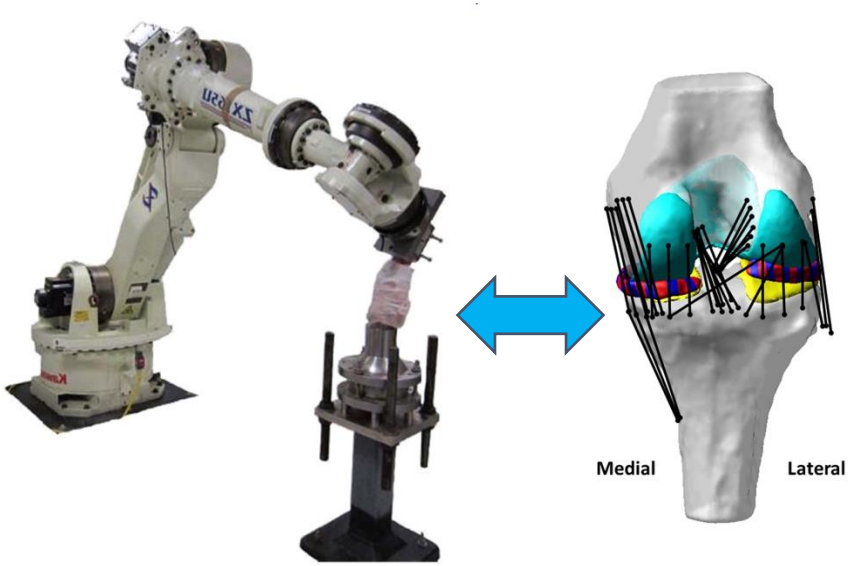


LET

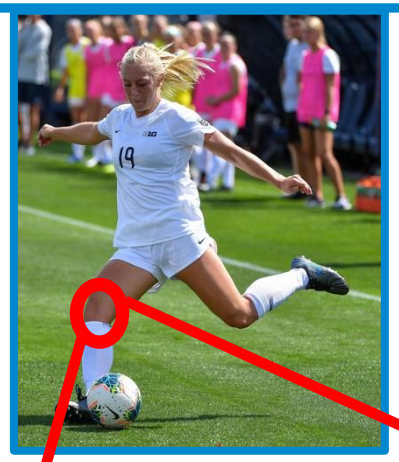


3. Credibility Assessment

Carl Imhauser

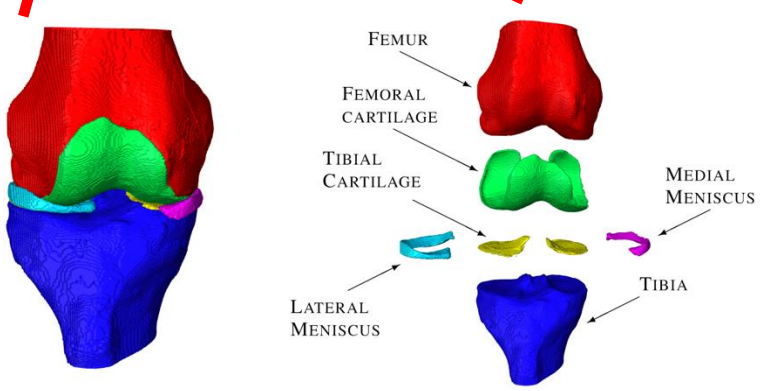


St Kitts ACLSG – Introduced HSS Knee Digital Twin *Platform*

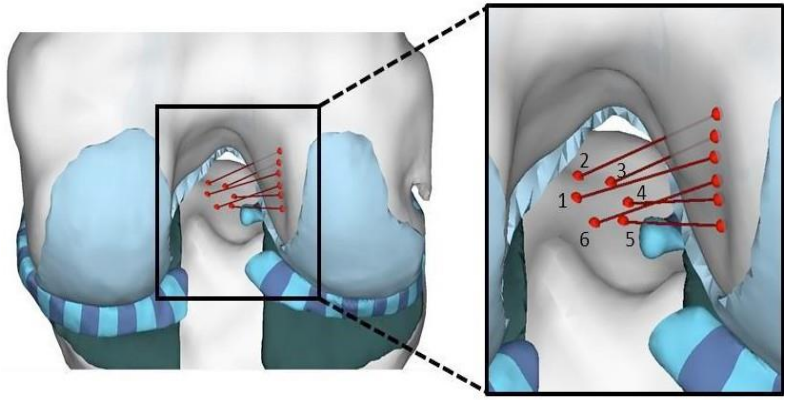


Digital Twin - Virtual Replica of a Physical Asset to Run Simulations

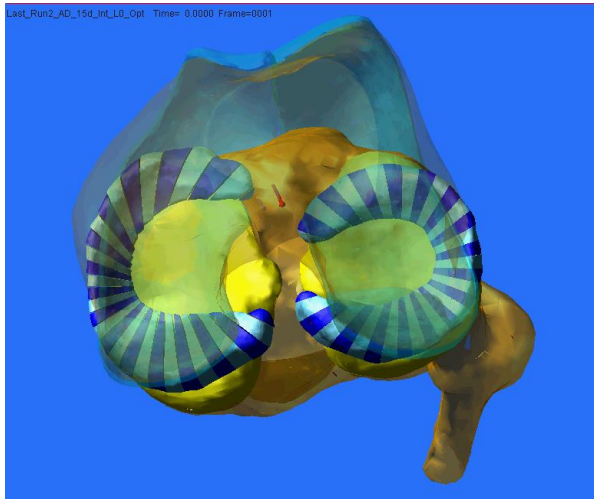
- Used for decades to optimize the engineering and manufacturing of complex systems



Autosegmentation of MRI (SPGR)
Patient Specific MRI data

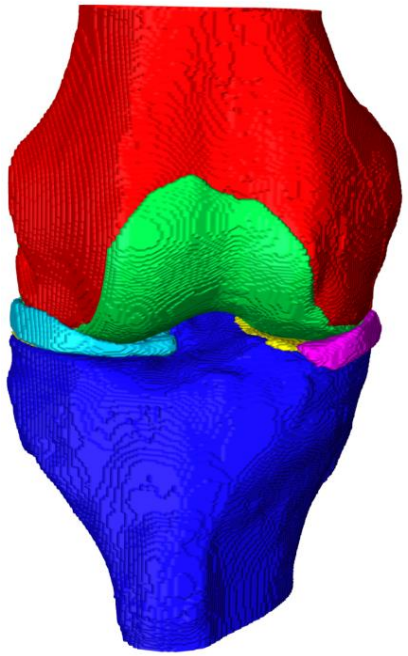


Integrate Physics Based Computational Model
10 Years of Development and Validation

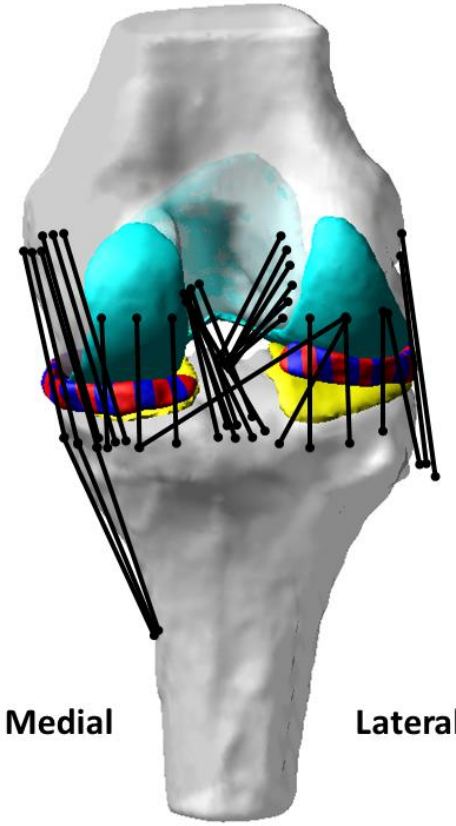


Run simulations to predict behavior

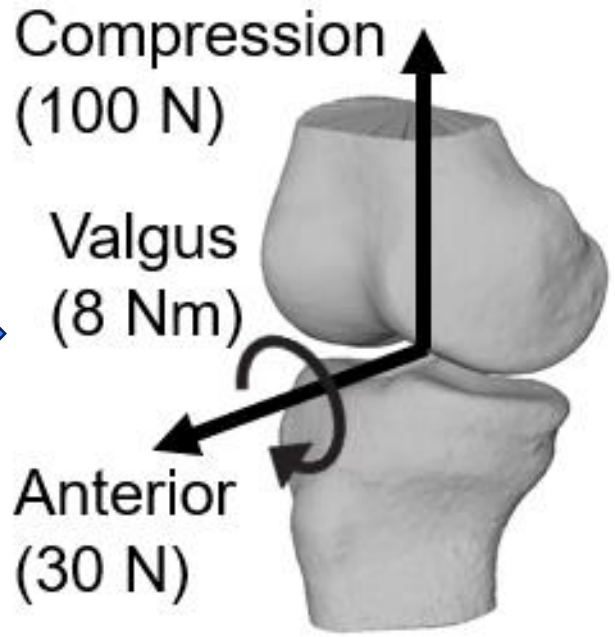
Automated Pipeline for HSS Knee Digital Twin
St Kitts ACLSG - Pilot Data n = 20



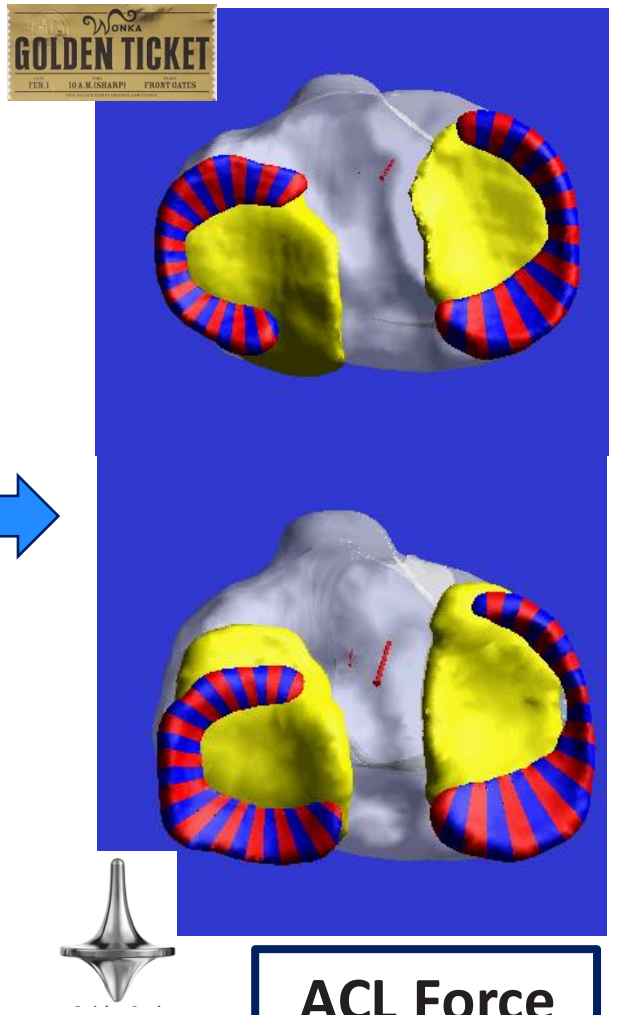
Geometry Specific
(Based on MRI)



42 ligaments (semiautomated)
(Ligament Properties Standardized)



Simulated Pivot Shift at 15 degrees



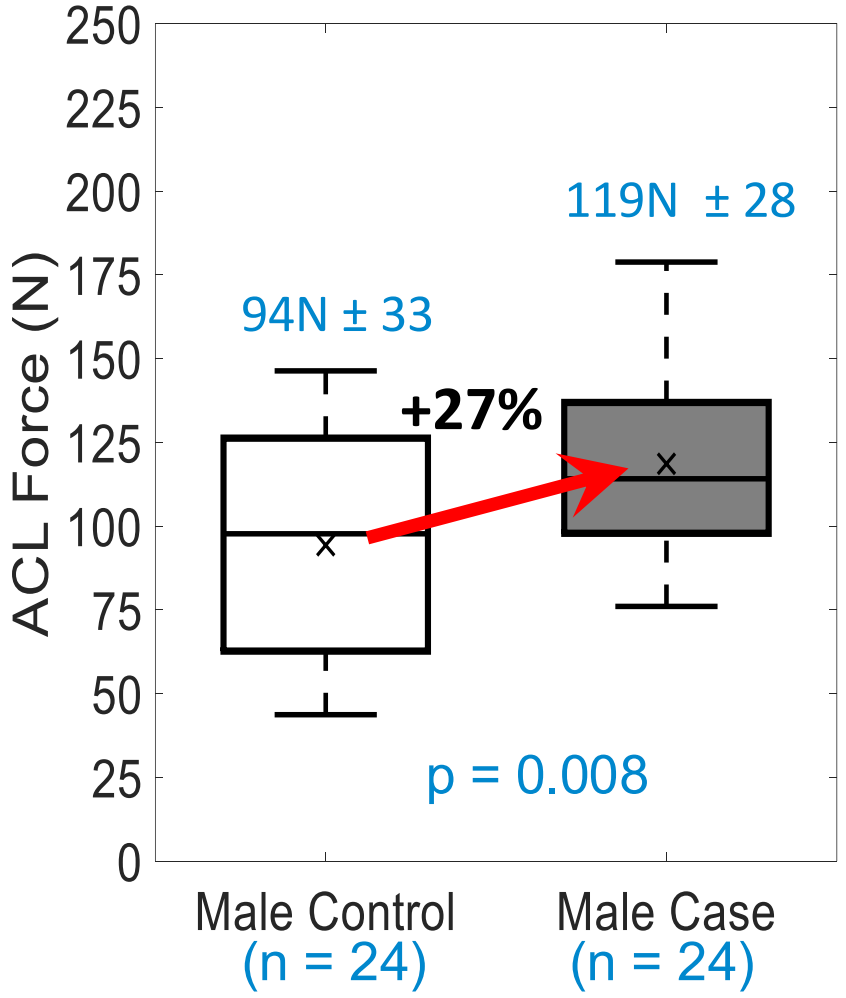
ACL Force

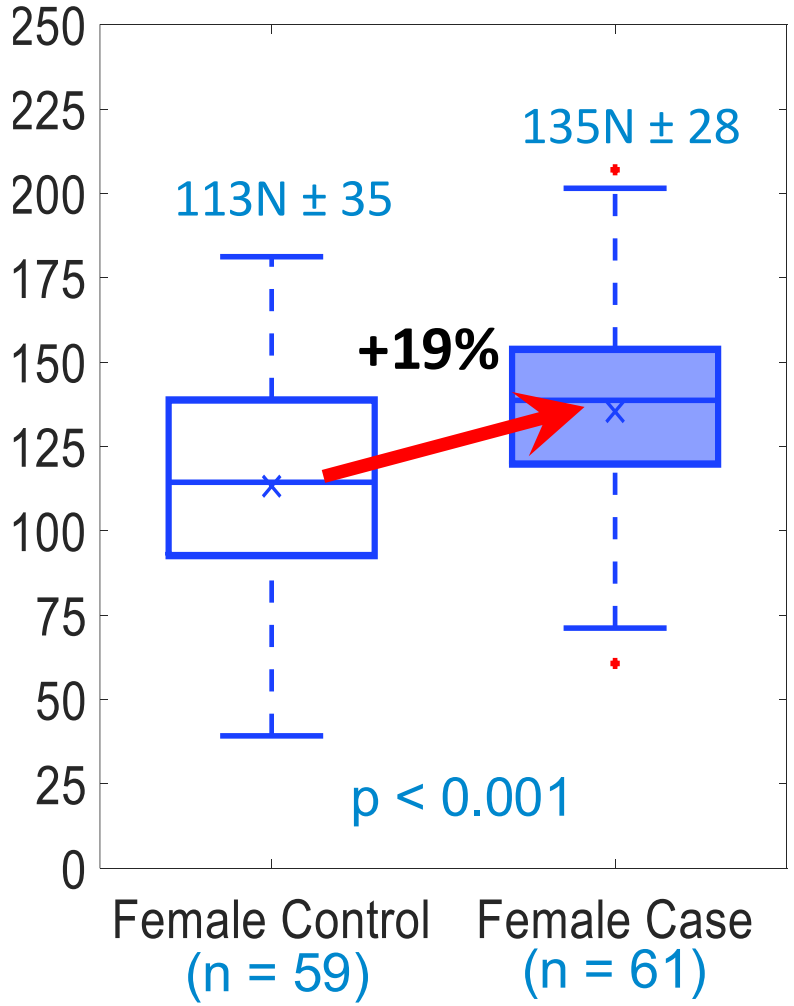
Japan ACLSG - Unique Case-Control ACL Injury Dataset

Cases – HS and College athletes who sustained non-contact ACLT

Controls – Age and sex matched uninjured teammates

Created Digital Twins and ran pivot simulations on 168 Athletes





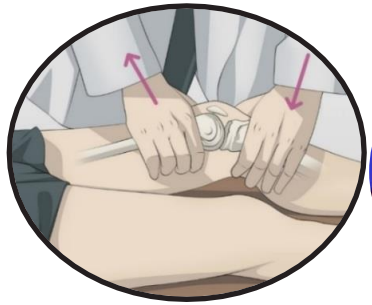
Implementing Tool into Clinical Workflow for Complex Cases

Goal – Full Clinical Implementation within 4 years

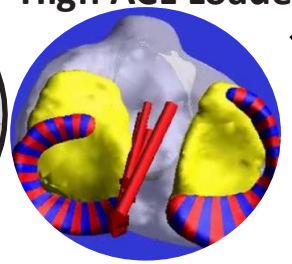
Significant philanthropic funding to make his possible

Patient comes to HSS

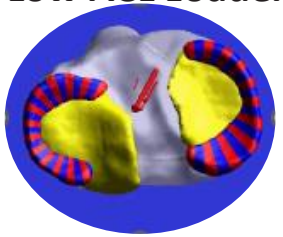
Patient receives clinical evaluation



High ACL Loader



Low ACL Loader

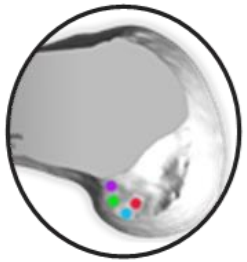


Derive a treatment plan

Augmentation

Osteotomy

Tunnel location



Rehab

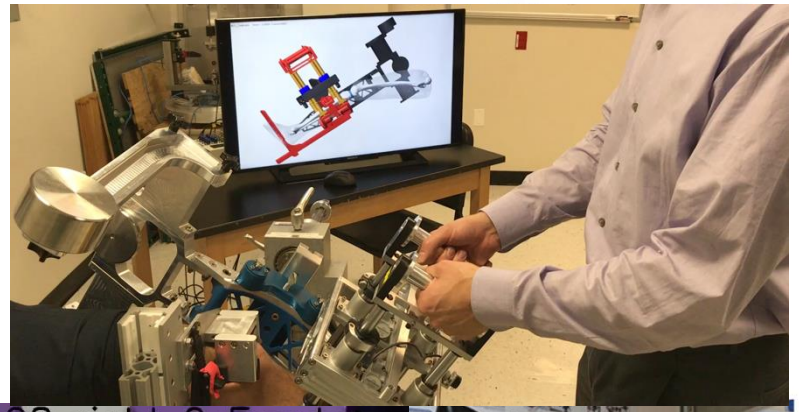
Graft Type

Where are we going – HSS Digital Twin 2.0

Input Additional Data Sources into Digital Twin Simulations

More data inputs, more personalized insights

- MoCap, Ligament Laxity, Muscle Strength Data, etc



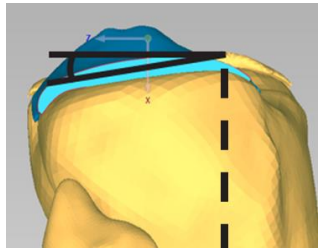
Digital Twin

As we work to develop, validate, and implement this tech, continue to use it to answer research questions

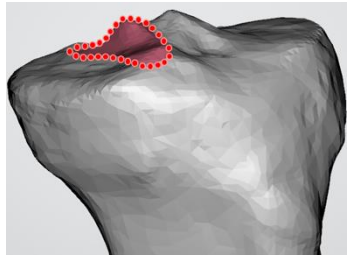
In Current HSS Digital Twin, *Variations in ACL Load are Driven Exclusively by Individual's Unique 3D Knee Shape*

- What Morphologic Features are Driving this Variation??

Lateral Tibial Slope



Medial Tibial Eminence



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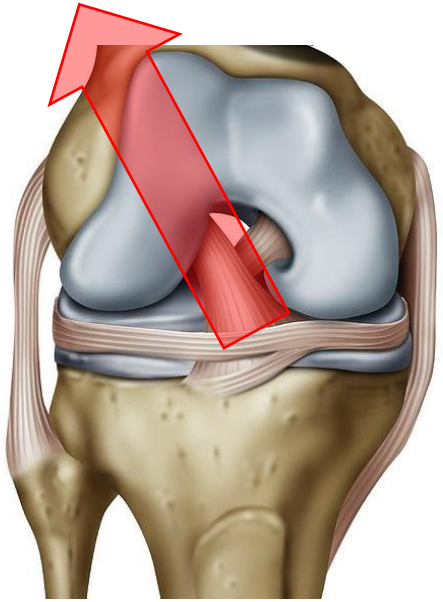
ACL Loading



Research Question

HSS

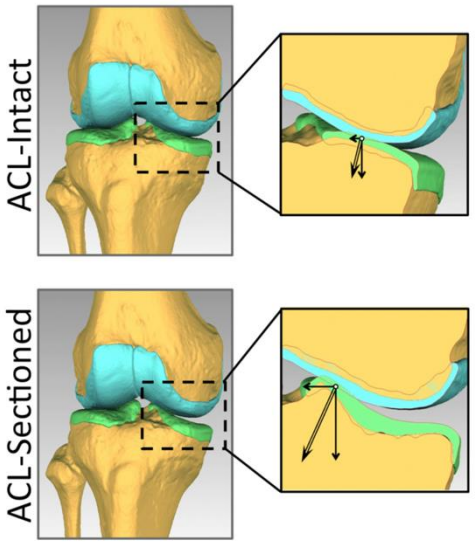
In Dataset of 168 Athletes, is ACL force associated with

1) **Lateral tibial slope**
2) **Medial tibial slope**
3) **Lateral tibial eminence volume**
4) **Medial tibial eminence volume**

ACL Deficiency Increases Forces on the Medial Femoral Condyle and the Lateral Meniscus with Applied Rotatory Loads

Lucas S. McDonald, MD, MPH&TM, James Boorman-Padgett, BS, Robert Kent, BS, Kyle Stone, MS, Thomas L. Wickiewicz, MD, Andrew D. Pearle, MD, and Carl W. Imhauser, PhD

Investigation performed at the Biomechanics Department, Hospital for Special Surgery, New York, NY

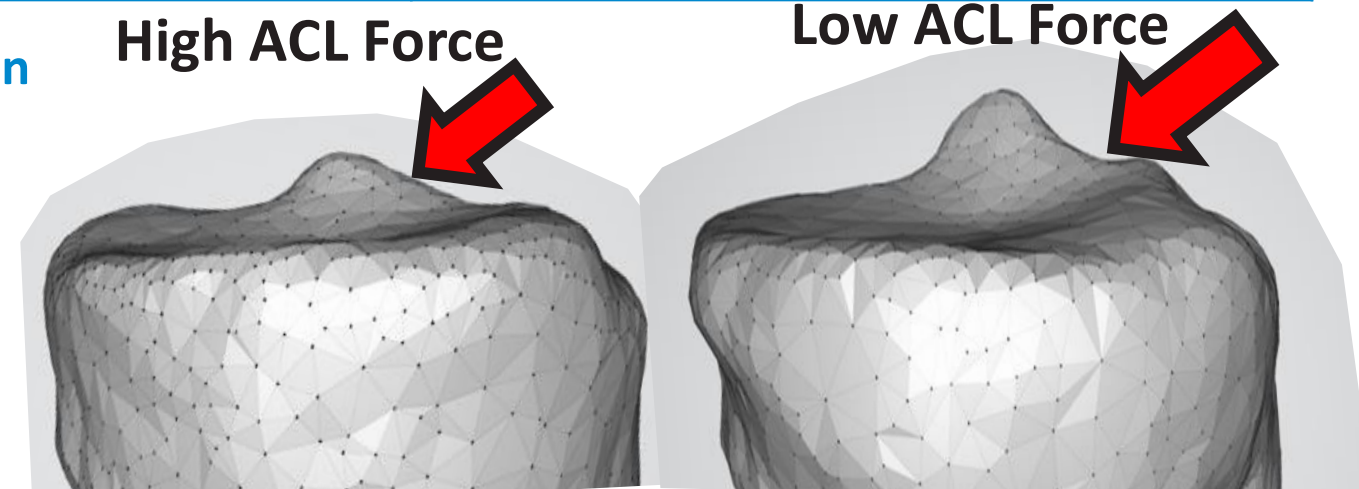


Note – Did not look at other shape features including any femoral morphologic features

Results: Increased Lateral Slope and Decreased Medial Tibial Eminence Volume Associated with Higher ACL Force

Knee Geometry	Relation to ACL Force (N) β, p-value	Δ 1 IQR in Knee Motion = Δ ACL Force (N)
Medial Tibial Slope (°)	β = +1.4 N per 1° increase, p = 0.12	+ 4.7 N
Lateral Tibial Slope (°)	β = +4.8 N per 1° increase, p < 0.001	+ 23 N
Medial Eminence Volume (mm^3)	β = -0.04 N per 1mm^3 DECREASE, p = 0.005	+ 10 N
Lateral Eminence Volume (mm^3)	β = +0.009 N per 1mm^3 increase, p = 0.18	+ 3.7 N

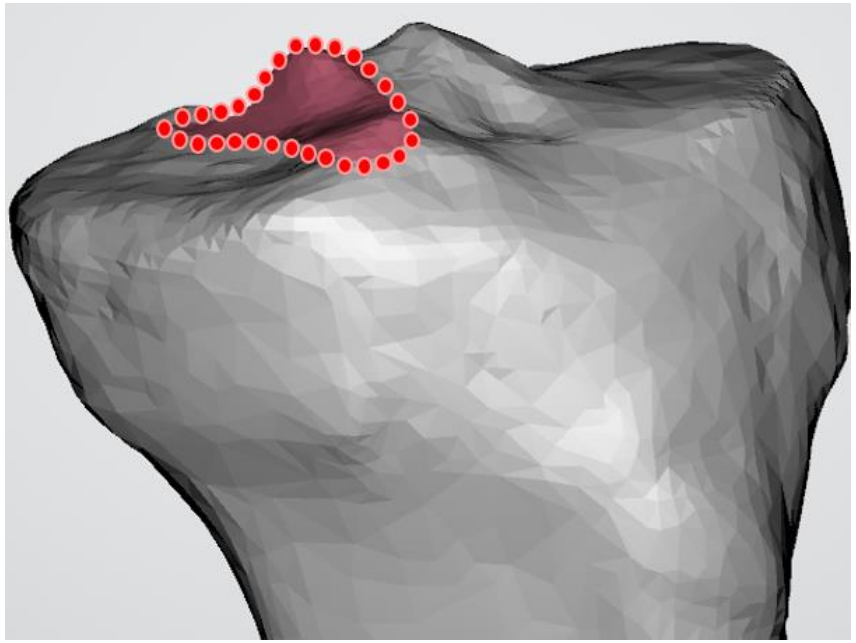
Slope-eminence ACL force multiple linear regression

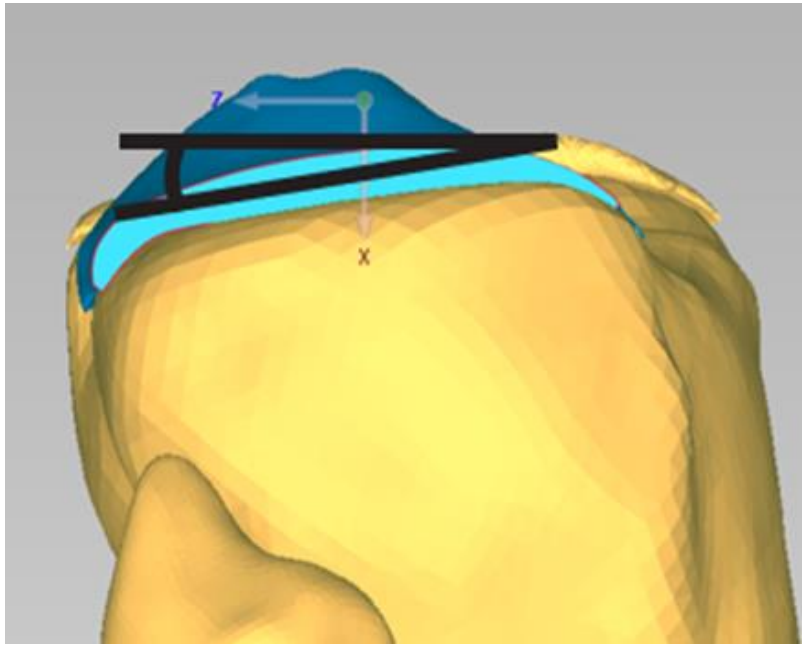


Stepwise Linear Regression

Lateral tibial slope accounted for ~25% of the variance in ACL force and medial tibial eminence volume contributing an additional ~10%

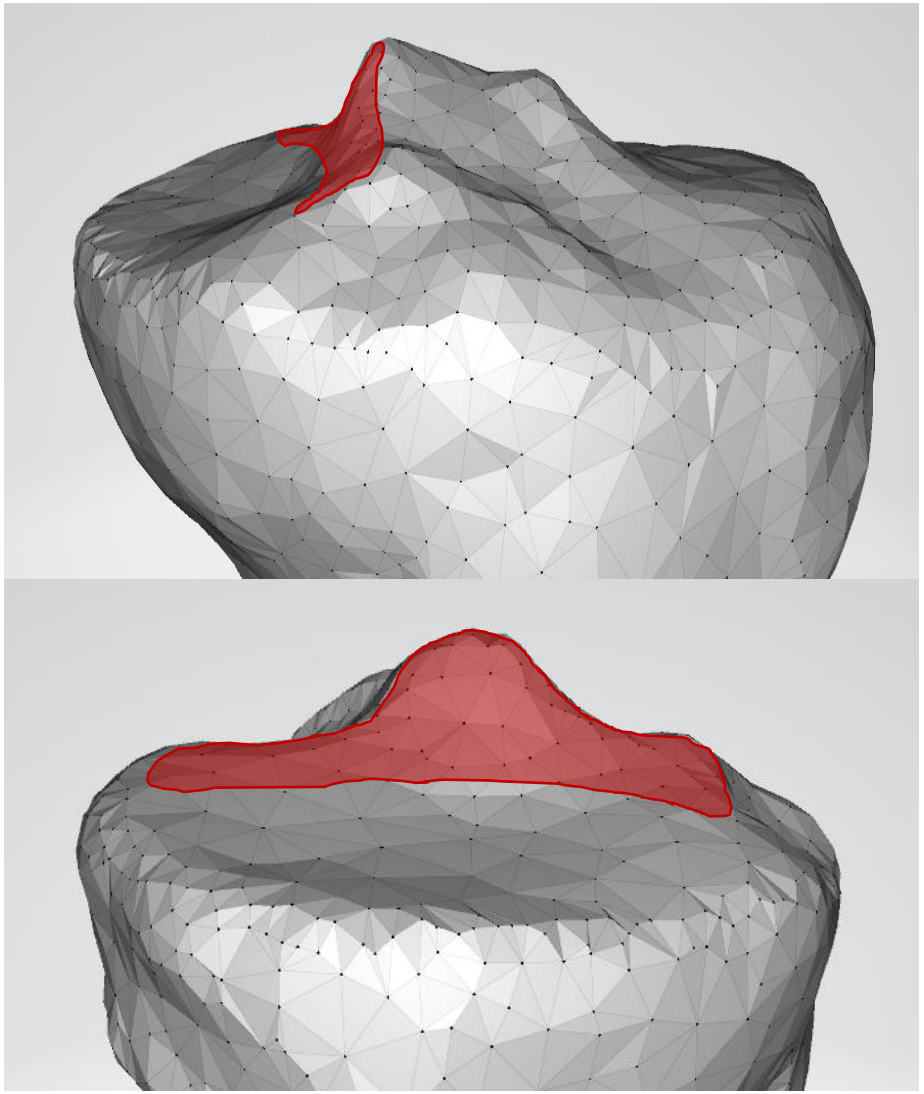
Obviously, other 3D shape features contribute to ACL force variance

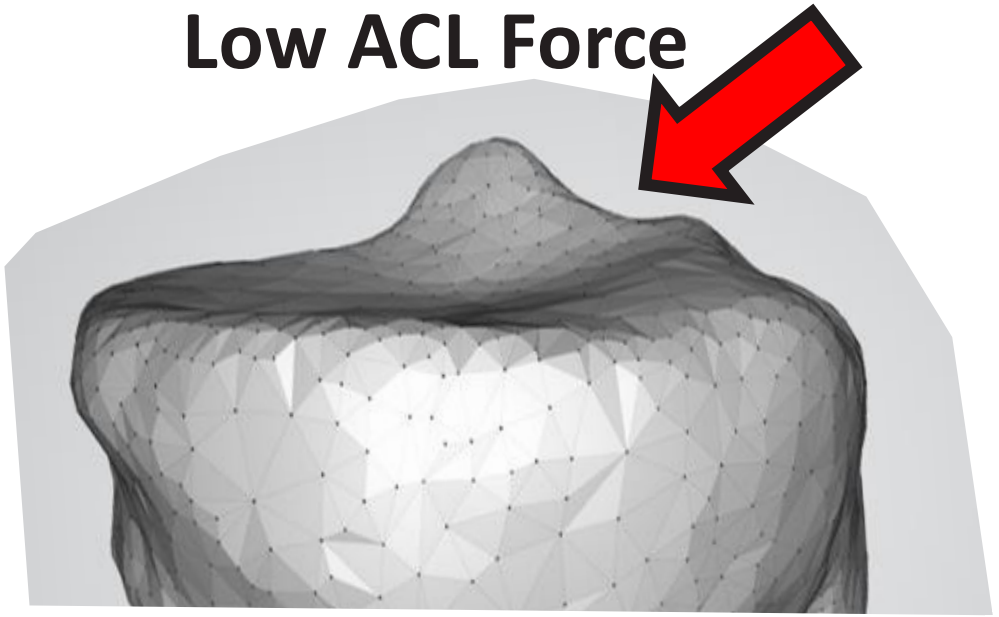


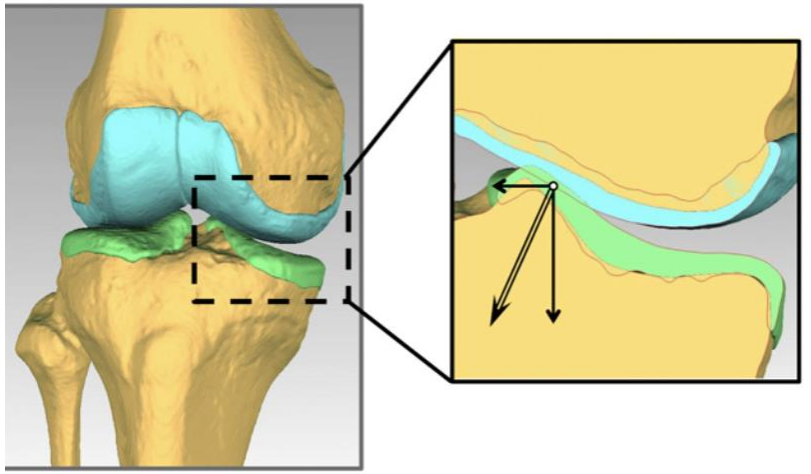


Emerging Theory

Increased Coronal Plane Concavity Created by a Large Medial Tibial Eminence May Act as a Bony Block to Internal Rotation during Pivot







Thank You!!

The HSS Digital Twin Platform

Clinical implementation of digital twin simulations to enable personalized surgical planning and care of orthopedic conditions