



# NHTSA

**NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION**

## Comparison of aPLI and FlexPLI-UBM Advanced Pedestrian Legforms

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*SAE Government/Industry Meeting 2020*

# Motivation

- Upper leg injuries are common for pedestrians in the U.S.<sup>1</sup>
- Questionable validity of FlexPLI femur measurements in vehicle tests
- FlexPLI does not adequately simulate the impact kinematics and bending loads above the knee
  - Lack of upper body mass believed to have an effect on leg kinematics and femur measurements
  - Currently no proposed injury assessment values
- New legforms with upper body mass have been introduced
  - FlexPLI-UBM (SENIORS)
  - aPLI (ISO)
- Potential for single legform test to replace two existing (lower/upper leg) tests

<sup>1</sup>Mallory et al. Relative Frequency of U.S. Pedestrian Injuries Associated With Risk Measured in Component-Level Pedestrian Tests. DOT HS 812 658

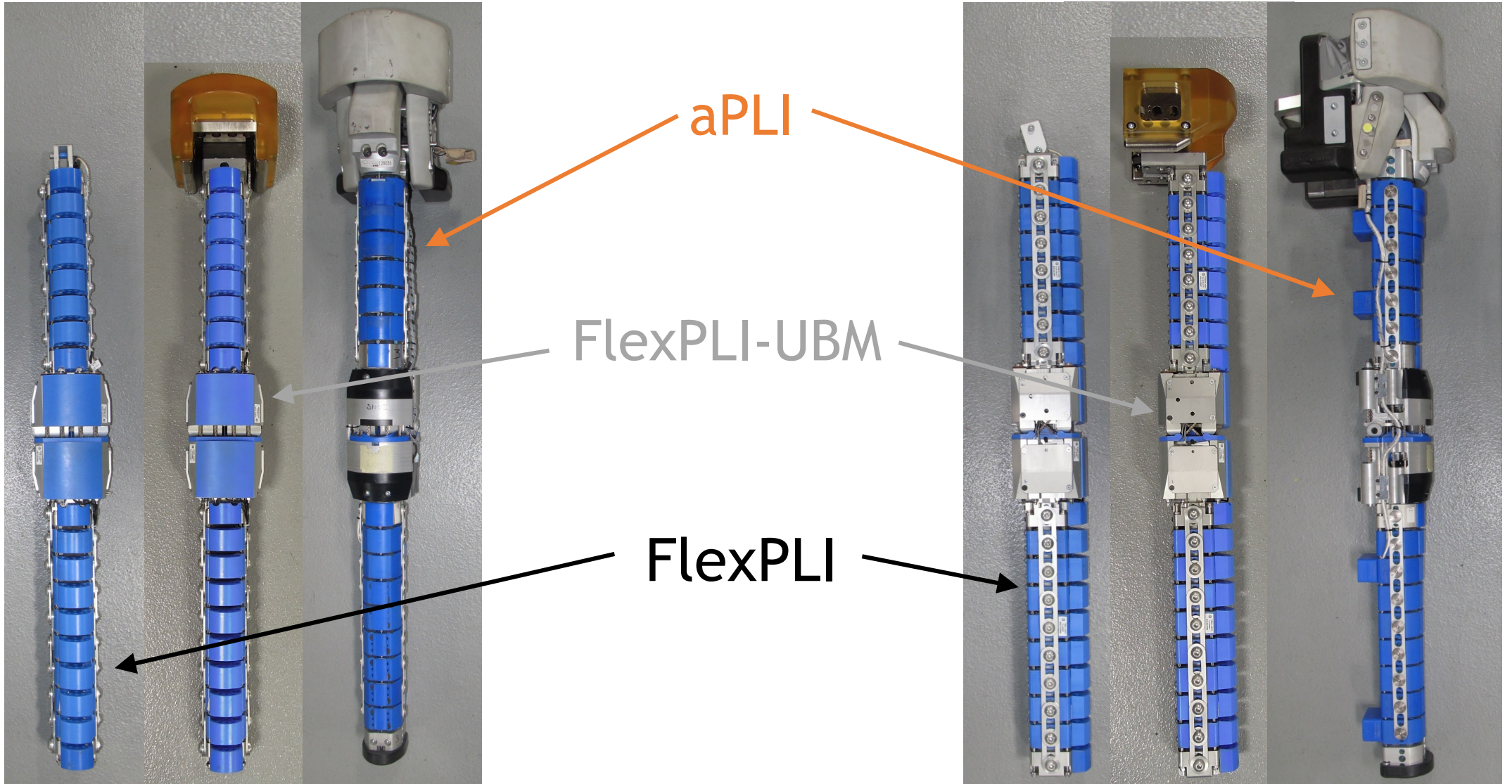
# Objective

- Perform a preliminary evaluation of the FlexPLI-UBM and aPLI and compare vehicle test results with one another and the current FlexPLI in matched impacts



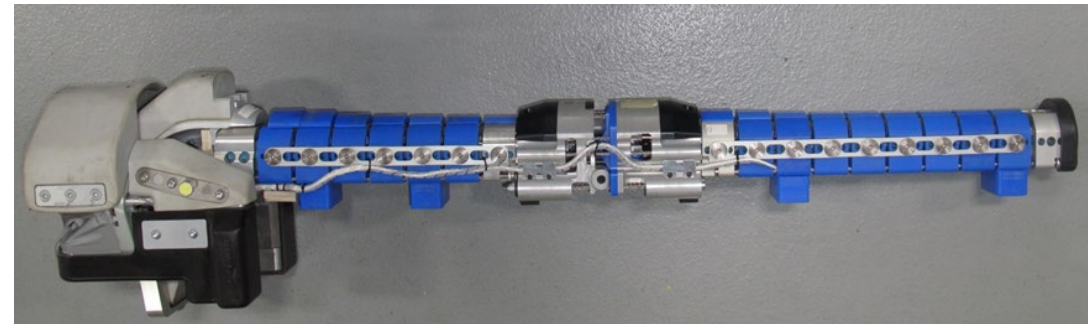
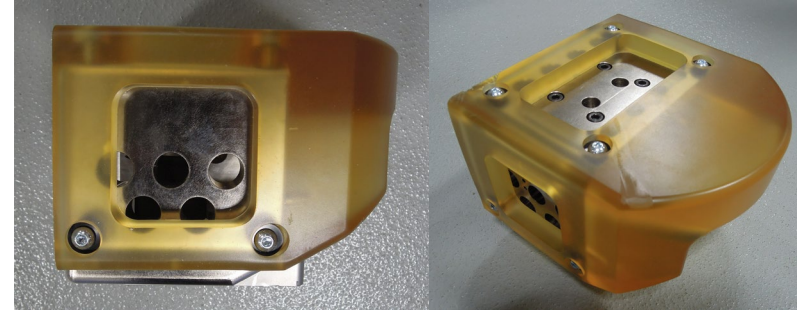


# Pedestrian Legform Impactors



# Pedestrian Legform Impactors

- **FlexPLI (13 kg total mass)**
- **FlexPLI-UBM\* (20 kg total mass)**
  - Bolt-on upper body part (7 kg)
  - Attaches to existing FlexPLI (13 kg)
- **aPLI\*\* (25 kg total mass)**
  - Redesigned legform
    - Mass distribution
    - Contact profile
    - Knee ligament geometry
    - Increased femur bone stiffness
    - Simplified upper body part with onboard DAS and additional instrumentation



\*Zander et al., *Development and Evaluation of an Upper Body Mass (UBM) for the Flexible Pedestrian Legform Impactor (FlexPLI) and for Incorporation within Improved Test and Assessment Procedures – Results from SENIORS, IRCOBI 2019*

\*\*Isshiki et al., *Consolidated Technical Specifications for the Advanced Pedestrian Legform Impactor (aPLI), IRCOBI 2018 (modified)*



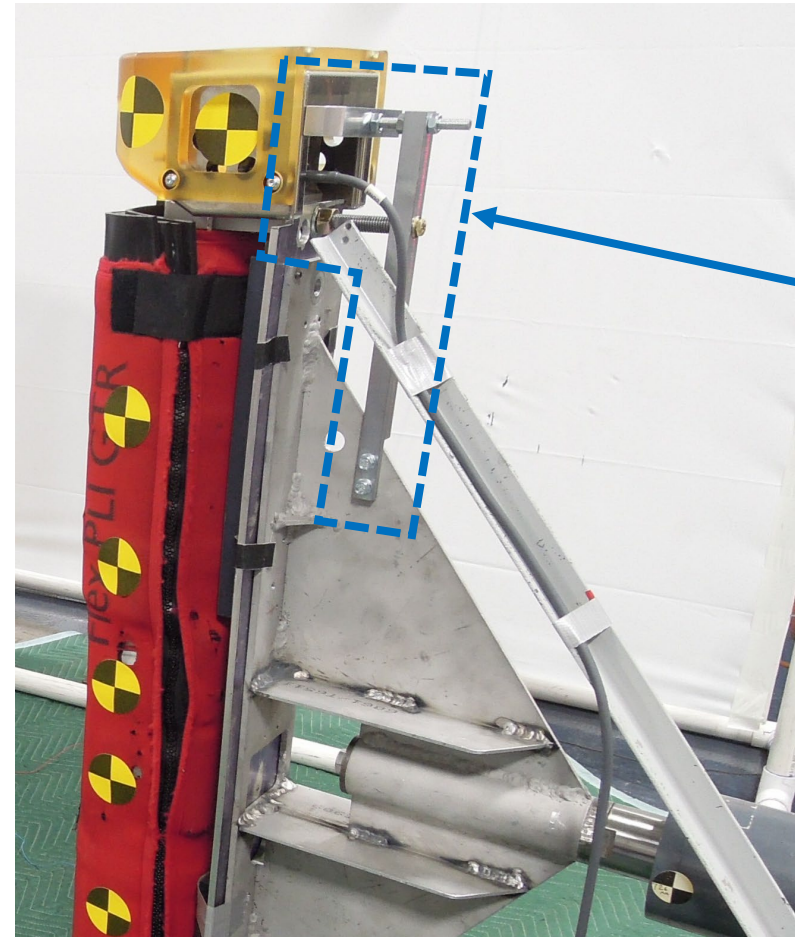
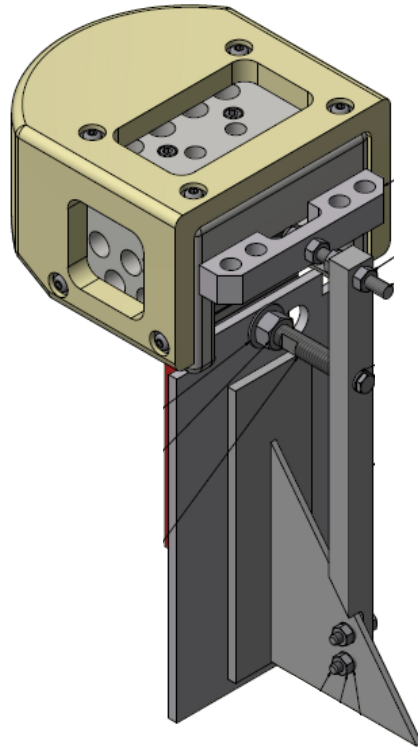
# aPLI Setup

- Launch carriage
  - Designed by Cellbond
- Custom adaptor
  - Attach to our launch system
  - Horizontal flight motion



# FlexPLI-UBM Setup

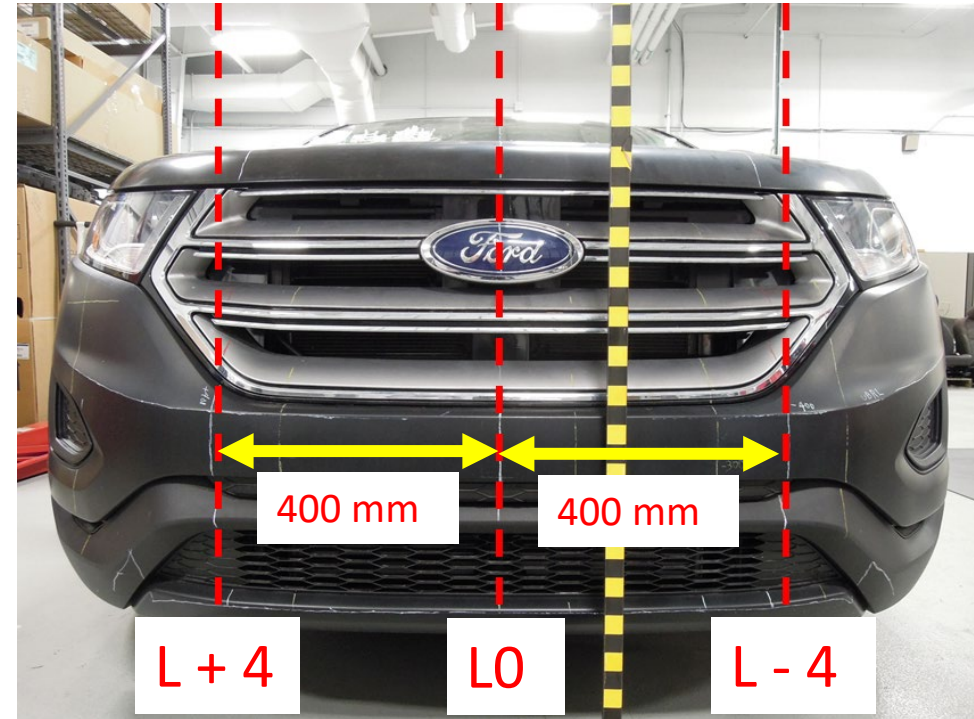
- Modifications to NHTSA launch carriage (coordinated with HIS)
  - Addition of UBM support bar to existing launch carriage
  - Bolt-on attachments



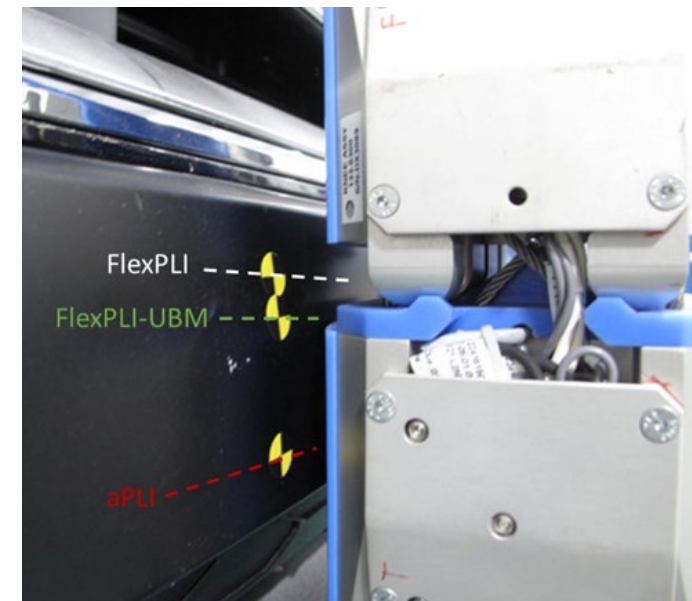
Additional  
support pieces

# Vehicle Test Setup

- **2016 Ford Edge**
  - Vehicle available
  - Previous FlexPLI testing
  - Global platform, higher bumper vehicle
- **VRTC launch system unable to reach 11.1 m/s due to increased total mass**
  - Target velocity 9 m/s



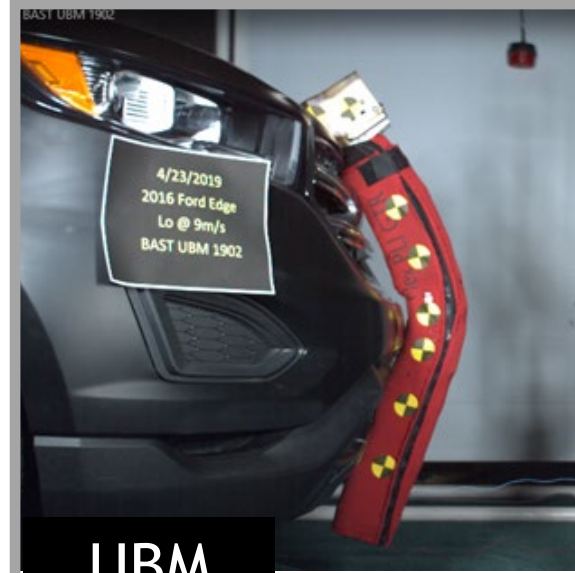
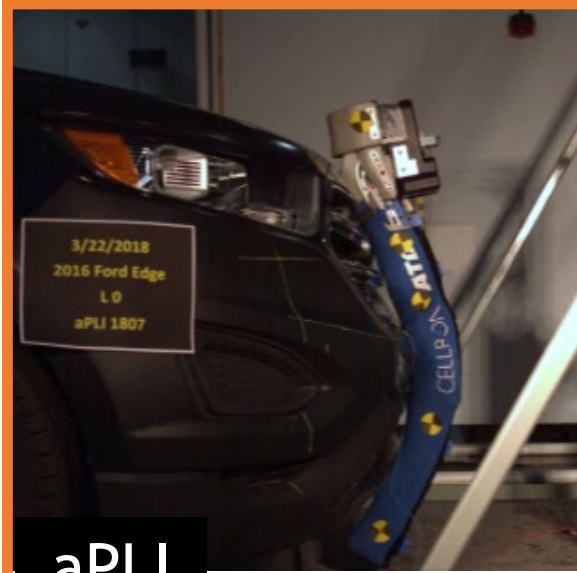
Test Matrix (n=1 in each condition)			
Legform	Target Velocity	Impact Location	Bottom of Legform Height from Ground
aPLI	9 m/s	L+4, Passenger	25 mm
		L0, Center	
FlexPLI-UBM		L+4, Passenger	63 mm
		L0, Center	
FlexPLI		L-4, Driver	75 mm
		L0, Center	



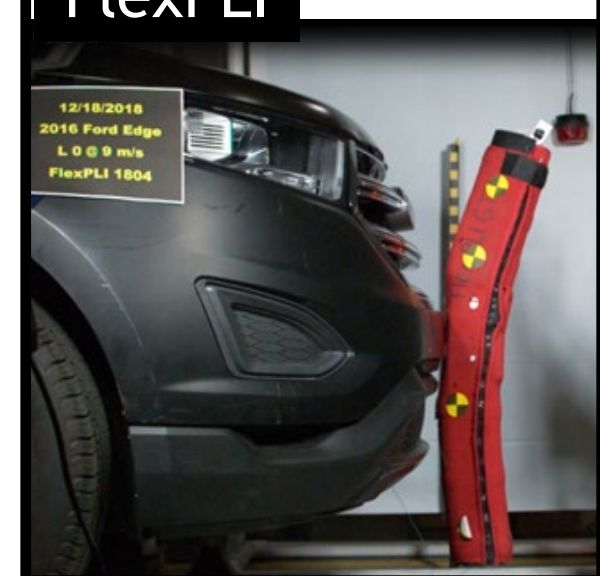
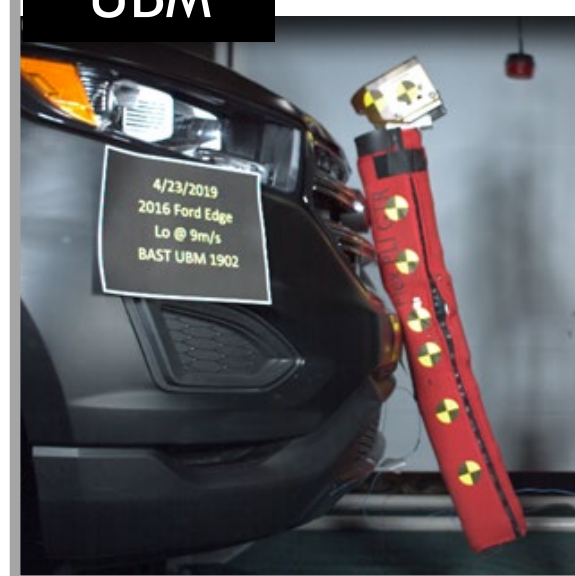
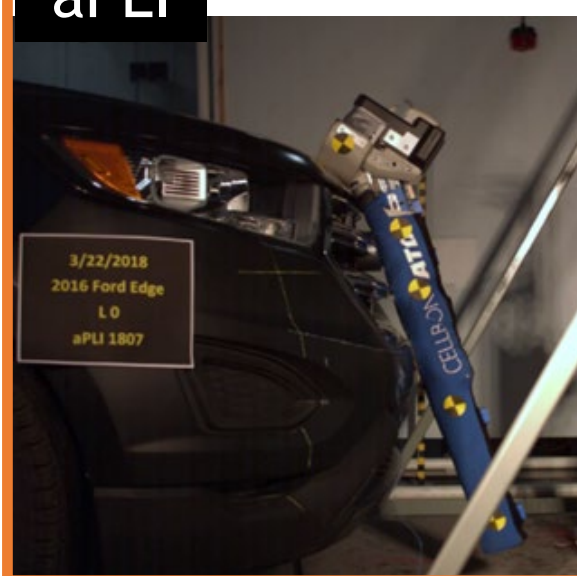


# Test Results: Center (L0), 9 m/s

T\_max

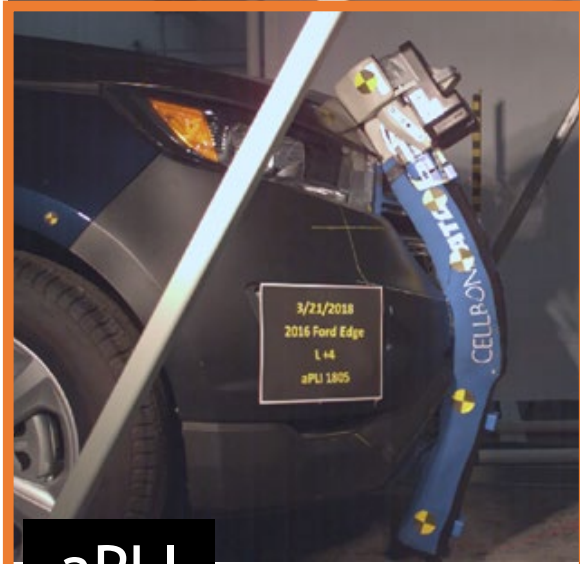


T\_reb

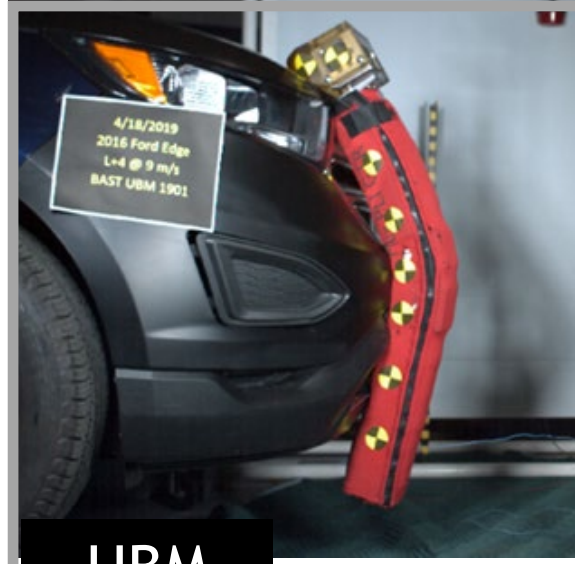


# Test Results: Outboard (L ± 4), 9 m/s

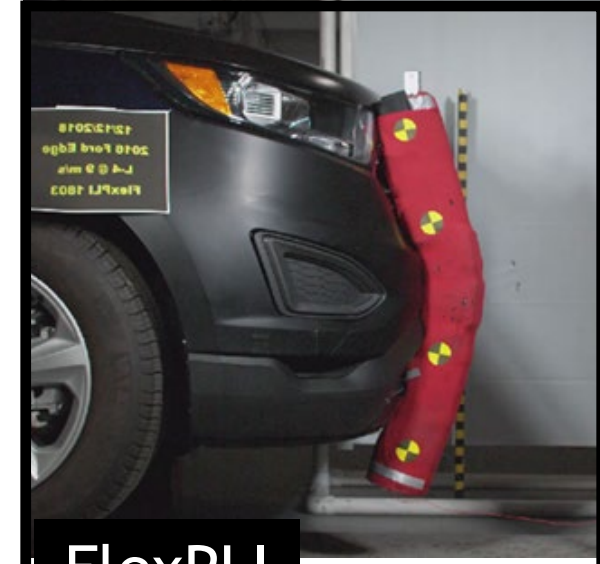
T\_max



aPLI

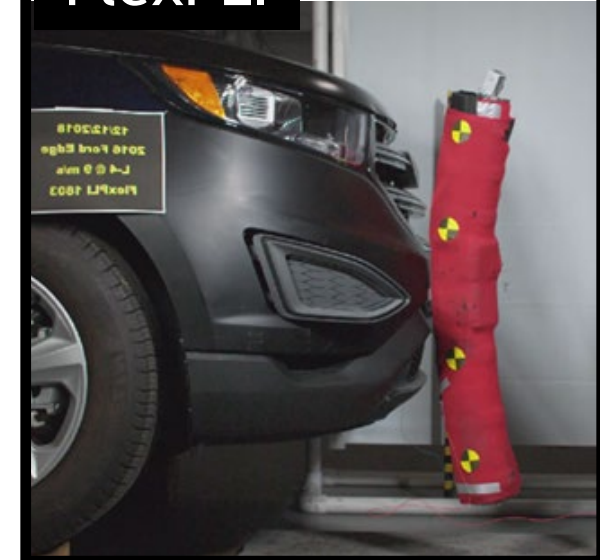
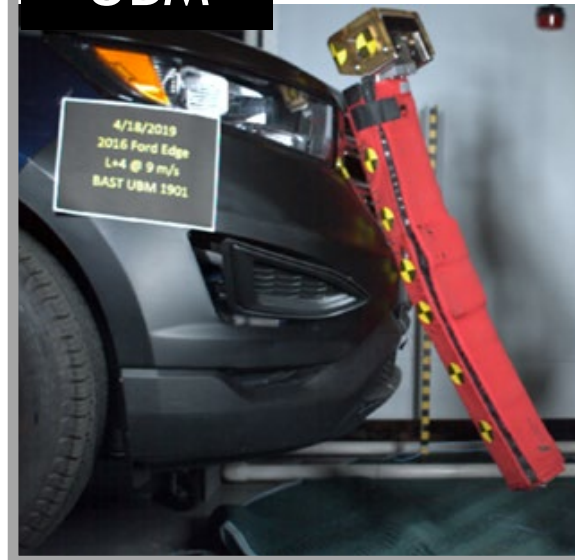
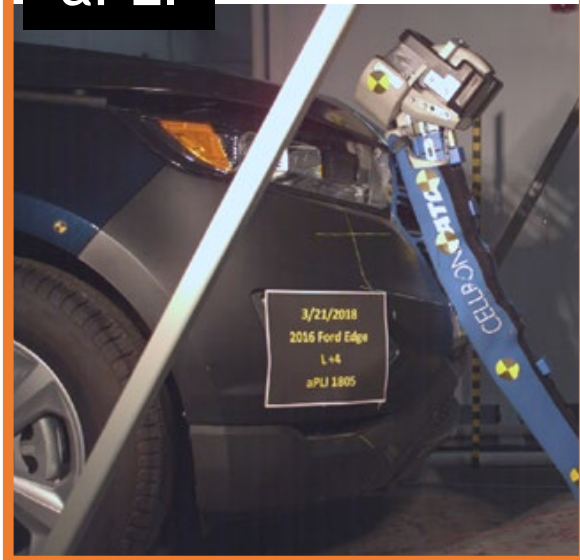


UBM

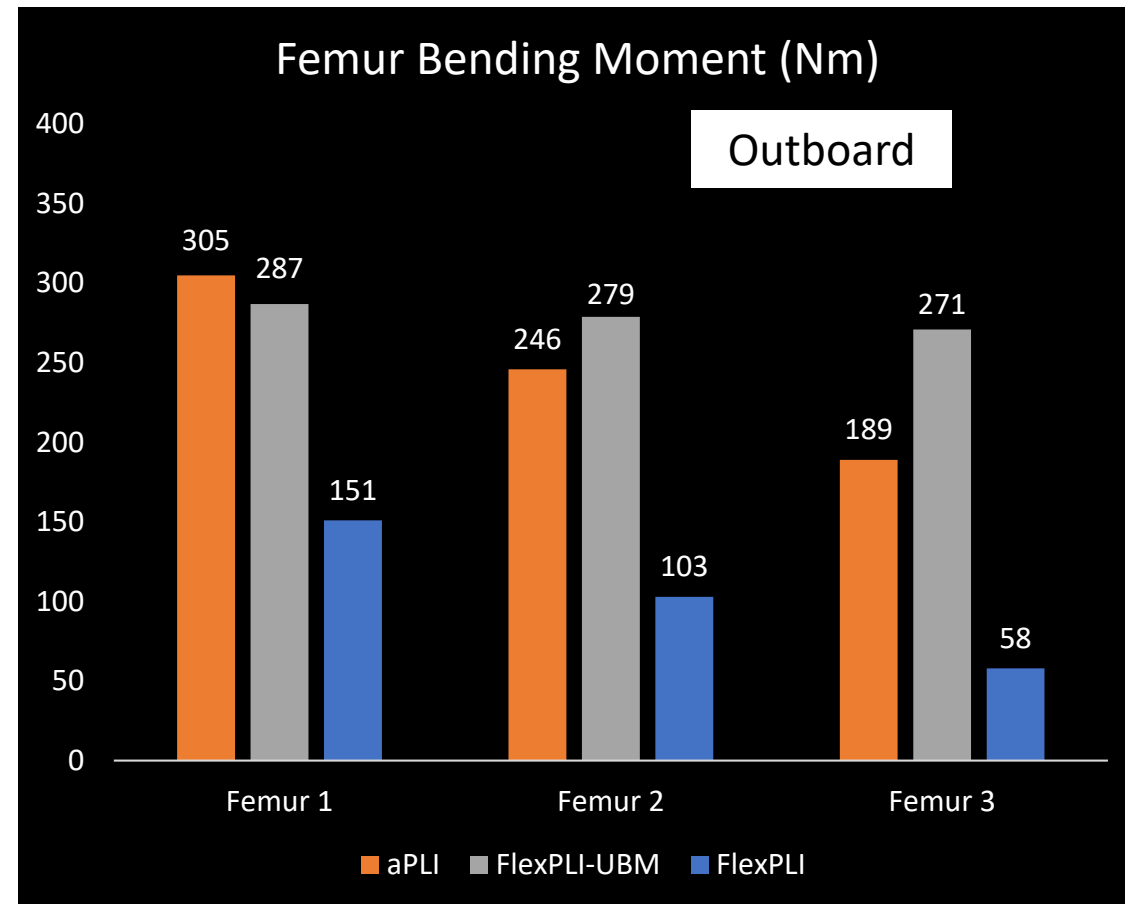
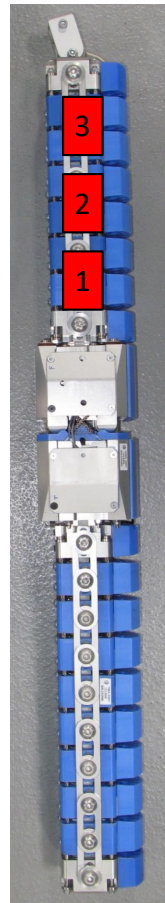
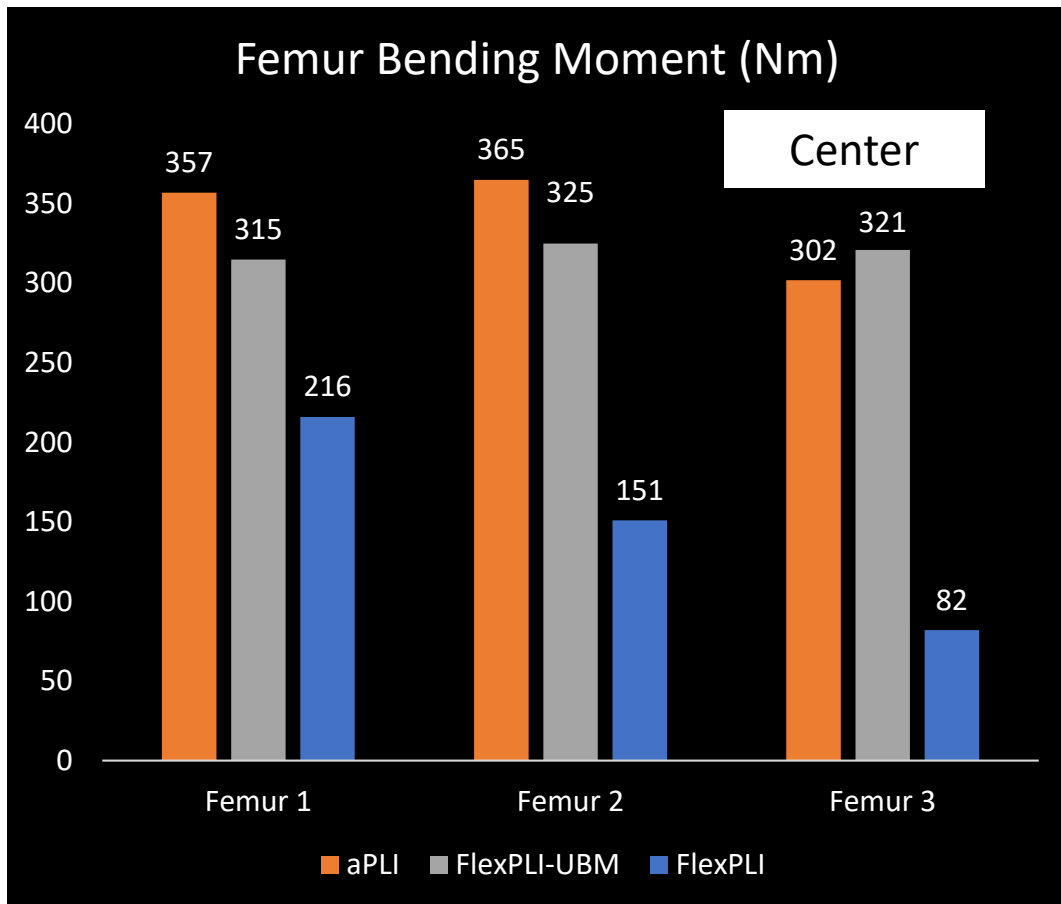


FlexPLI

T\_reb



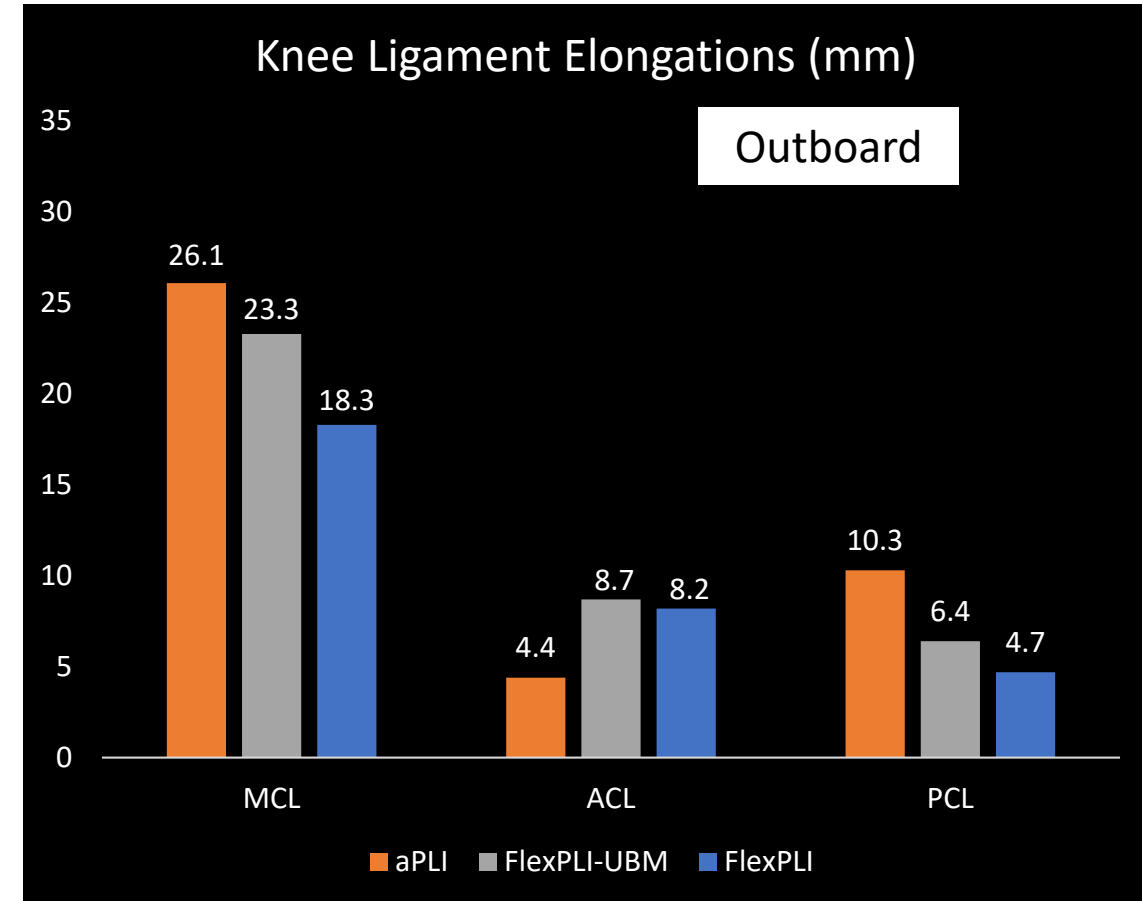
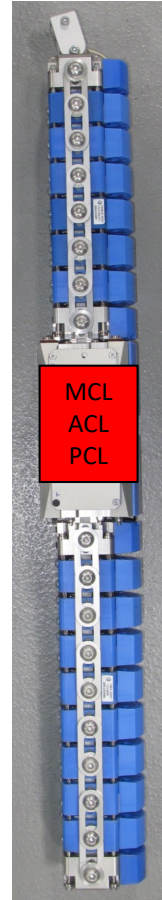
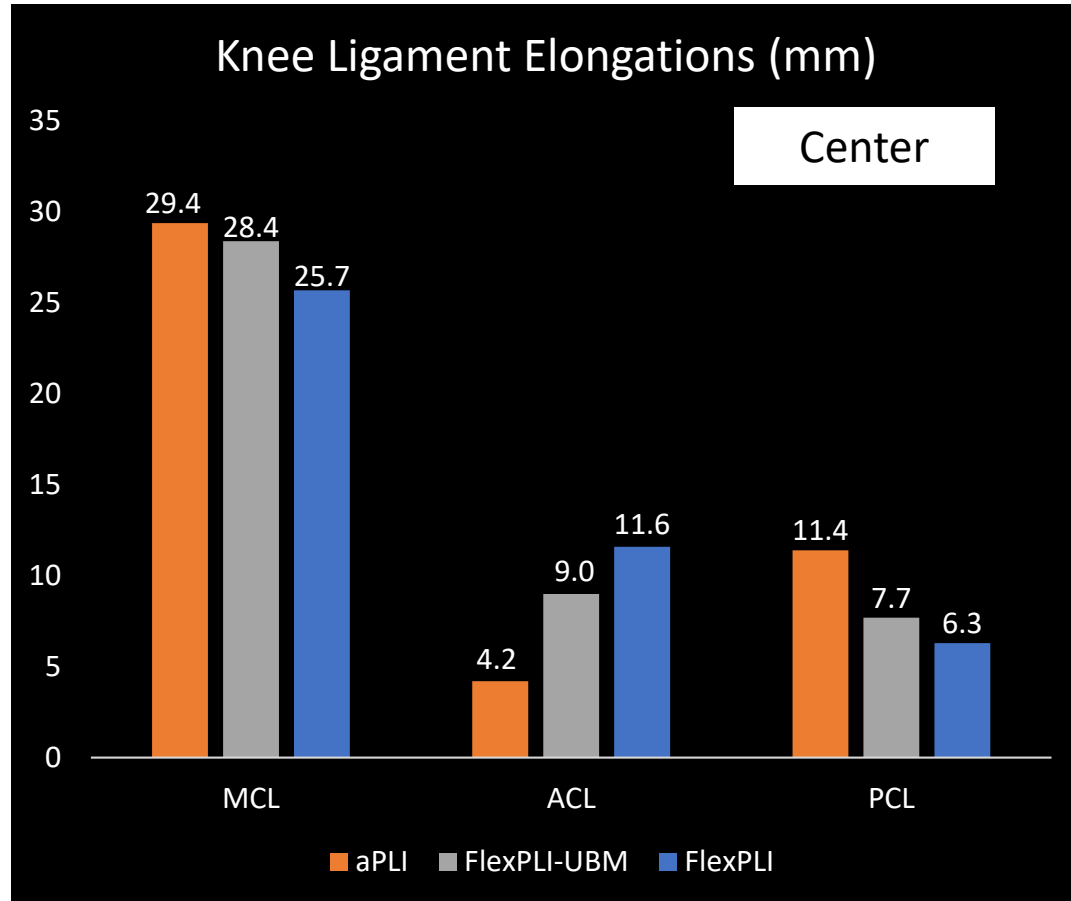
# Test Results: Femur Bending Moment



- Legforms with upper body mass had higher femur moments
- Further from knee: FlexPLI and aPLI decreased, Flex-UBM more consistent along length

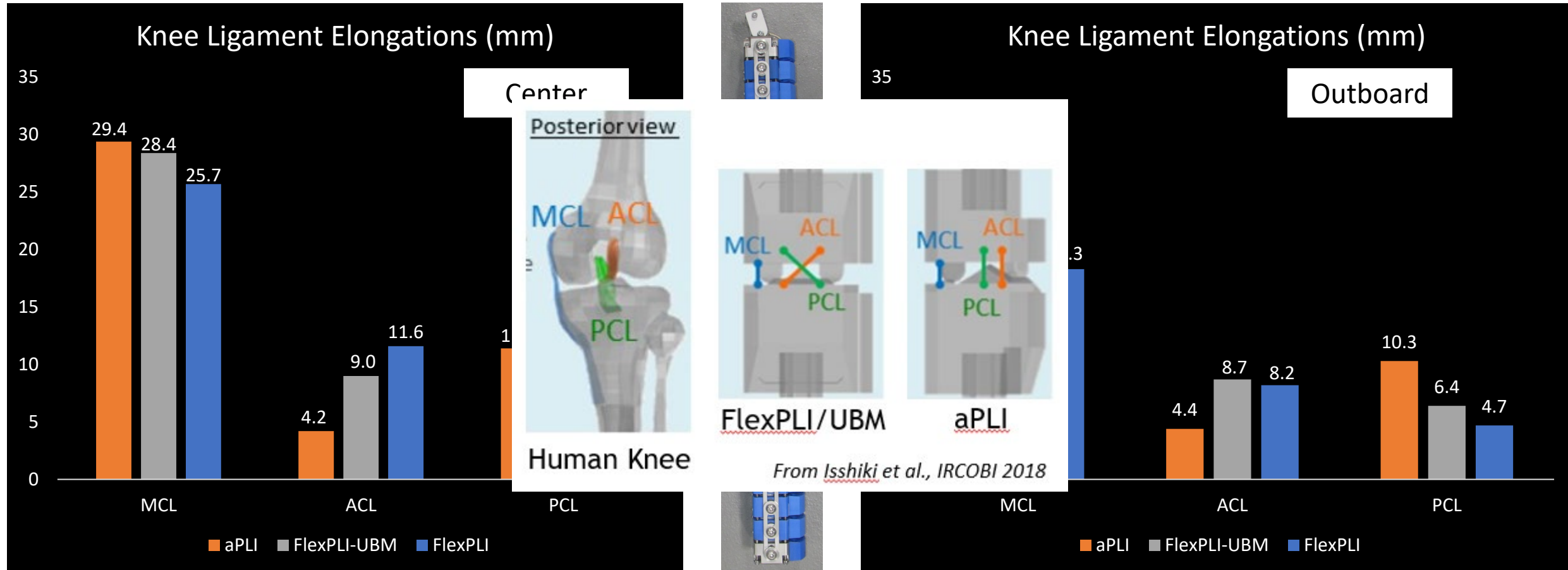


# Test Results: Knee Ligament Elongations



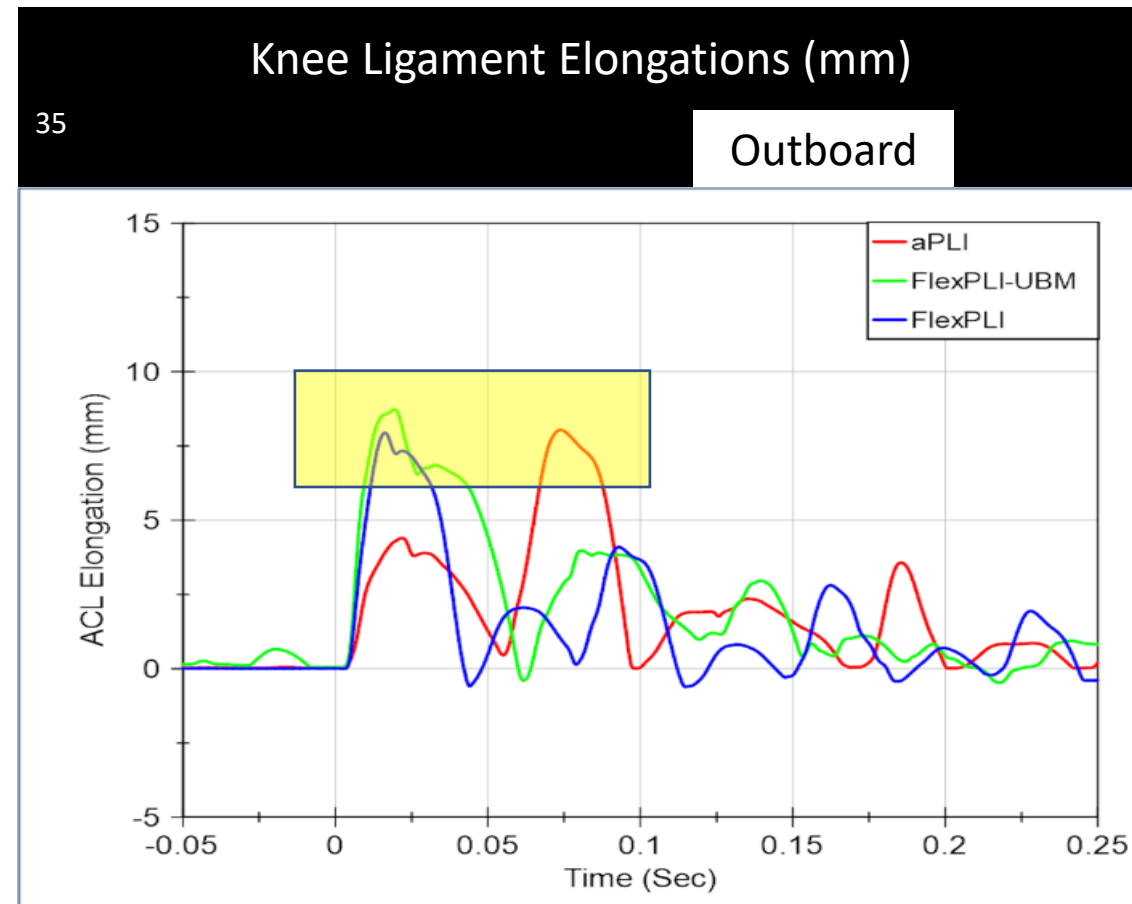
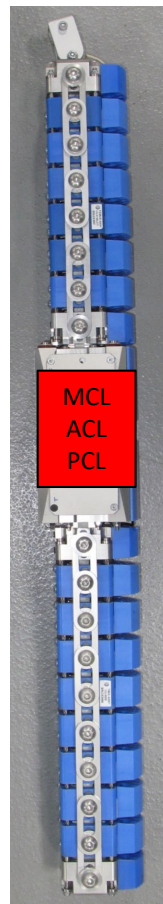
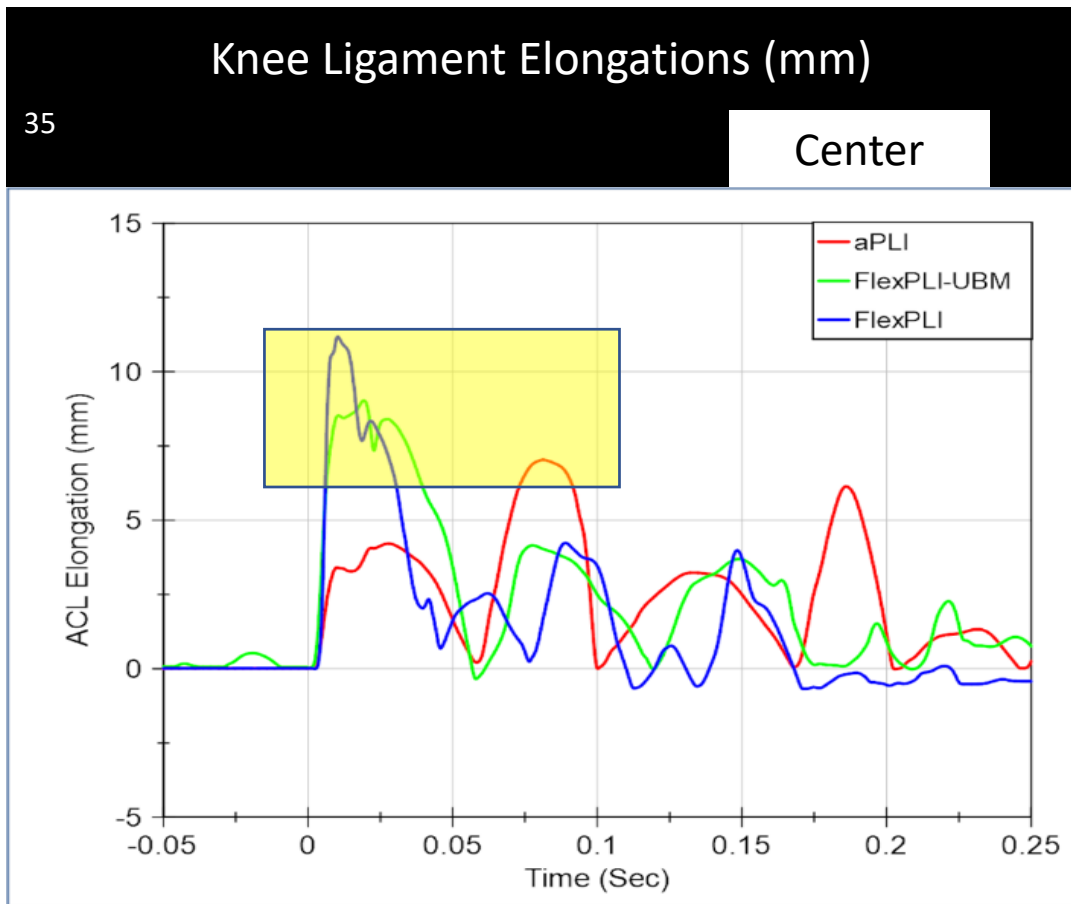
- Legforms with upper body mass had higher MCL and PCL

# Test Results: Knee Ligament Elongations



- Legforms with upper body mass had higher MCL and PCL
- ACL different in aPLI: ligament orientation

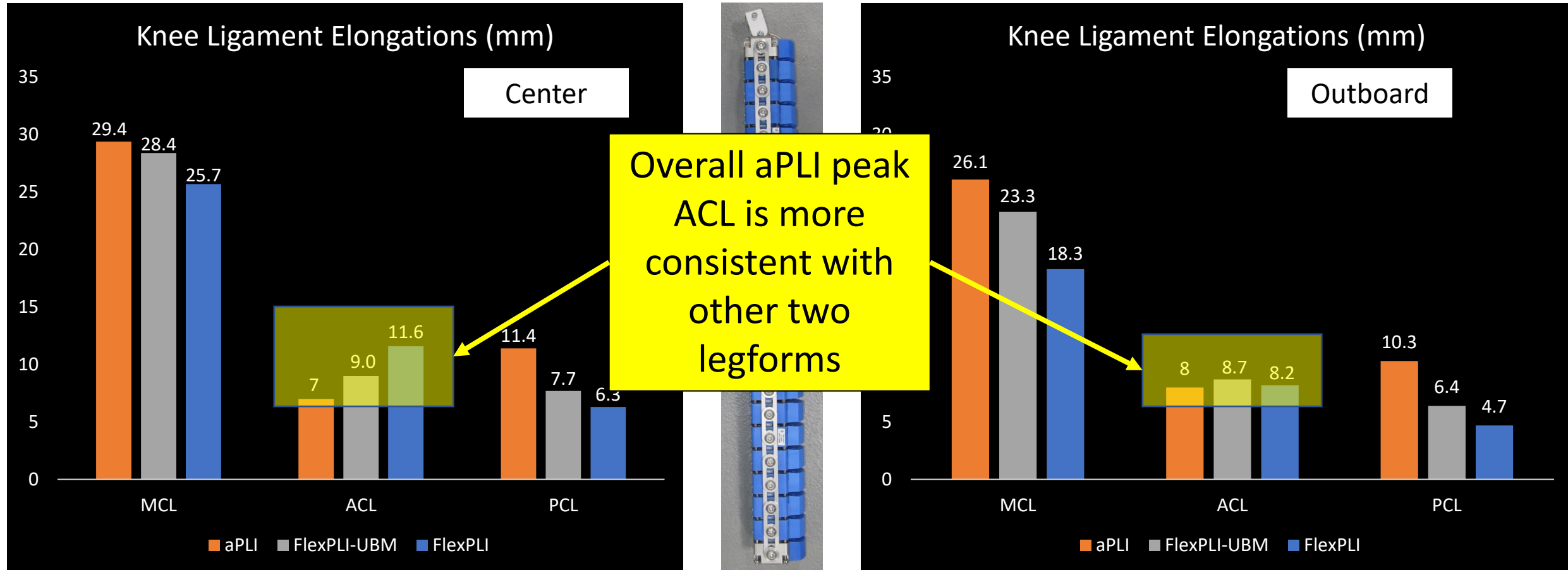
# Test Results: Knee Ligament Elongations



- Legforms with upper body mass had higher MCL and PCL
- ACL different in aPLI: ligament orientation, **secondary peak higher**

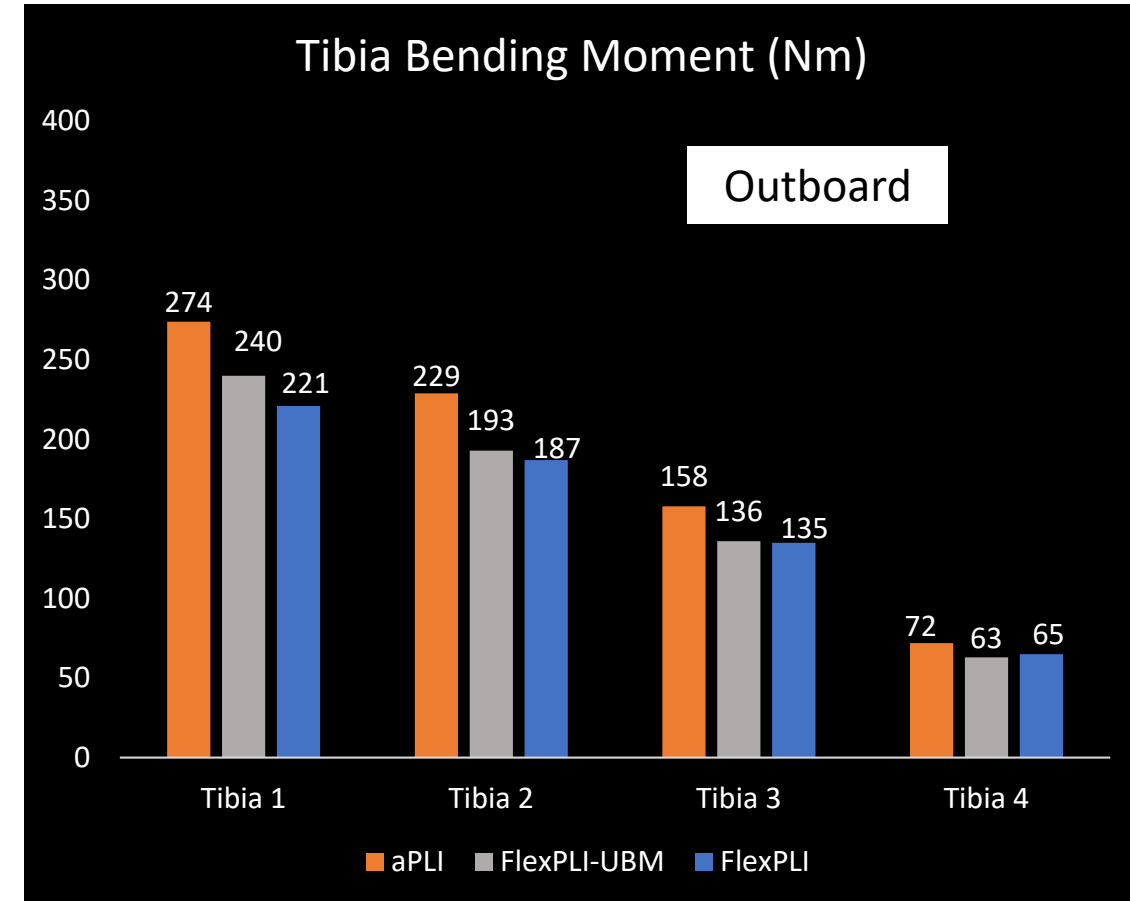
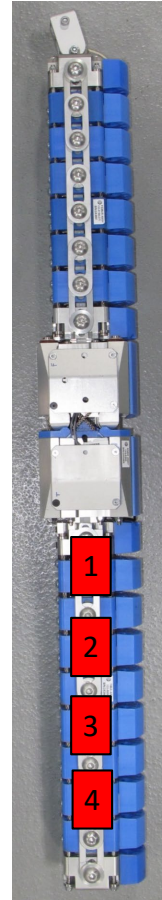
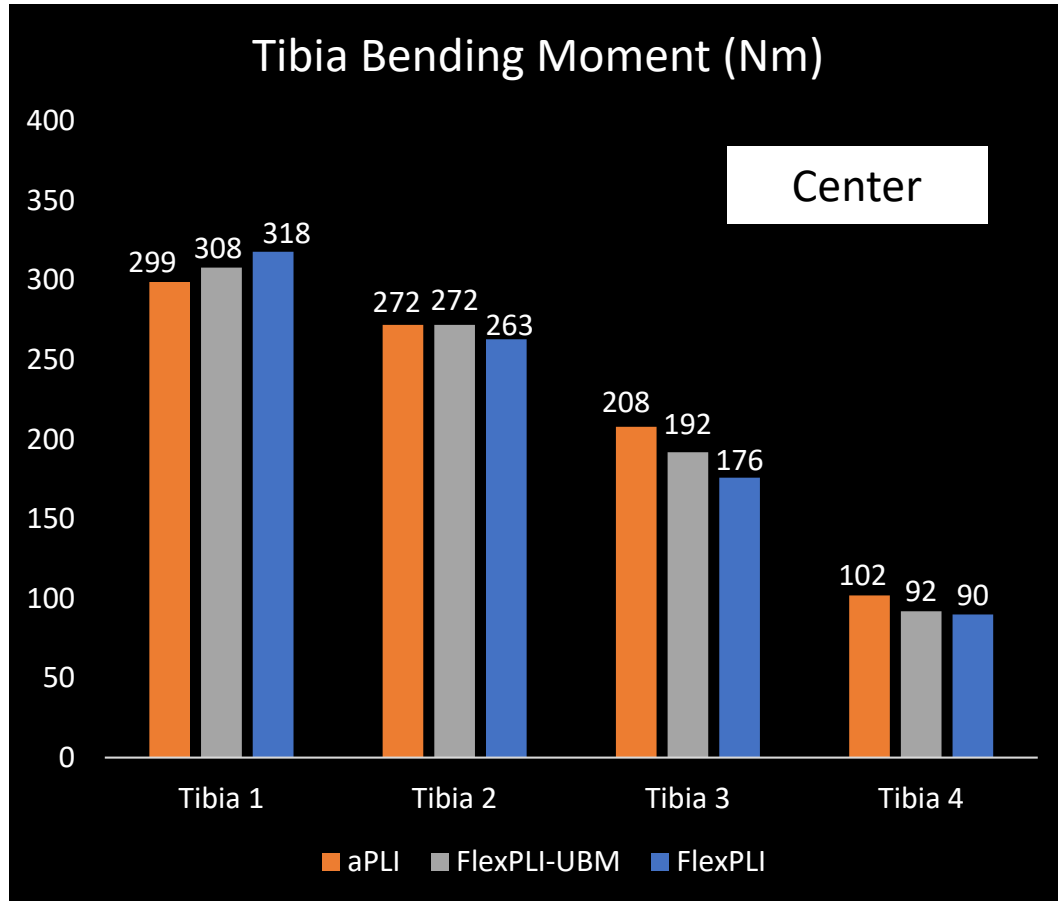


# Test Results: Knee Ligament Elongations



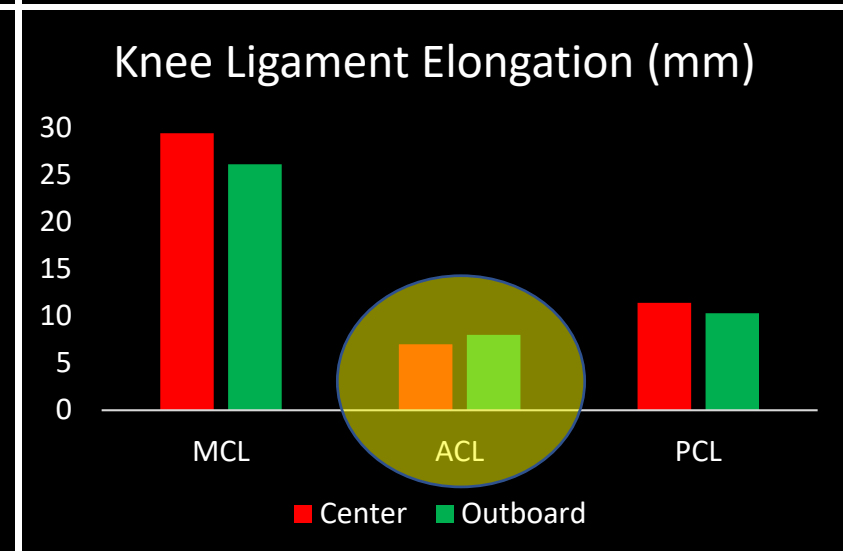
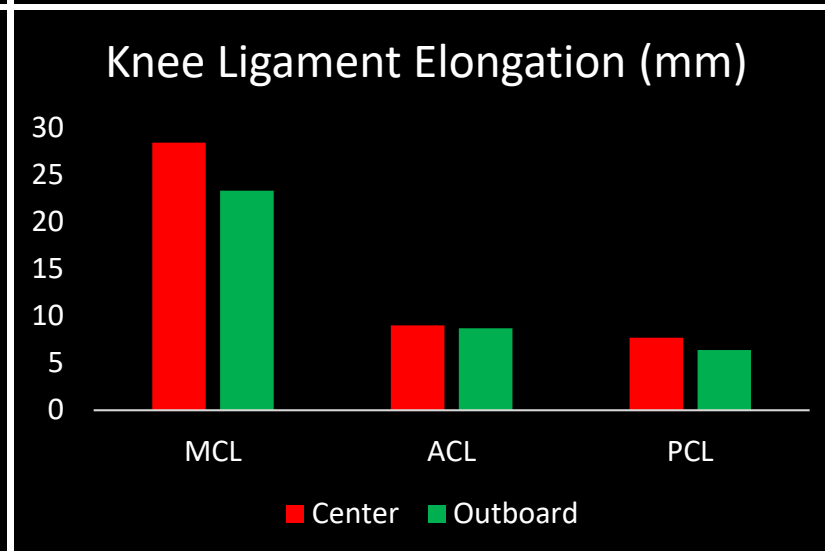
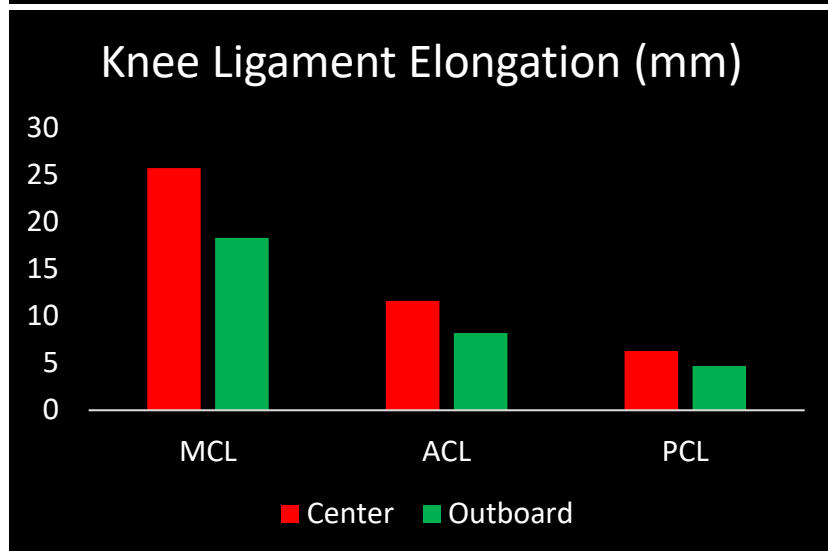
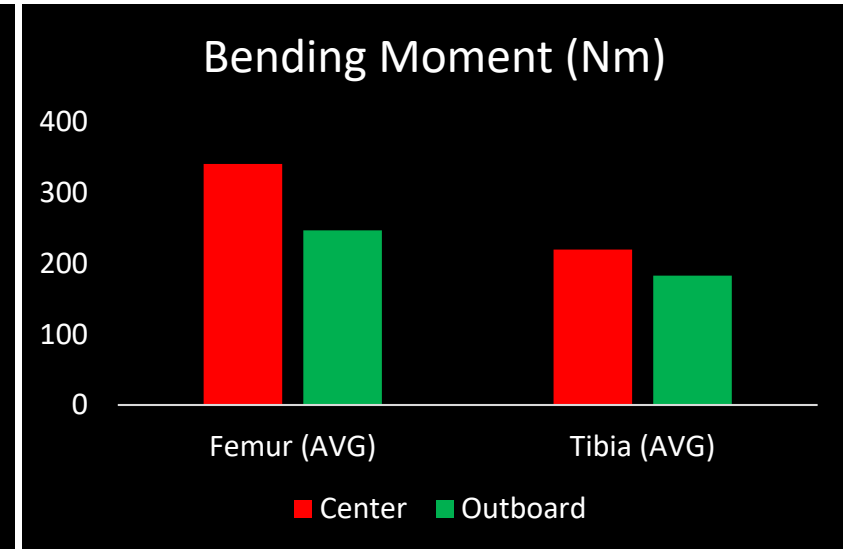
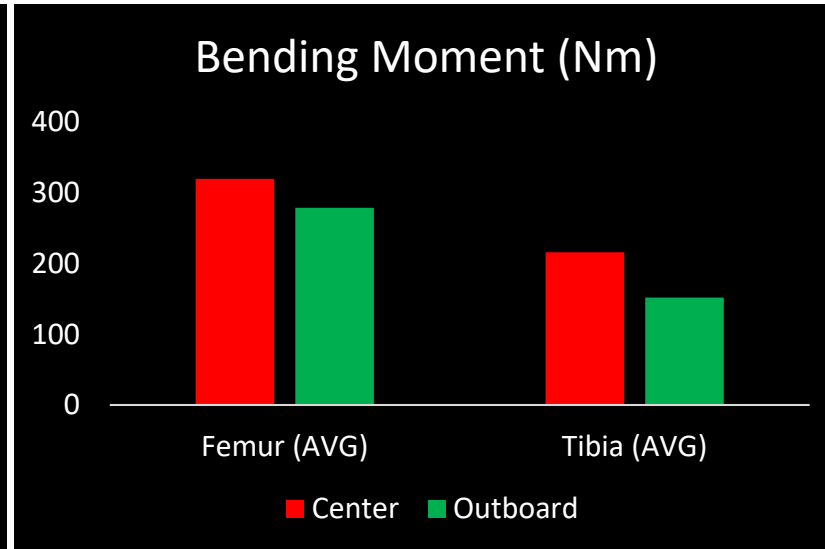
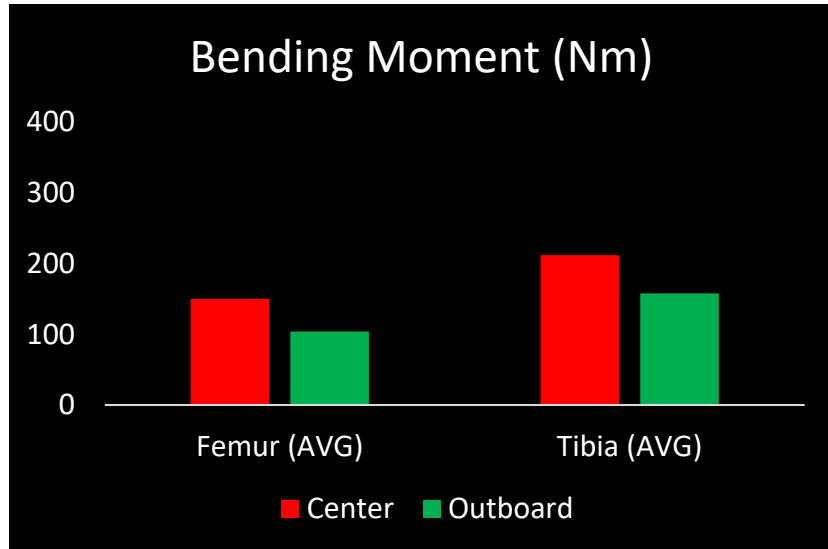
- Legforms with upper body mass had higher MCL and PCL
- ACL different in aPLI: ligament orientation, **secondary peak higher**

# Test Results: Tibia Bending Moment



- Center: legforms similar at all locations
- Outboard: Flex-UBM & FlexPLI similar, aPLI higher

# Test Results: Center > Outboard (All Legforms)



FlexPLI

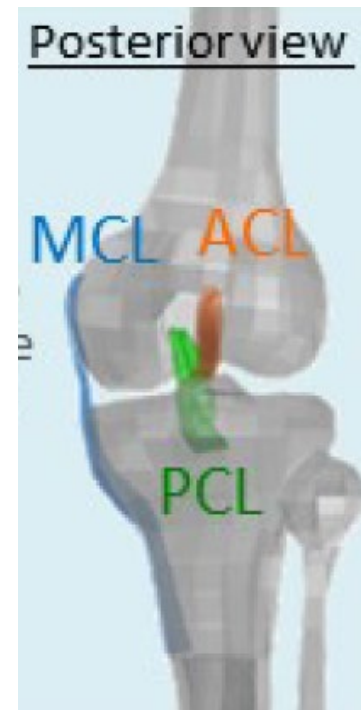
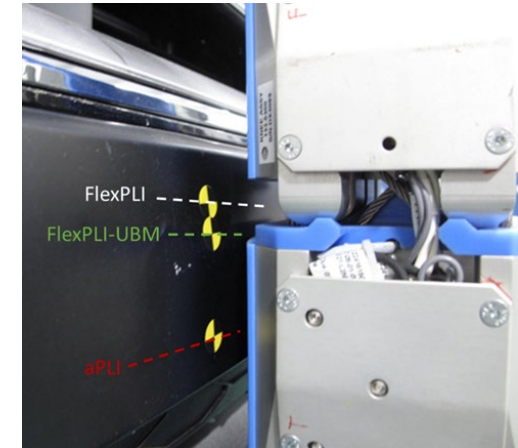
Flex-UBM

aPLI



# Discussion

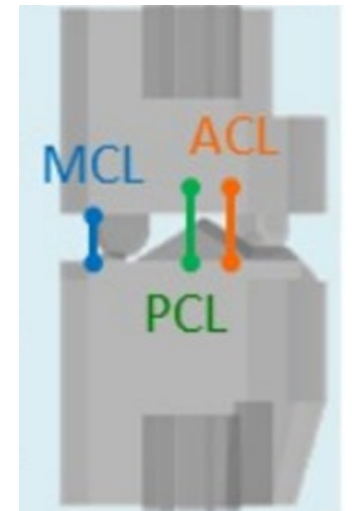
- Increased femur bending moments in FlexPLI-UBM & aPLI
  - Upper body mass & higher CG location
  - Lower impact height
- Increased MCL/PCL elongations
  - Lower impact height
- Varying ACL elongations
  - Ligament orientation in aPLI
- Relative measurements for 3 legforms
  - Maybe vehicle shape specific



Human Knee



FlexPLI/UBM



aPLI

# Discussion

- FlexPLI-UBM and aPLI exhibited more realistic kinematics with respect to human body model simulations
- FlexPLI and FlexPLI-UBM exhibited greater yaw rotation than aPLI at the outboard impact location
  - Possibly due to different knee shape



VS



# Conclusions

- Both FlexPLI-UBM and aPLI easy to use and adapt to VRTC system
  - At 9 m/s (we are now upgrading our system to achieve 11.1 m/s)
- Preliminary FlexPLI-UBM and aPLI results show:
  - Increased femur bending moments & MCL/PCL elongations
  - Varying ACL elongations
  - Similar tibia bending moments
  - More realistic kinematics

# Future Work

- Need to better understand how design updates affect legform response by performing tests that isolate influences of:
  - Upper body mass
  - Legform impact height
  - Knee-bumper interaction
  - Cruciate ligament orientation
- Testing at 11.1 m/s on the Ford Edge and additional vehicles
- Need to investigate upper leg part of the equation
  - Upper leg/UBM measurements vs. upper legform in matched pair tests





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