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

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Background – Pedestrian GTR

- **GTR 9 was adopted November 2008**

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

- **Amendment 1 to GTR 9**

  -Incorporates the Flex-PLI 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
  - At least one measurement exceeded GTR requirements with the TRL legform
  - 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

Test Matrix

	Flex GTR Tests VRTC		TRL Tests VRTC	
2001 Honda Civic	2009	Reported at 10th Flex-PLI Technical Evaluation Group (Flex-TEG) Meeting, December 1, 2009	2009^^	Not previously reported
2006 Nissan Fuga bumper (on 2006 Infiniti M-35)	2009		2009	
2005 Honda CR-V	2009		2007	Mallory & Stammen, ESV 2009.
2002 Mazda Miata	2009		2007	
2006 VW Passat	2009		2007^^	

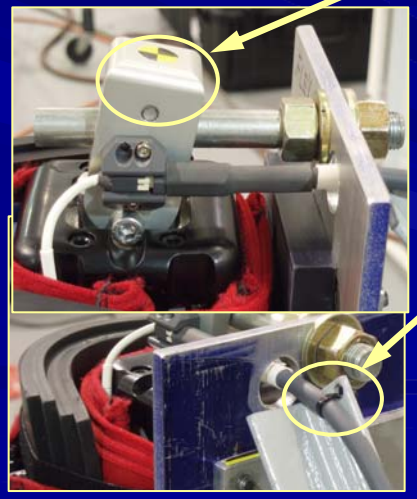
^^ The Passat exceeded two limits and the Civic exceeded three limits (but only by narrow margin). All other TRL tests passed.

Test Setup - Instrumentation

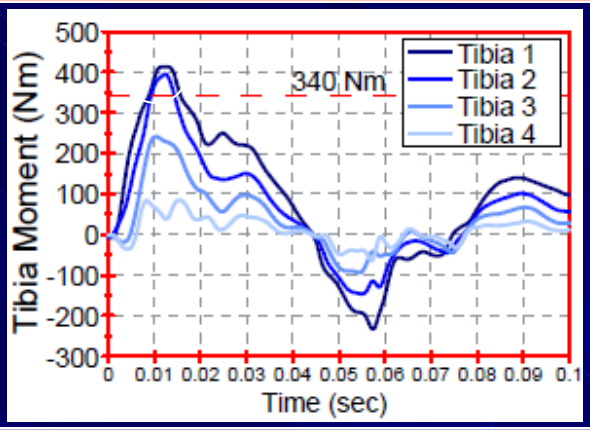
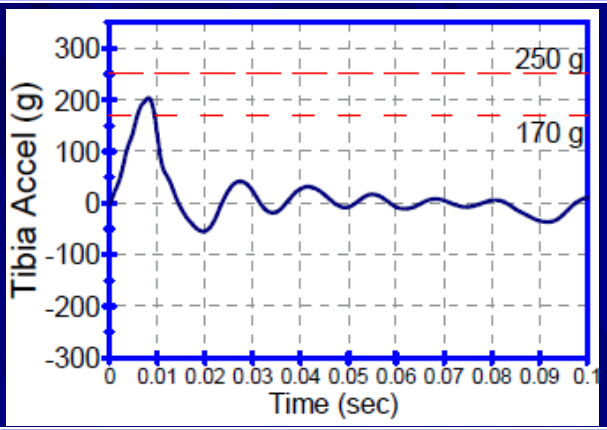
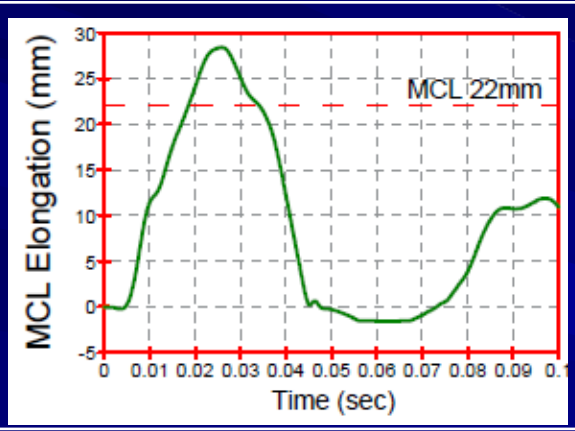
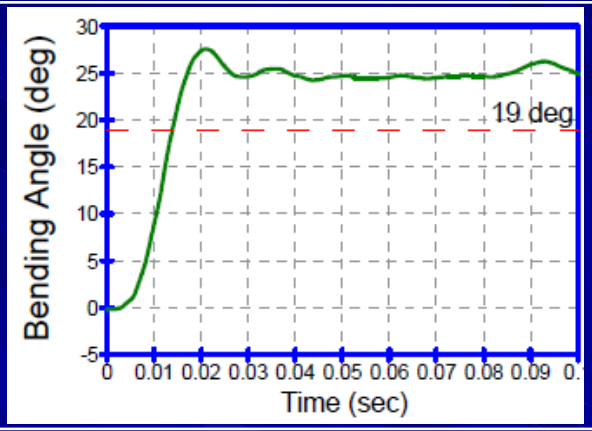
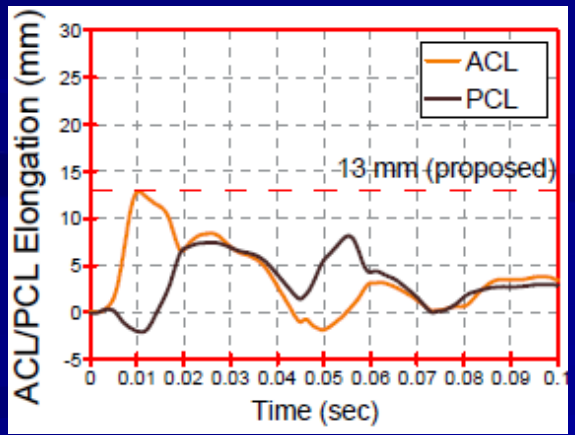
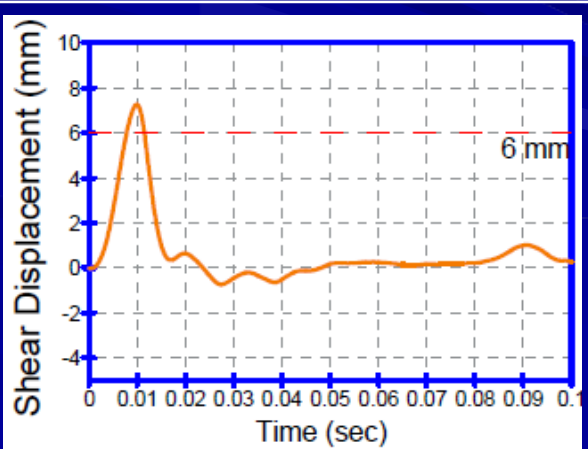
	FlexGTR *Onboard DTS Slice*	TRL
Fracture Risk	Tibia bending moment	Upper tibia acceleration
Ligament Injury Risk (Bending)	MCL elongation	Knee bending angle
Ligament Injury Risk (Shear)	PCL/ACL elongation	Knee shear displacement
Additional measures	Femur bending moment Tibia acceleration LCL elongation	

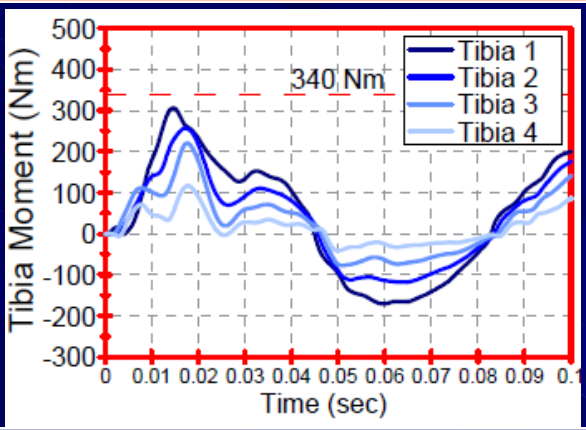
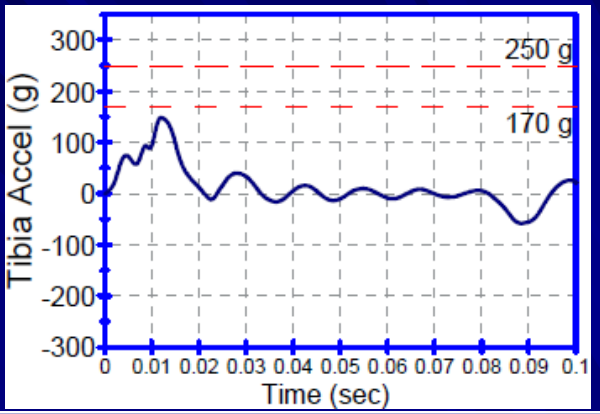
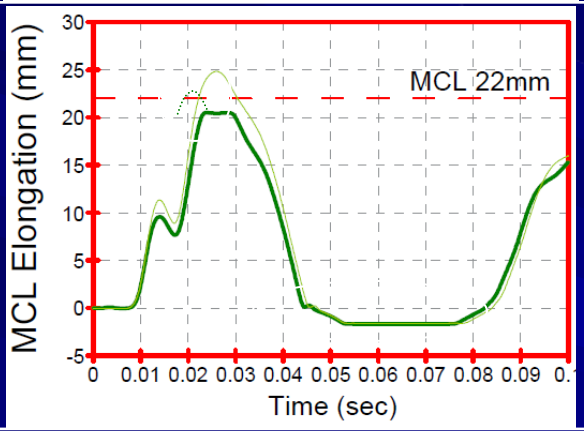
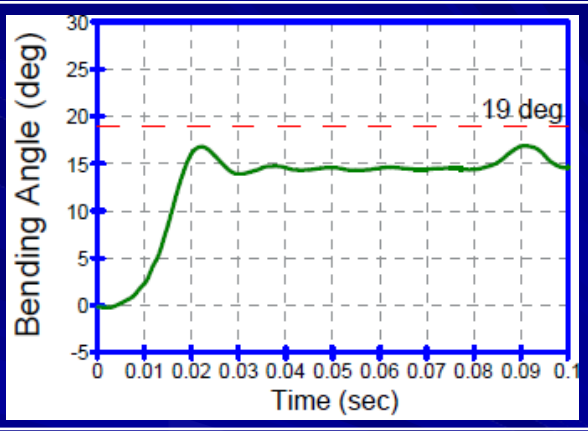
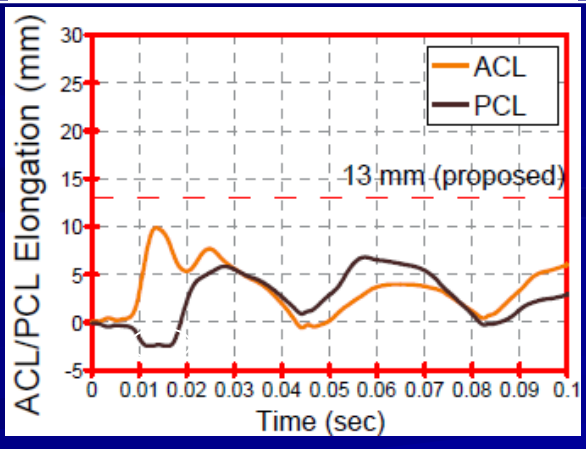
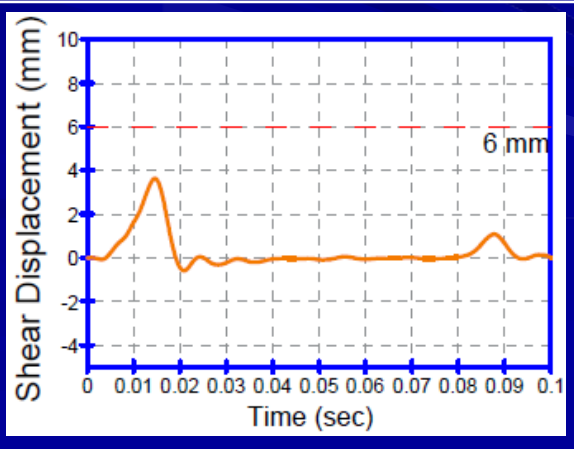
Test Setup - Method

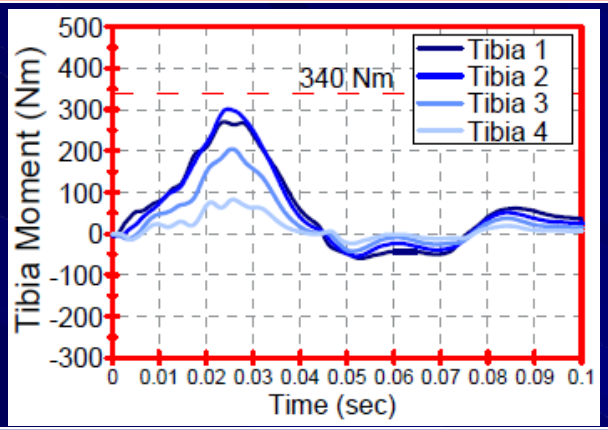
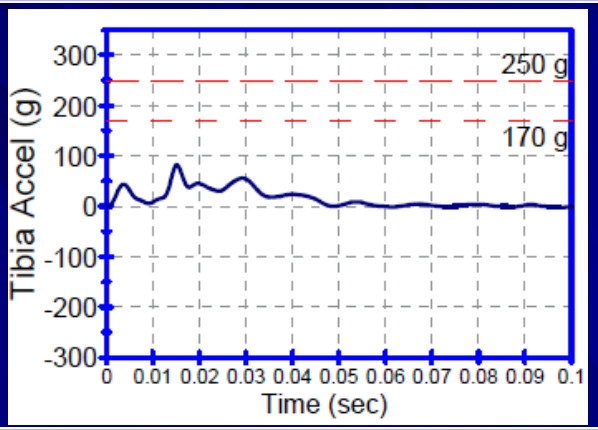
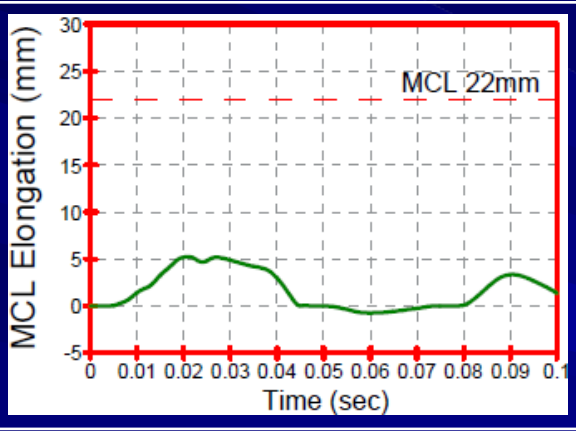
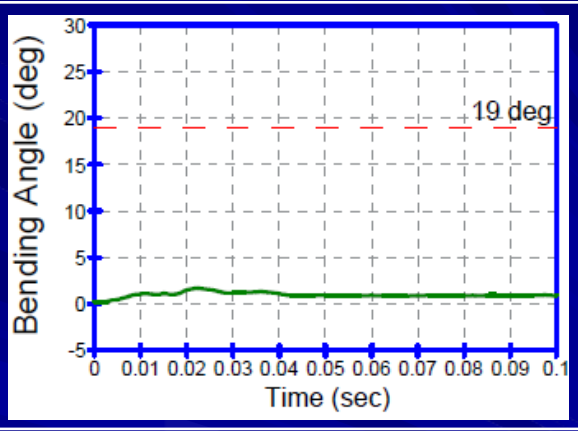
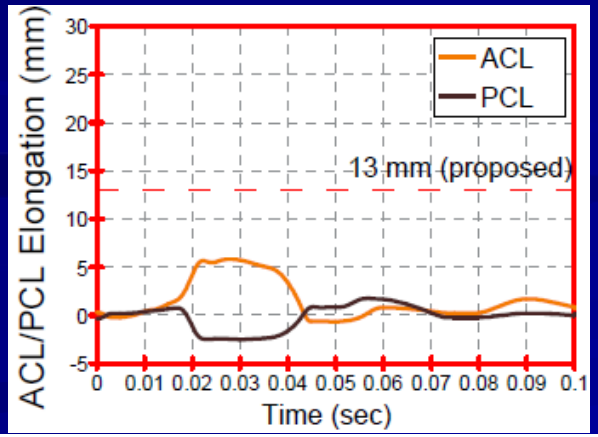
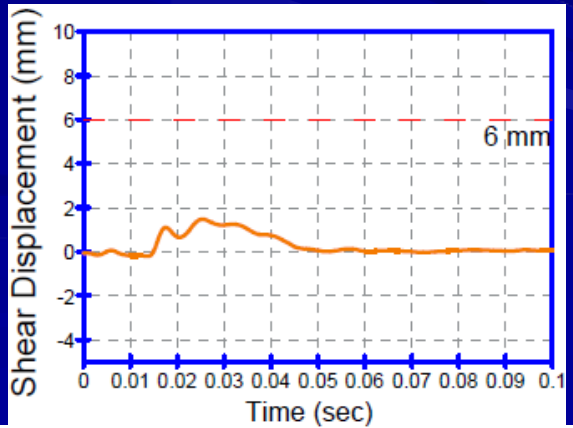
- GTR conditions (40 km/h)
  - Ground reference level: EEVC/TRL=25 mm, Flex-GTR=75 mm
  - Laser speed-traps to measure impact velocity
- Center impacts
- Overhead and lateral video
  - Monitor alignment during flight
- Flex-GTR: Onboard DAS

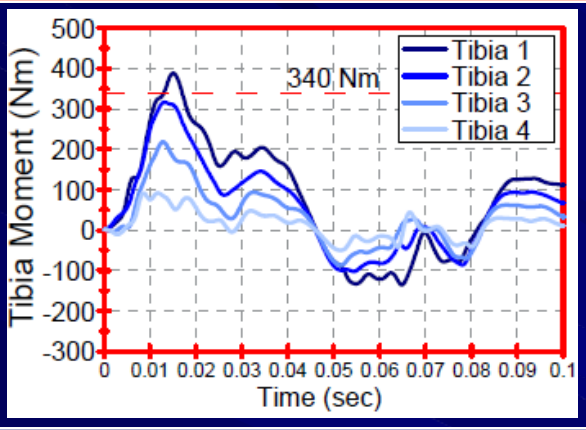
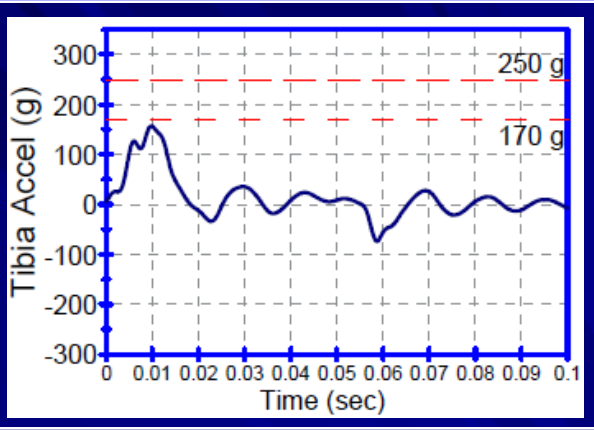
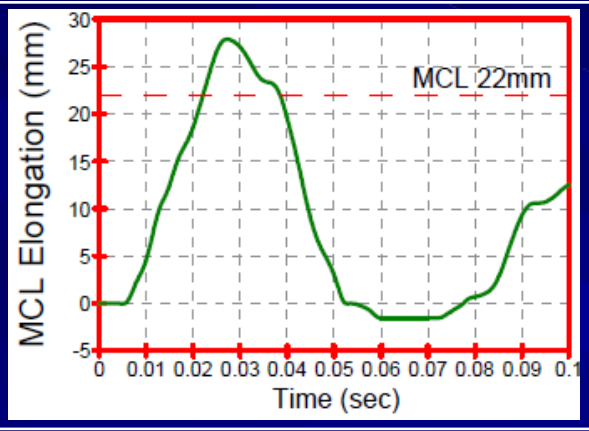
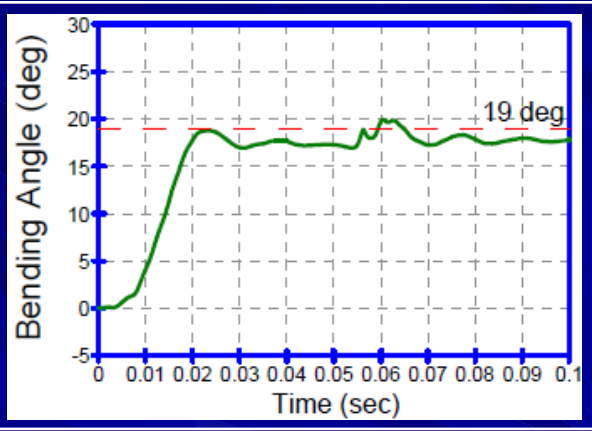
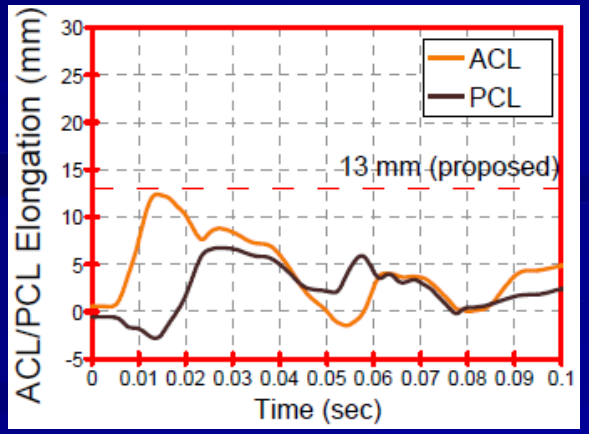
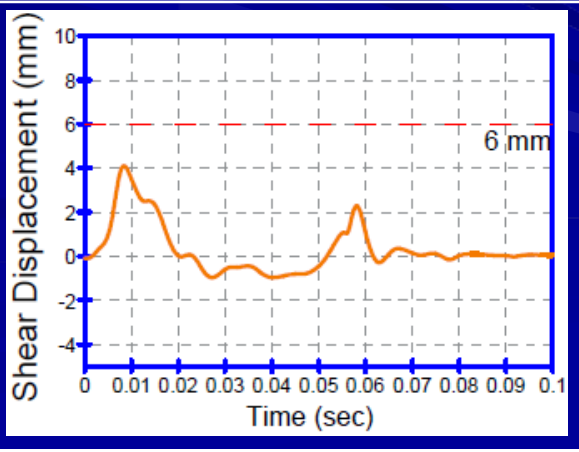


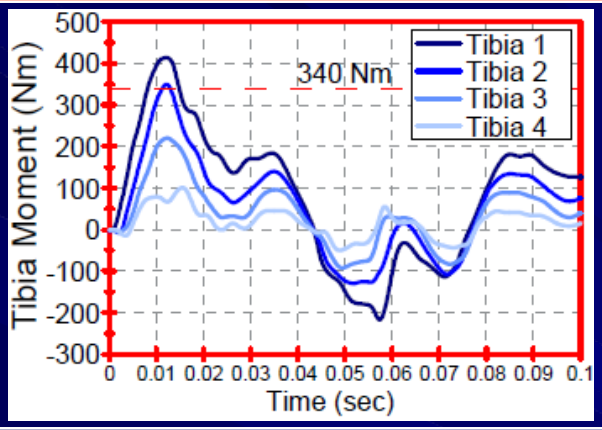
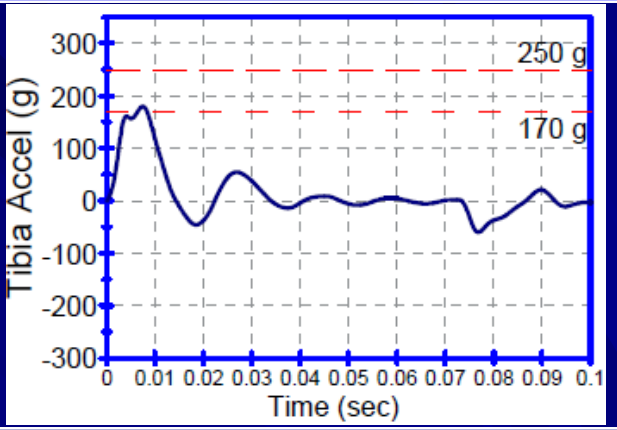
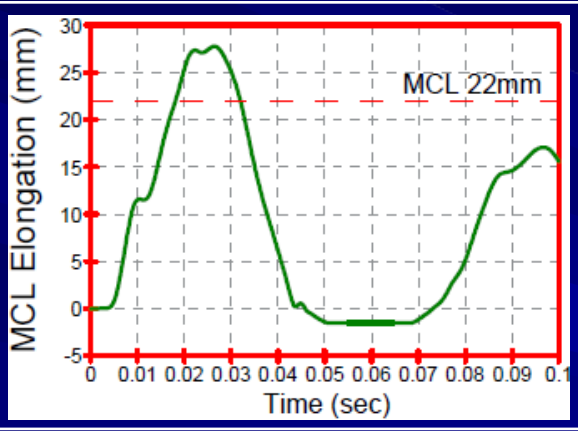
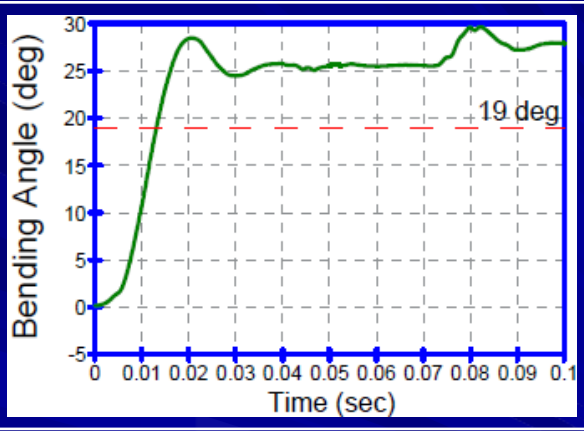
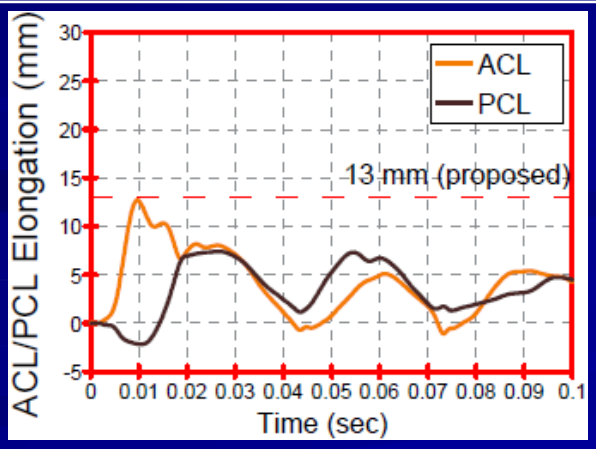
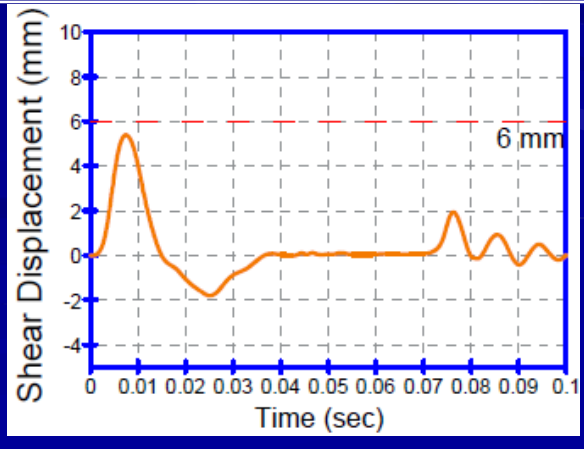
Results

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

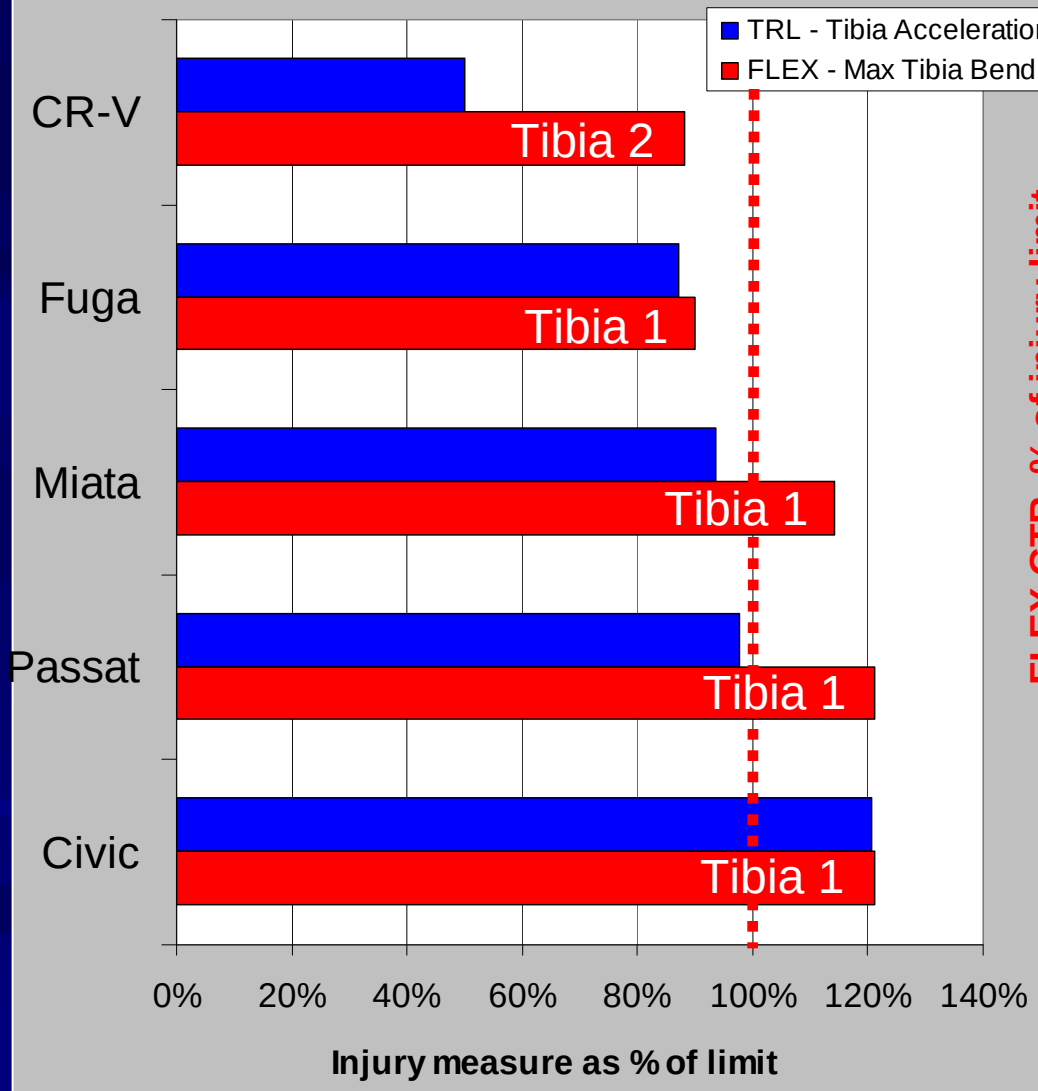
FUGA	Flex	TRL
Fracture Risk		
Ligament Injury Risk (Bending)		
Ligament Injury Risk (Shear)		

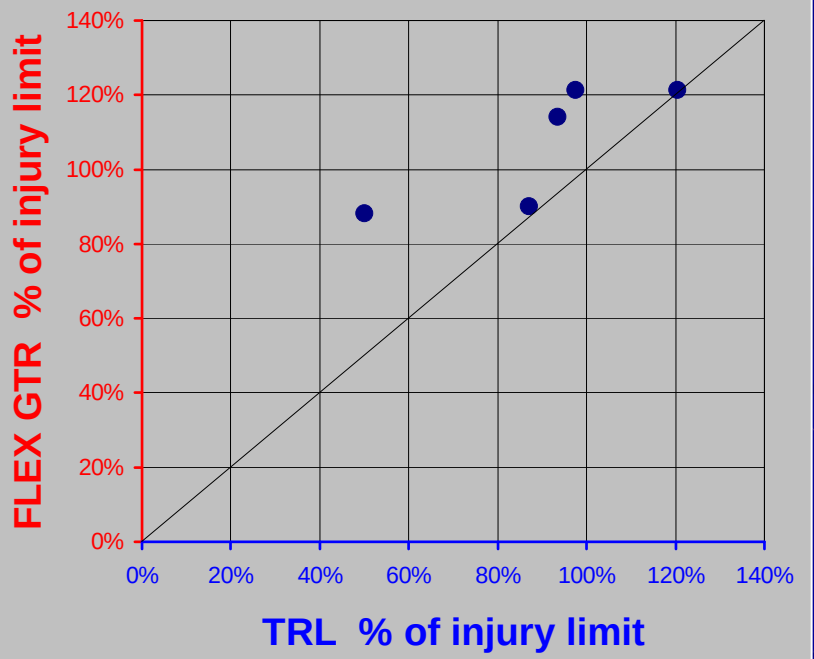
CRV	Flex	TRL
Fracture Risk		
Ligament Injury Risk (Bending)		
Ligament Injury Risk (Shear)		

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

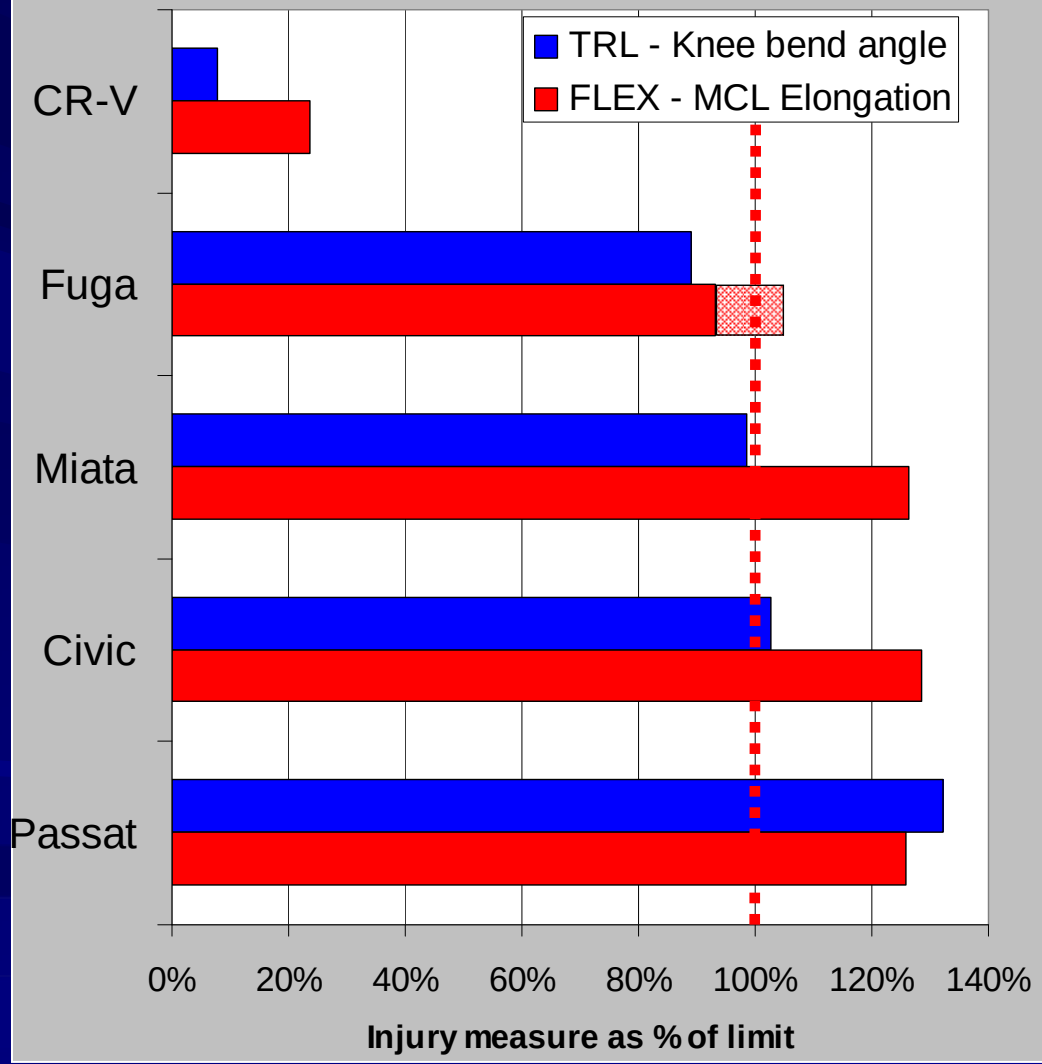
PASSAT	Flex	TRL
Fracture Risk		
Ligament Injury Risk (Bending)		
Ligament Injury Risk (Shear)		

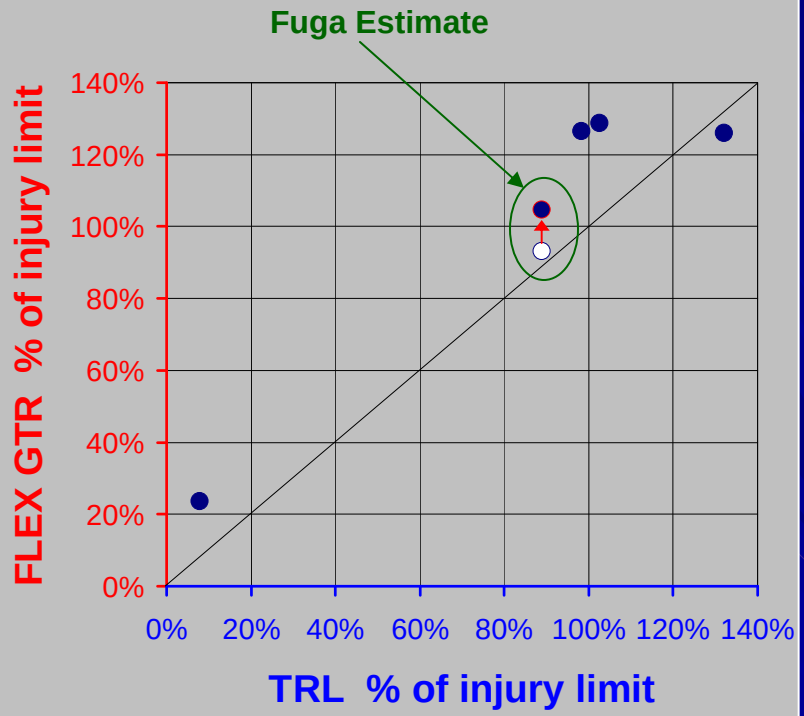
Injury Measures: Fracture



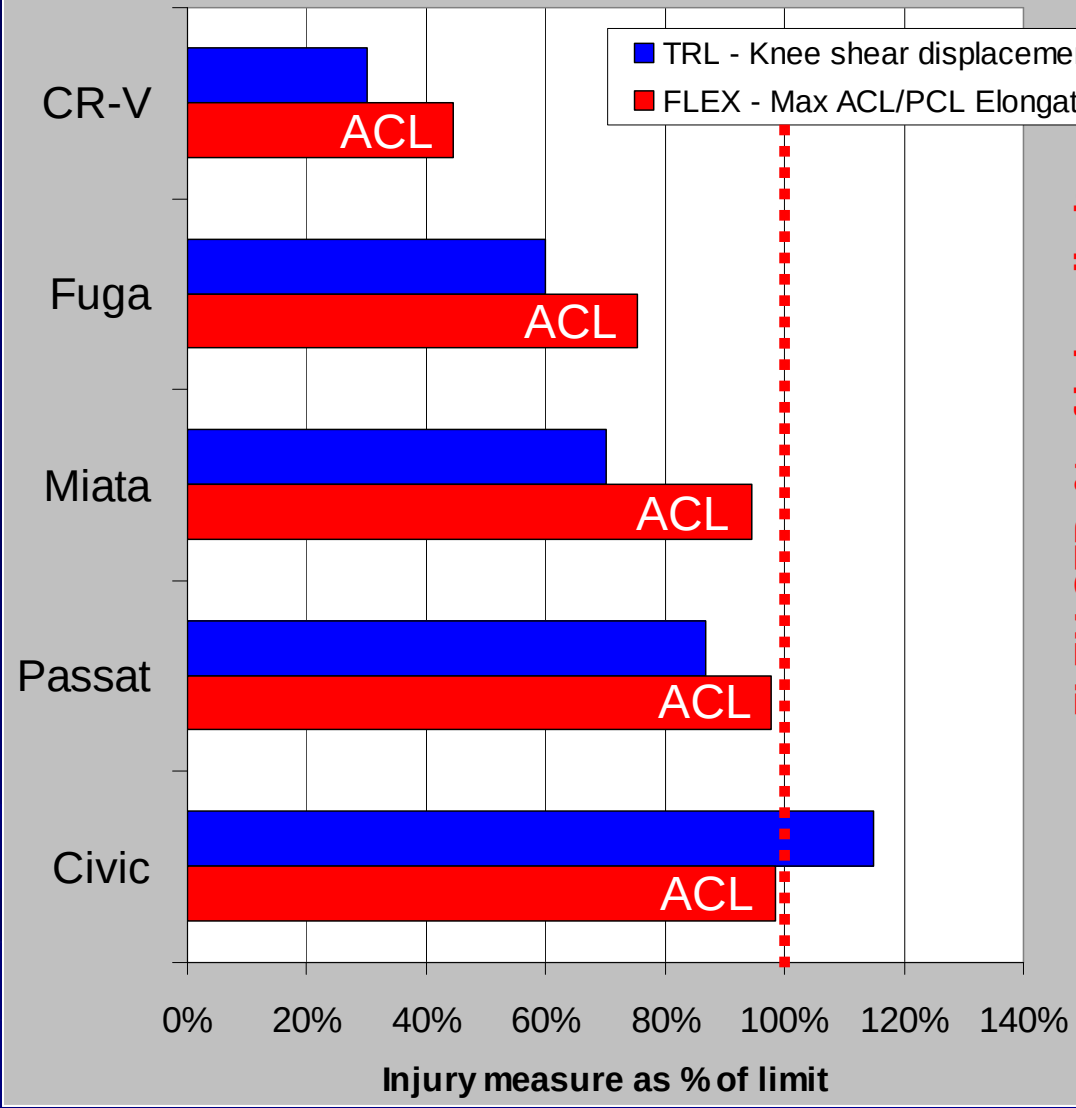


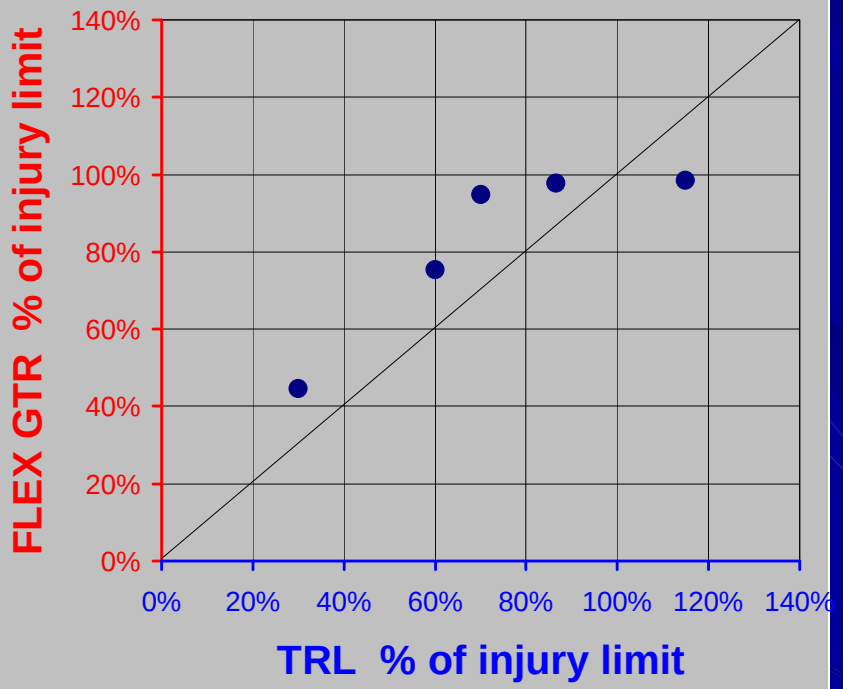
Injury Measures: Ligament Injury (Bending)





Injury Measures: Ligament Injury (Shear)



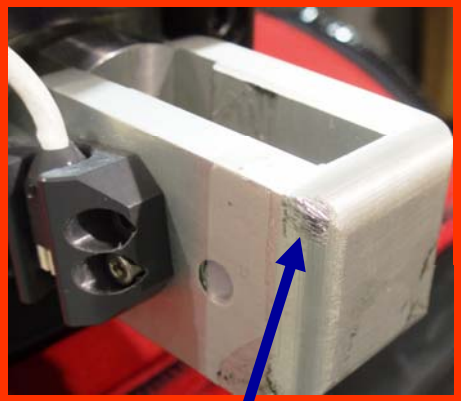
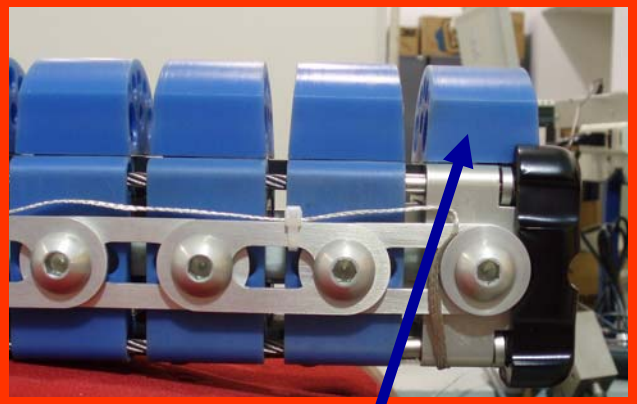
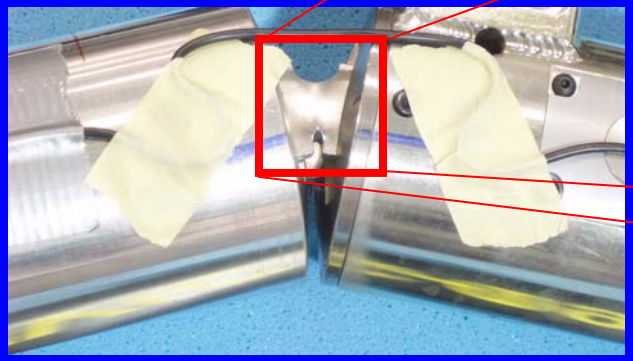
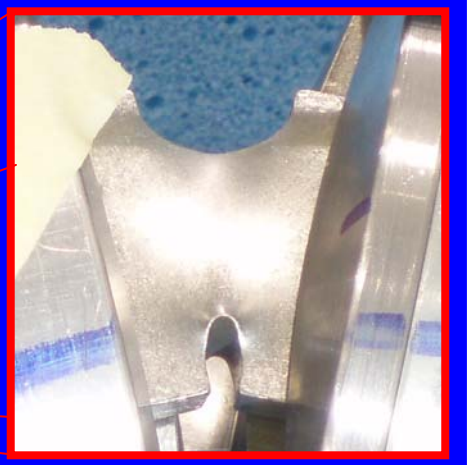


Injury Measures: Overall Injury Prediction

	Fracture		Ligament Injury (Bending)		Ligament Injury (Shear)		Overall	
	TRL	FLEX	TRL	FLEX	TRL	FLEX	TRL	FLEX
CR-V	1	1	1	1	1	1		
FUGA	2	2	2	2	2	2		
MIATA	3	3	3	3	3	3		
PASSAT	4	4	5	3	4	3		
CIVIC	5	4	4	5	5	5		

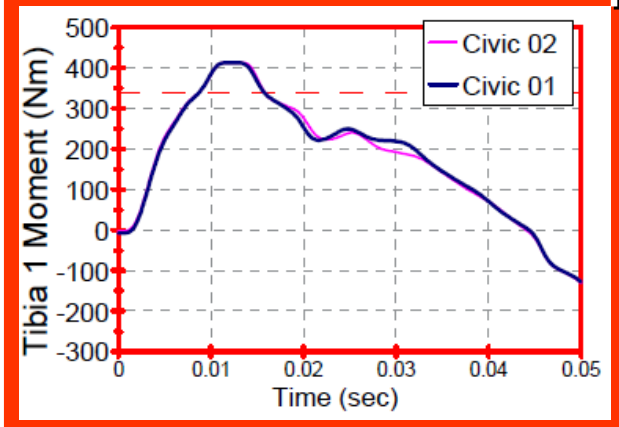
Flex-GTR durability, repeatability, and usability

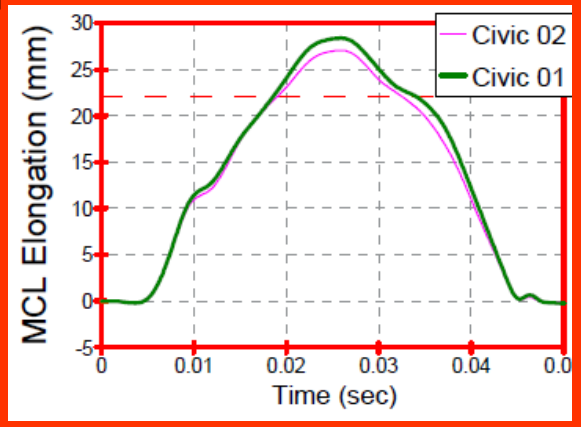
Comparison: Durability

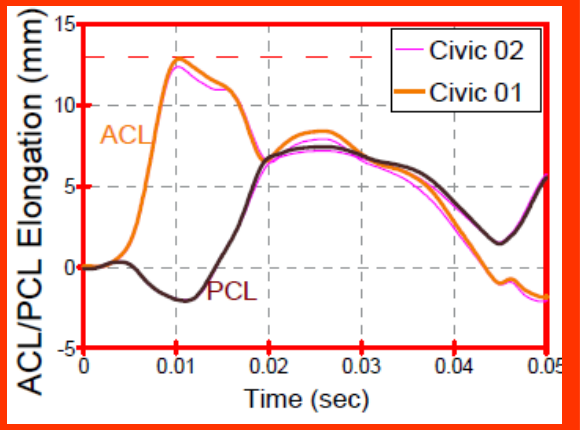
Flex GTR	Minor or cosmetic damage only	 Scuffing (rebound)  Segment face displaced (rebound)
TRL	Damage limited to frangible consumables	 

Comparison: Repeatability

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







TRL: Repeatability not assessed in this series

Comparison: Ease of Use

	FlexGTR	TRL
Between-test maintenance	▪ Cable adjustment	▪ Ligament replacement ▪ Foam replacement, gluing, soaking
Temperature and Humidity Control	▪ No problem in typical lab conditions	▪ Challenging in typical lab conditions
Maintaining Orientation In Flight	▪ Possibly made easier by flat pushing surface ▪ Onboard acquisition system eliminates cable drag	▪ Possibly complicated by data acquisition cables
Certification Procedure	▪ Proposed dynamic pendulum-type test ▪ Proposed dynamic ram-type tests NOT EVALUATED IN THIS SERIES	▪ Every 20 vehicle impacts ▪ Dynamic ram-type certification tests ▪ Static bending and shear certification tests ▪ Setup can be time-consuming

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