NHTSA Pedestrian Testing with TRL and Flex-GTR Legforms and the Status of the GTR

Ann Mallory

Transportation Research Center Inc.

Jason Stammen & Susan Meyerson

NHTSA

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Background – Pedestrian GTR

- **GTR 9 was adopted November 2008**

  -NHTSA has initiated Rulemaking efforts and plans to publish an NPRM by late 2010

- **Amendment 1 to GTR 9**

  -Incorporates the FlexGTR into the GTR

  -NHTSA is participating in evaluation efforts of the pedestrian legform

Background – Previous Tests

- Previous VRTC testing of prototype FlexPLI
  - FlexPLI (Mallory, Stammen and Legault, ESV 2005)
    - Durability → Unable to test at GTR speed on US vehicles
  - FlexGT (Mallory and Stammen, SAE Gov't Ind 2008)
    - Durability improved → Tested 2 US vehicles at GTR speed
    - Compared to TRL for same vehicles
      - → Injury risk ranked similarly (fracture, knee ligaments bend/shear)
      - → FlexGT more likely to exceed injury limits than TRL
- Current tests
  - FlexGTR SN/01
    - Prototype provided by Flex Technical Evaluation Group (TEG)

Objectives

- Test 5 US vehicles using newest Flex (FlexGTR)
- Include vehicles where
  - –Previous performance with TRL legform was not overly aggressive
  - – A reasonable range of performance was expected
- Compare the FlexGTR injury results with TRL results from the same vehicles
- Evaluate FlexGTR: durability, usability, repeatability

Vehicles Tested

FlexGTR tests performed on 5 vehicles[1]

- 2006 VW Passat
- 2005 Honda CR-V
- 2002 Mazda Miata
- 2001 Honda Civic
- 2006 Nissan Fuga bumper
  (on 2006 Infiniti M-35)

Compared to TRL tests performed previously

- Passat, CR-V, and Miata[2]
- Civic, Fuga

Relatively good performance with TRL legform

[1] NHTSA,10th Flex-PLI Technical Evaluation Group (Flex-TEG) Meeting, December 2009.

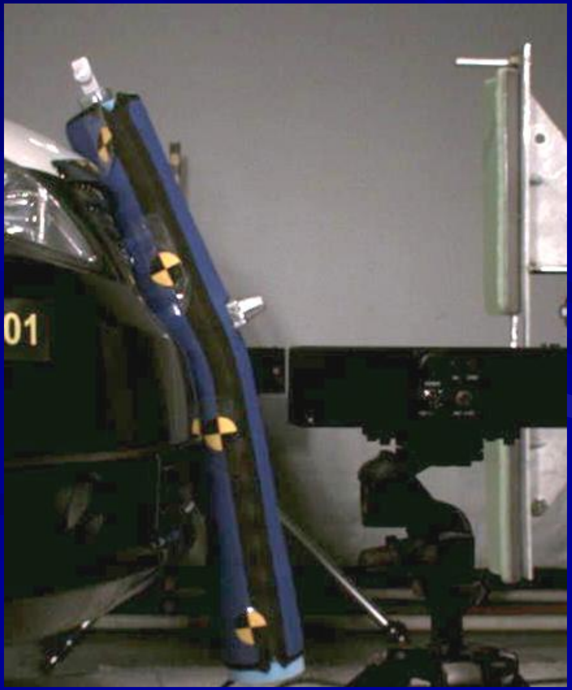
[2] Mallory and Stammen, ESV, June 2009

Instrumentation and Injury Measures

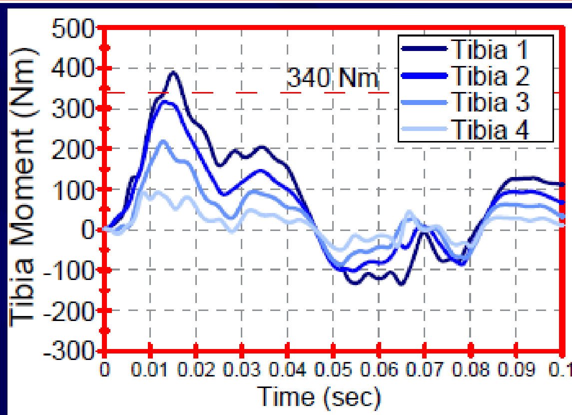
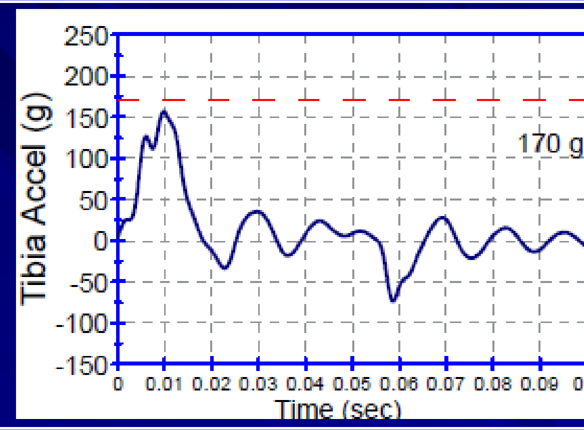
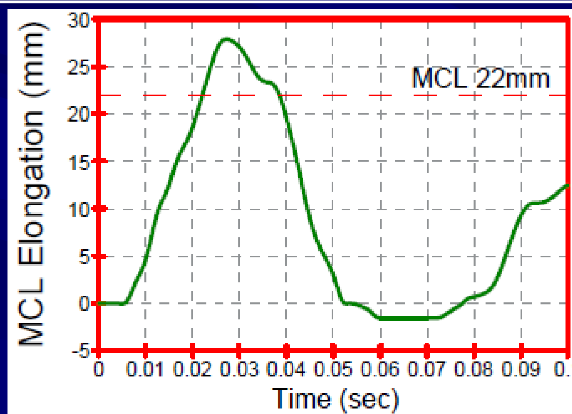
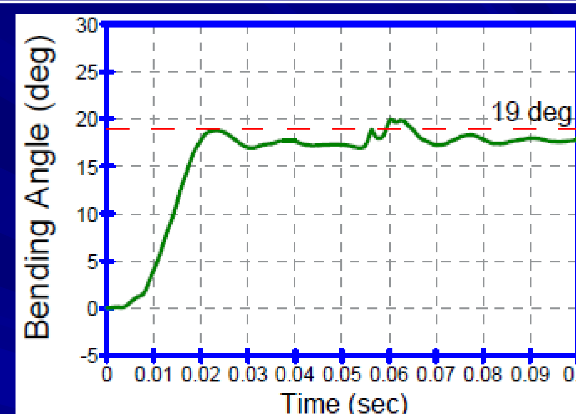
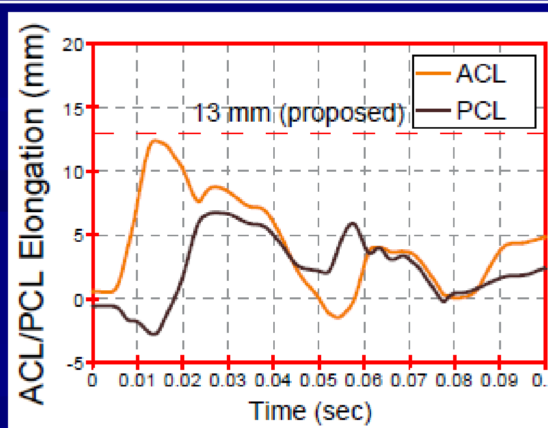
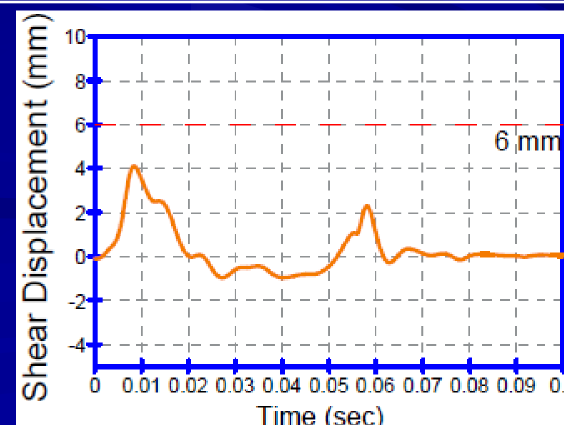
	FlexGTR *Onboard DTS Slice*	TRL
Fracture Risk	Tibia bending moment	Upper tibia acceleration
Ligament Injury Risk (Bending)	MCL elongation	Knee bending angle
Ligament Injury Risk (Shear)	PCL/ACL elongation	Knee shear displacement
Additional measures	Femur bending moment Tibia acceleration LCL elongation	

Test Setup - Method

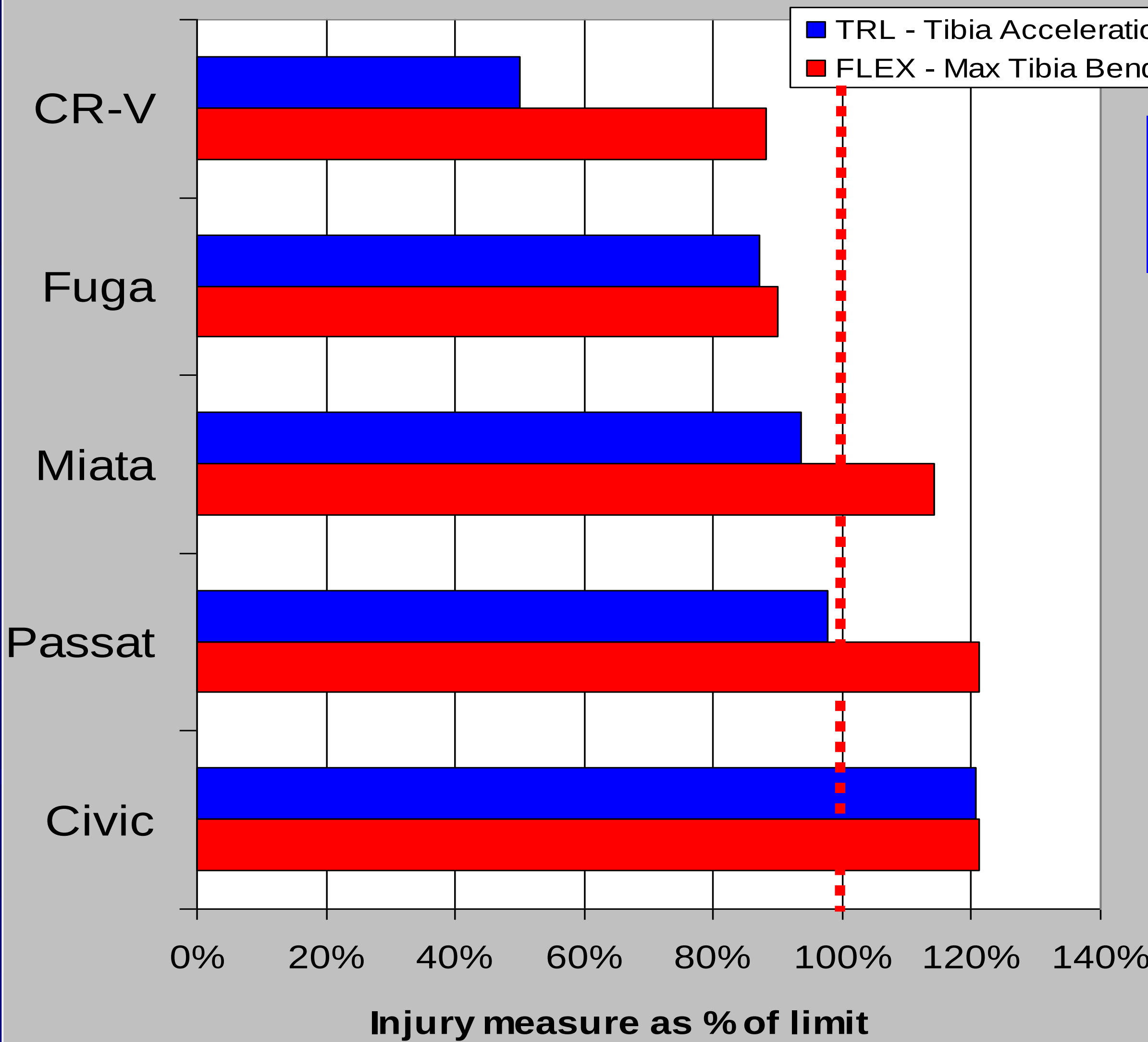
- GTR conditions (40 km/h)
  - Ground reference level: EEVC/TRL=25 mm, Flex-GTR=75 mm
- Center impacts
- Speed and alignment
  - Video analysis to monitor alignment during flight
  - Laser speed-traps to measure impact velocity



Results

MIATA	FlexGTR	TRL
Fracture Risk		
Ligament Injury Risk (Bending)		
Ligament Injury Risk (Shear)		

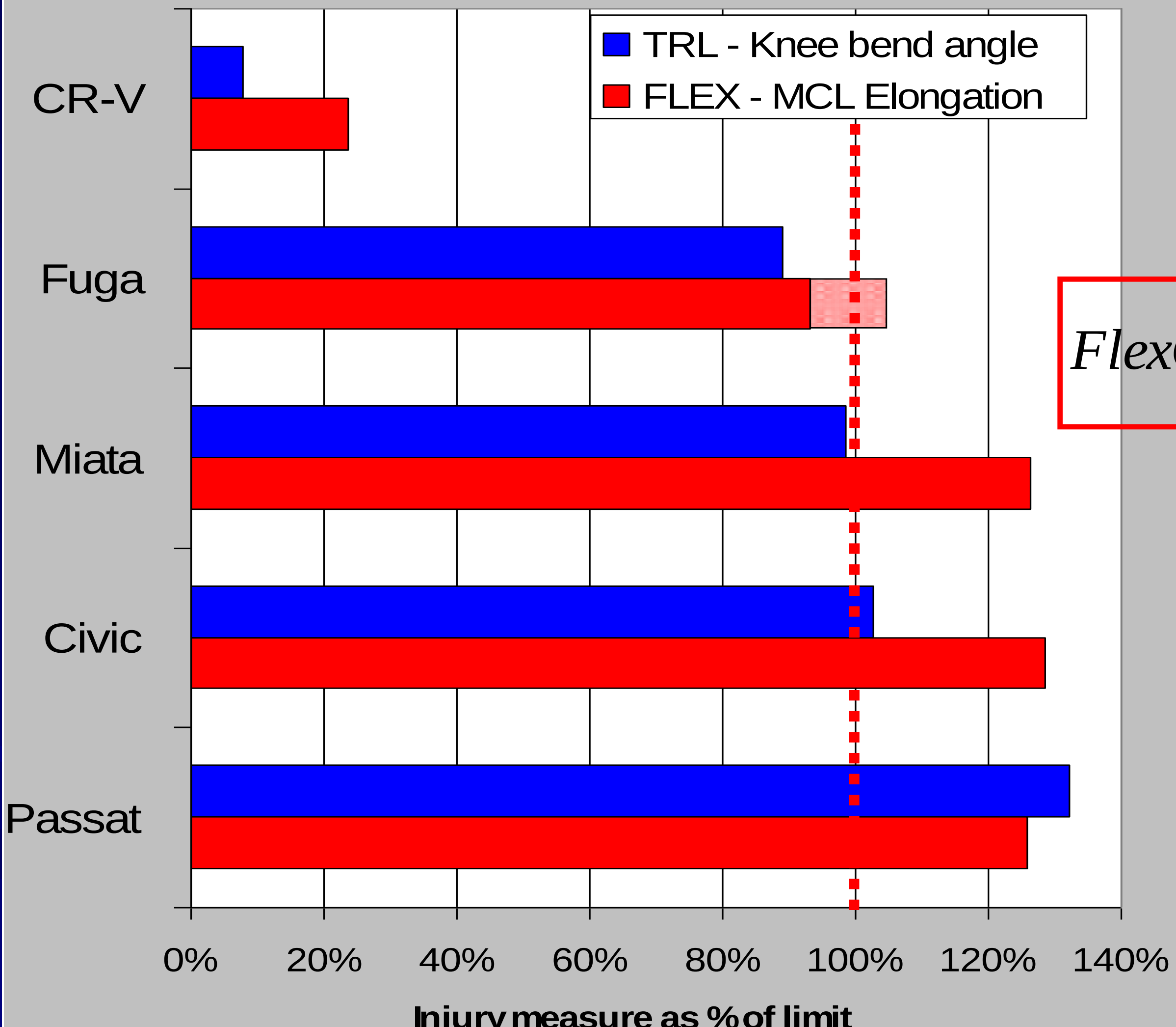
Injury Measures: Fracture



$$TRL - \frac{TibiaAcceleration}{170g}$$

$$FlexGTR - \frac{TibiaMoment}{340\,Nm}$$

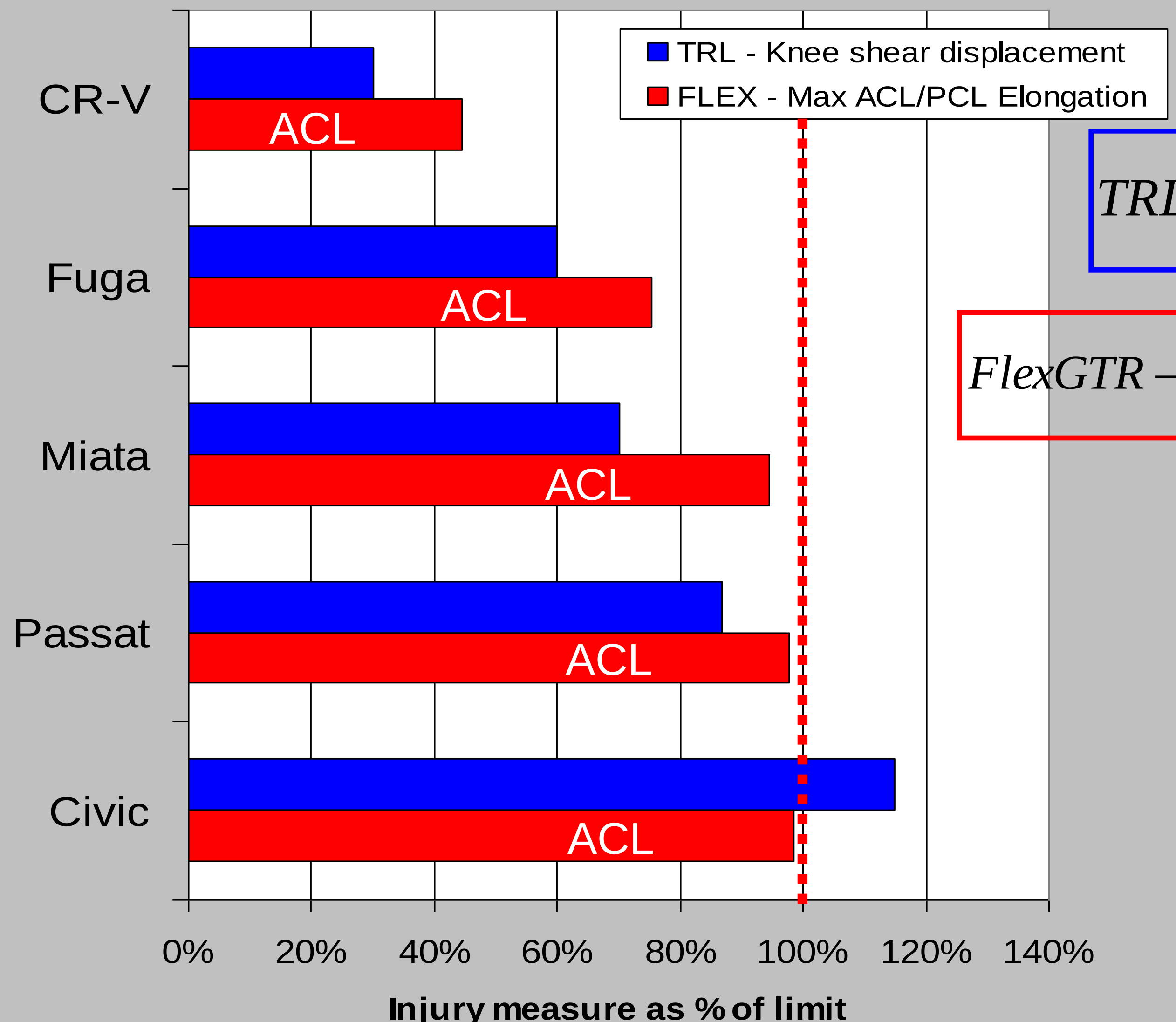
Injury Measures: Ligament Injury (Bending)



$$TRL - \frac{BendAngle}{19°}$$

$$FlexGTR - \frac{MCL\_Elongation}{22mm}$$

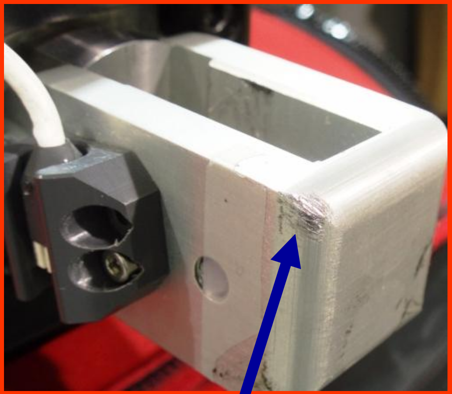
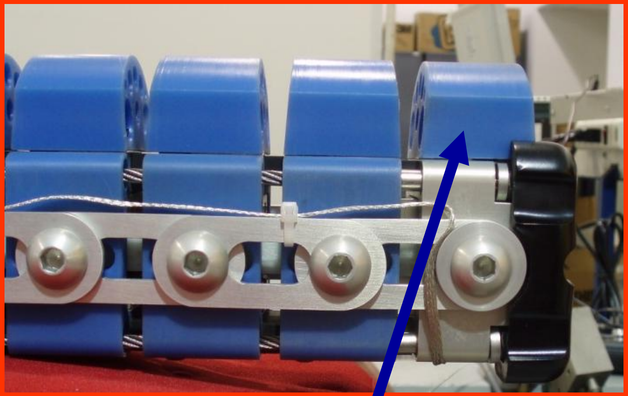
Injury Measures: Ligament Injury (Shear)



$$TRL - \frac{ShearDisplacement}{6mm}$$

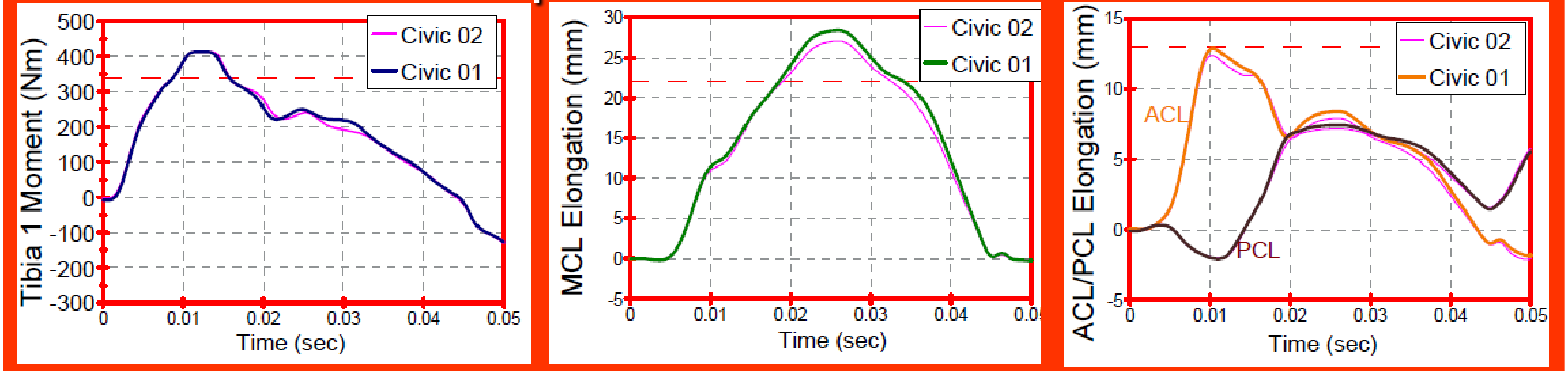
$$FlexGTR - \frac{ACL / PCL\_Elongation}{13mm}$$

FlexGTR Durability

Minor or cosmetic damage only	 Scuffing (rebound)  Segment face displaced (rebound)

FlexGTR Repeatability

FlexGTR: Good repeatability in paired tests
Example – 2001 Honda Civic



Flex-GTR durability, repeatability, and usability

Comparison: Ease of Use

	FlexGTR	TRL
Between-test Maintenance	■ Cable adjustment	■ Ligament replacement ■ Foam replacement, gluing ■ Temperature and humidity soaking
Flight Orientation	■ Flat pushing surface ■ Onboard acquisition system eliminates cable drag	■ Foam pushing surface ■ Possibly complicated by data acquisition cables

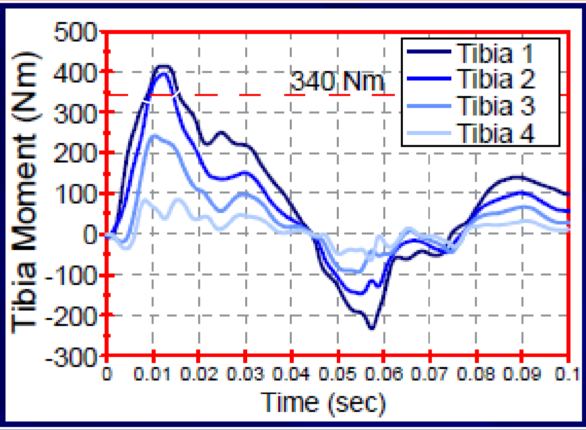
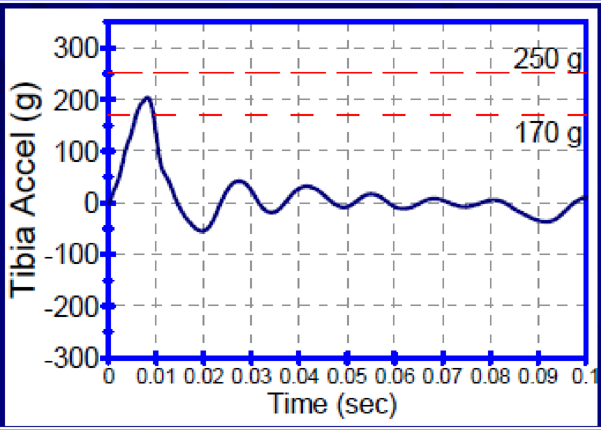
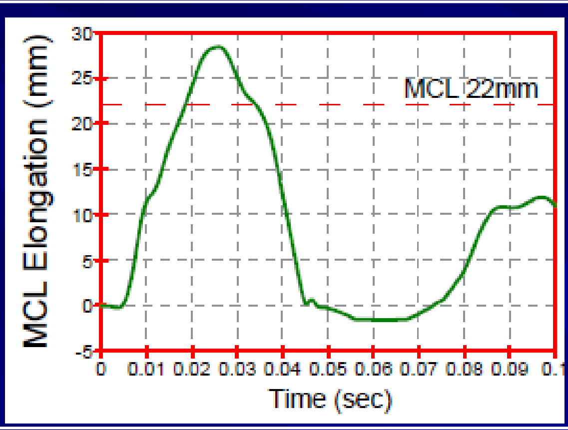
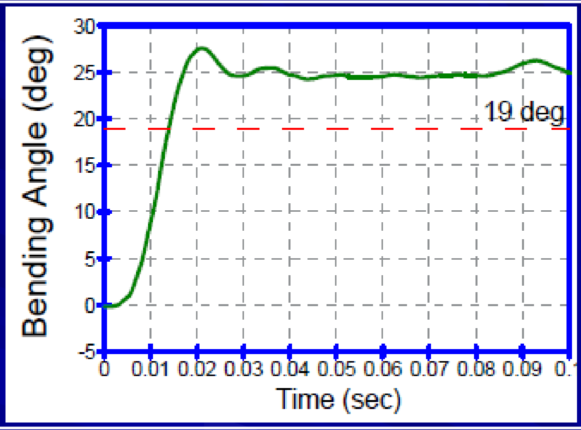
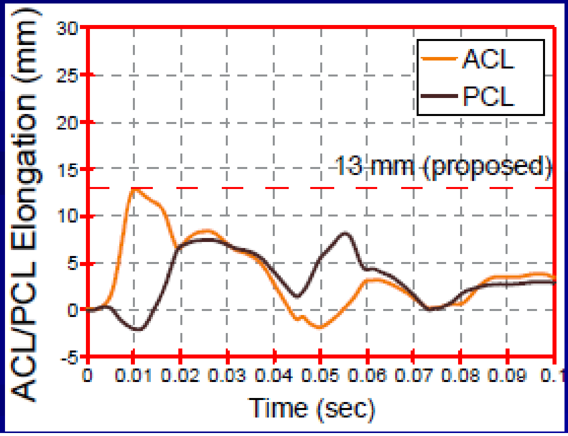
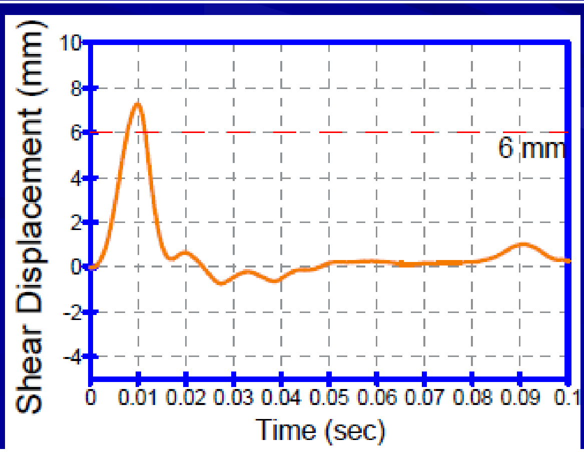
Summary

- FlexGTR tended to measure higher injury risk than TRL relative to proposed injury limits.
- The two legforms ranked these 5 vehicles similarly in terms of fracture risk and knee ligament risk (bending, shear).
  - →Corresponded especially well for vehicles that passed GTR in TRL testing.
- FlexGTR tended not to discriminate among more aggressive vehicles (even when TRL indicated there was a performance difference)

Summary (Cont.)

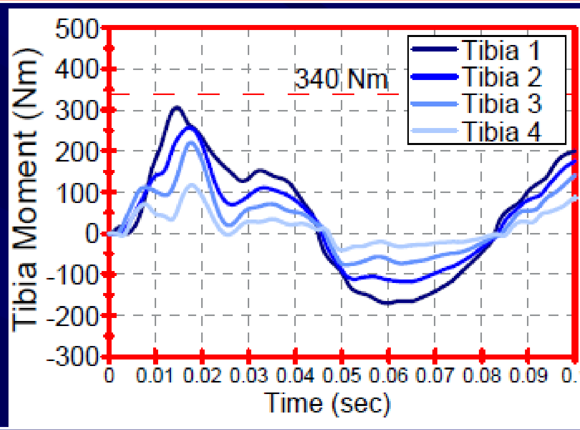
- Preliminary results show Flex has good repeatability and has several features that make it easier to use than the TRL legform.
  – Certification procedures were not compared.
- The current set of tests did not result in functional damage to either legform.
- The FlexGTR is more robust than the FlexGT. However, thorough evaluation of the durability of the FlexGTR for use with the US fleet would require testing of more aggressive vehicles than those included in this test matrix.

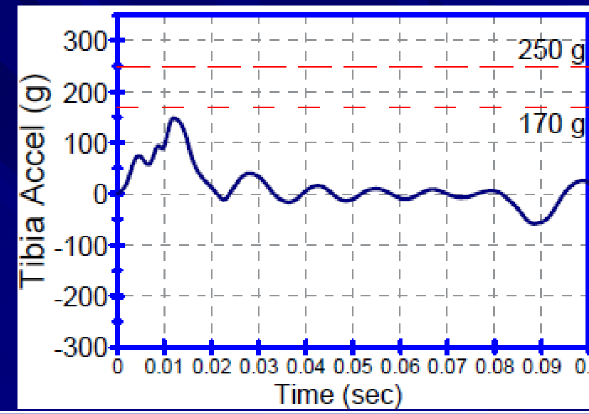
Thank You

Civic	FlexGTR	TRL
Fracture Risk		
Ligament Injury Risk (Bending)		
Ligament Injury Risk (Shear)		

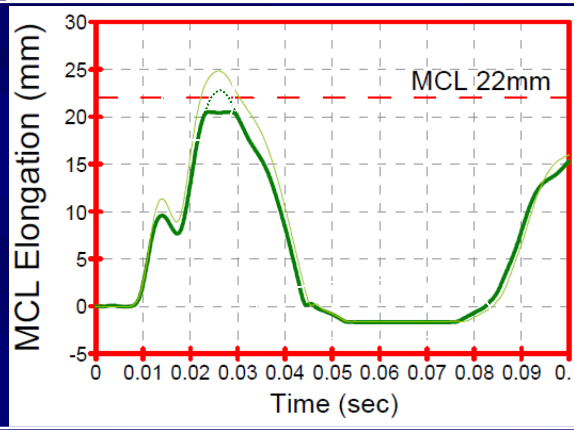
FUGA	FlexGTR	TRL

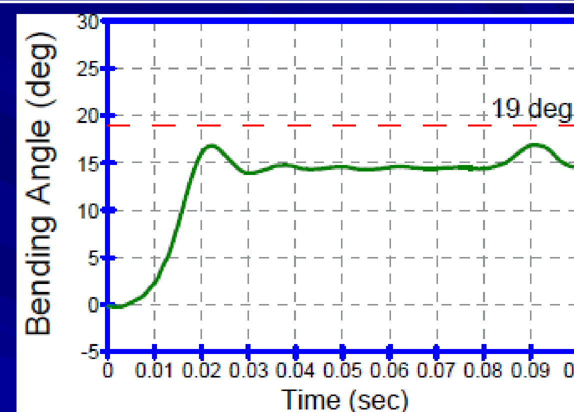
Fracture Risk



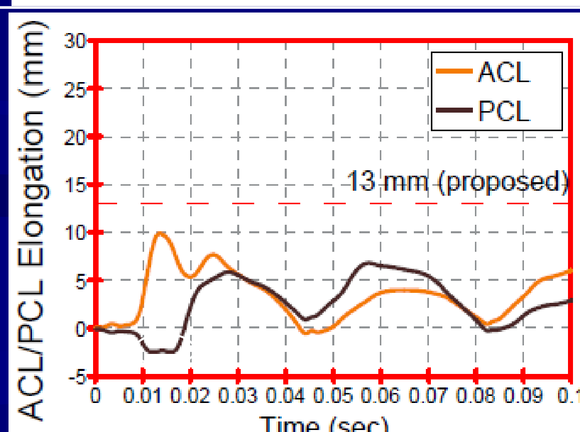


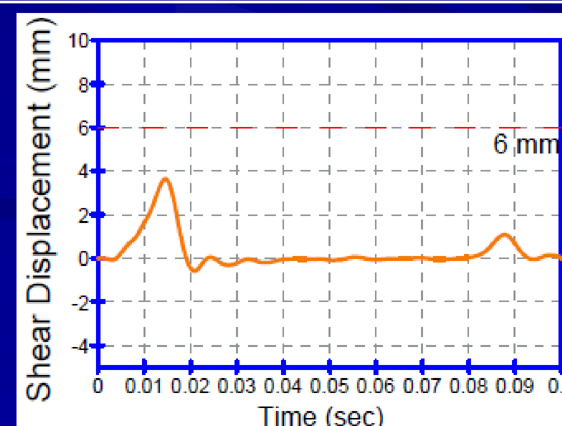
Ligament Injury Risk (Bending)

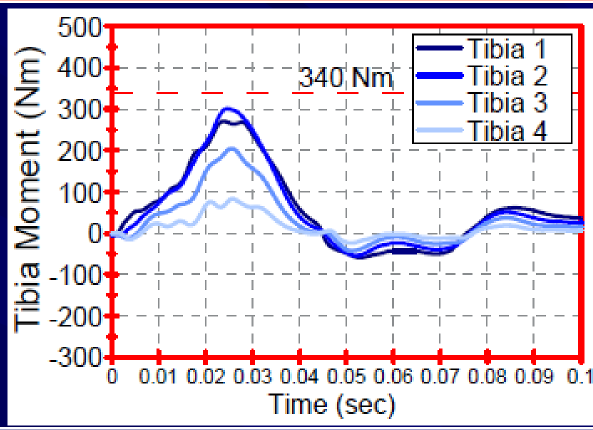
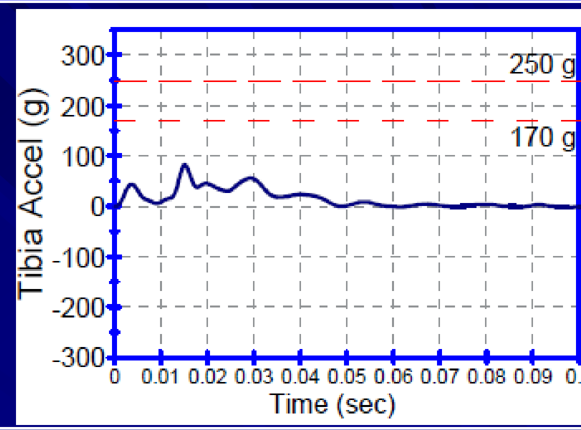
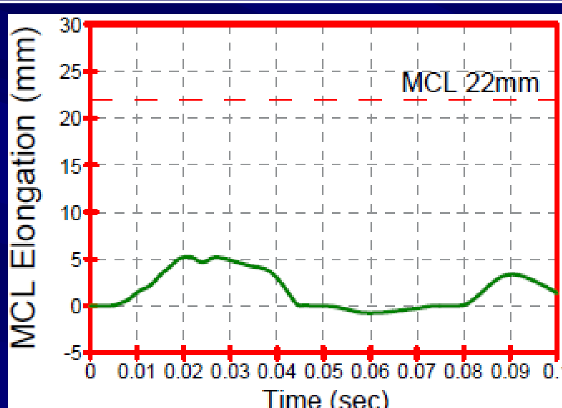
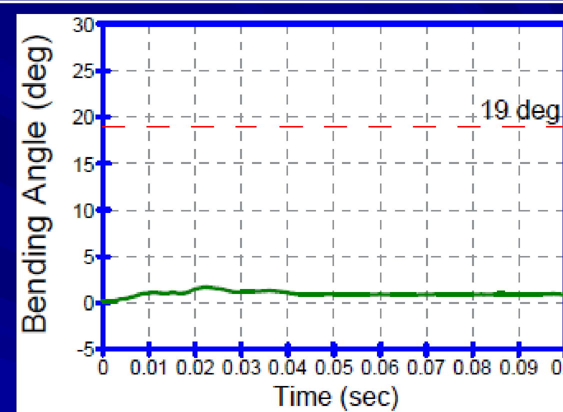
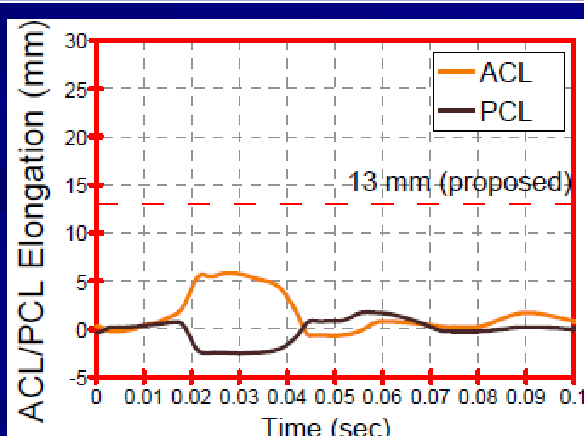
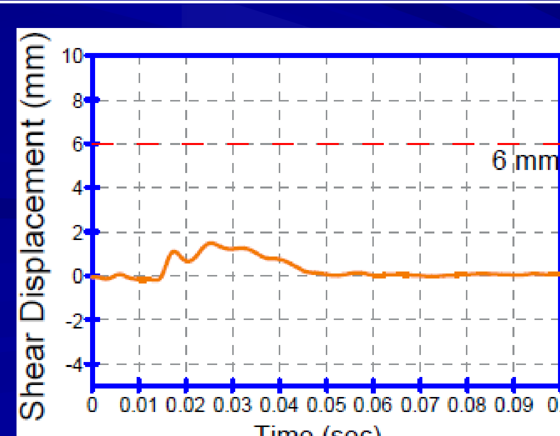




Ligament Injury Risk (Shear)



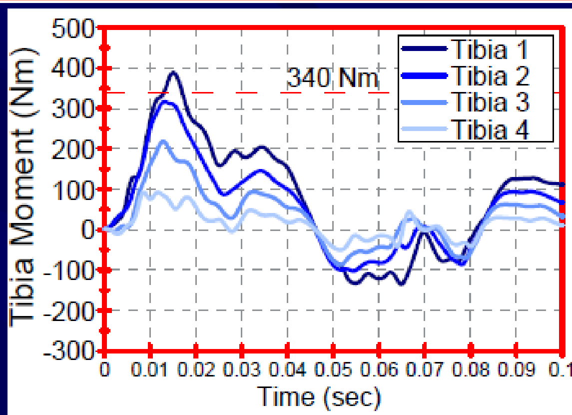


CRV	FlexGTR	TRL
Fracture Risk		
Ligament Injury Risk (Bending)		
Ligament Injury Risk (Shear)		

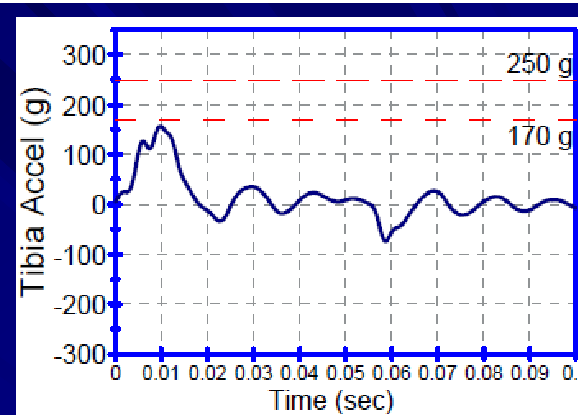
MIATA	FlexGTR	TRL

Fracture Risk

FlexGTR

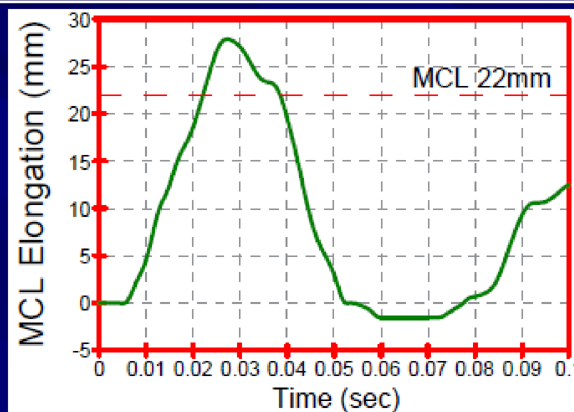


TRL

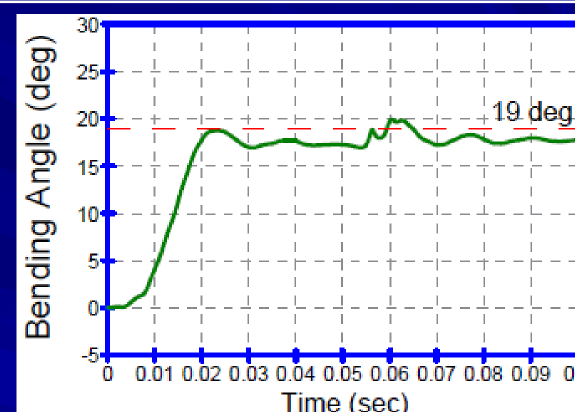


Ligament Injury Risk (Bending)

FlexGTR

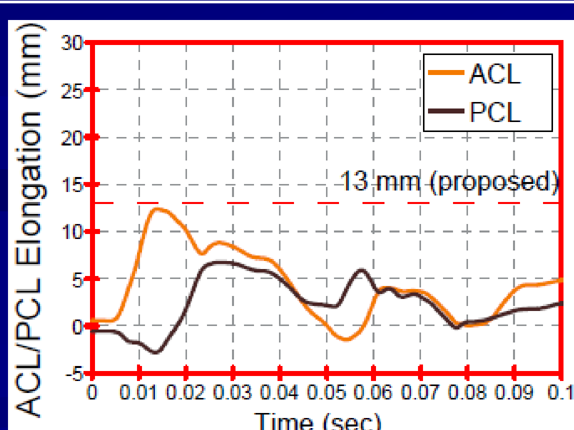


TRL

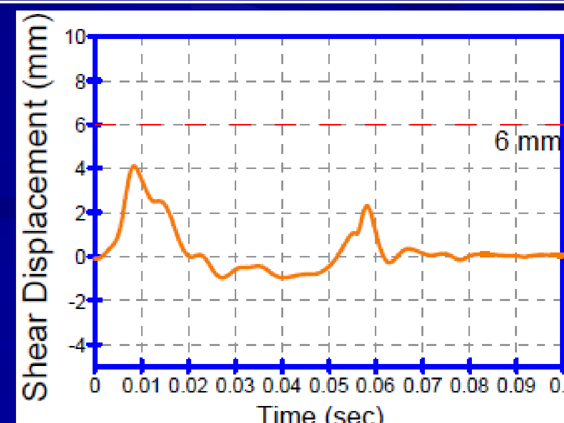


Ligament Injury Risk (Shear)

FlexGTR



TRL

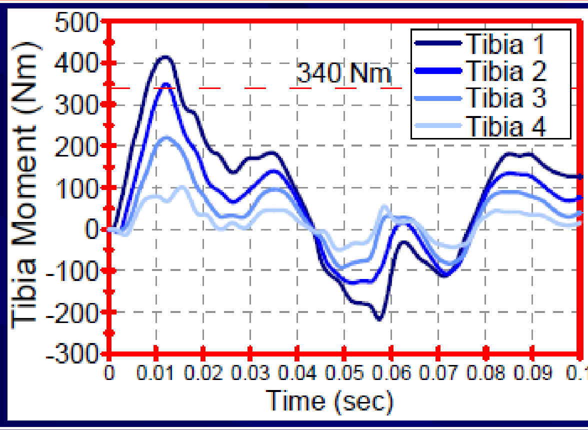


PASSAT

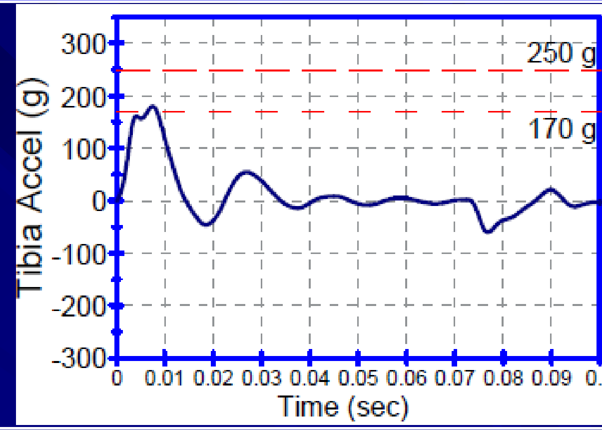
	FlexGTR	TRL

Fracture Risk

FlexGTR:

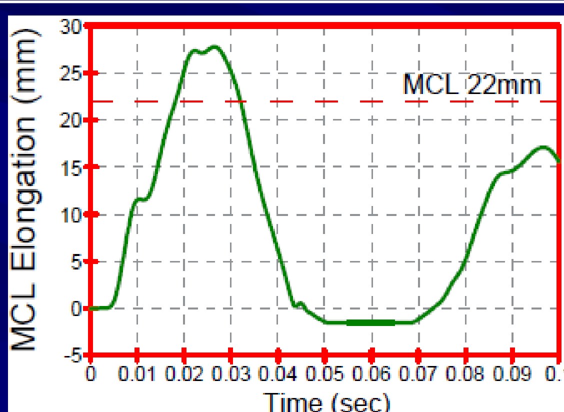


TRL:



Ligament Injury Risk (Bending)

FlexGTR:



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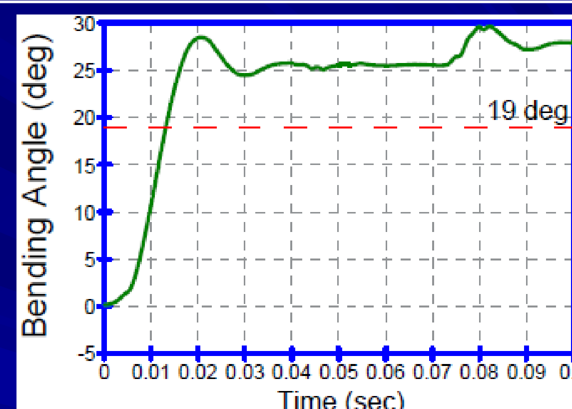
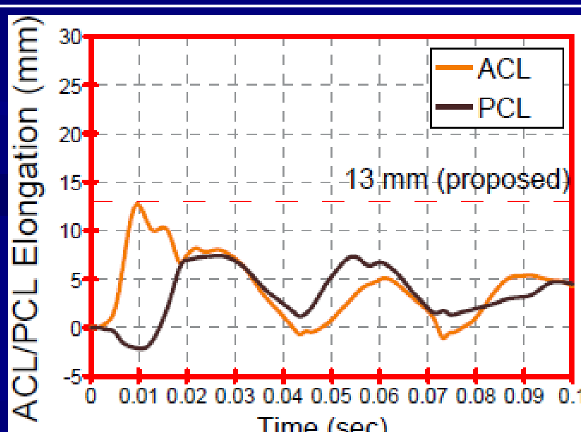


Ligament Injury Risk (Shear)

FlexGTR:



TRL: