

FlexPLI Round Robin Testing

Revision #1

- Corrected PCL & LCL elongation plots on slides 6, 11, and 16

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Objectives & Overview

- Evaluate repeatability & reproducibility
- Vehicle testing @ center bumper location

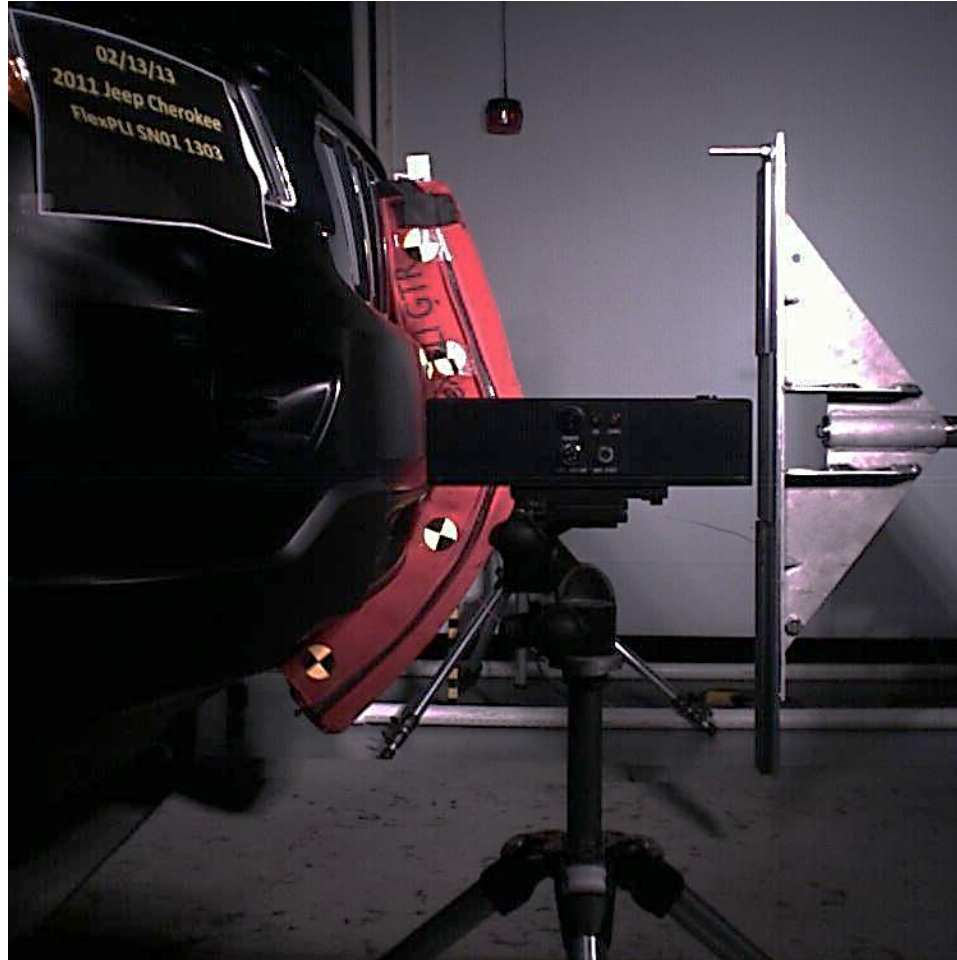
| Vehicle | Legform | | |
|--------------------------|-------------|-------------|--------------|
| | Test #1 | Test #2 | Test #3 |
| 2011 Jeep Grand Cherokee | Master SN01 | Master SN01 | Master SN01 |
| 2006 Volkswagen Passat | VRTC | Master SN01 | Master E-Leg |
| 2011 Hyundai Tucson | VRTC | Master SN01 | Master E-Leg |

*VRTC legform was not a round robin leg

*Bumper systems replaced for every test

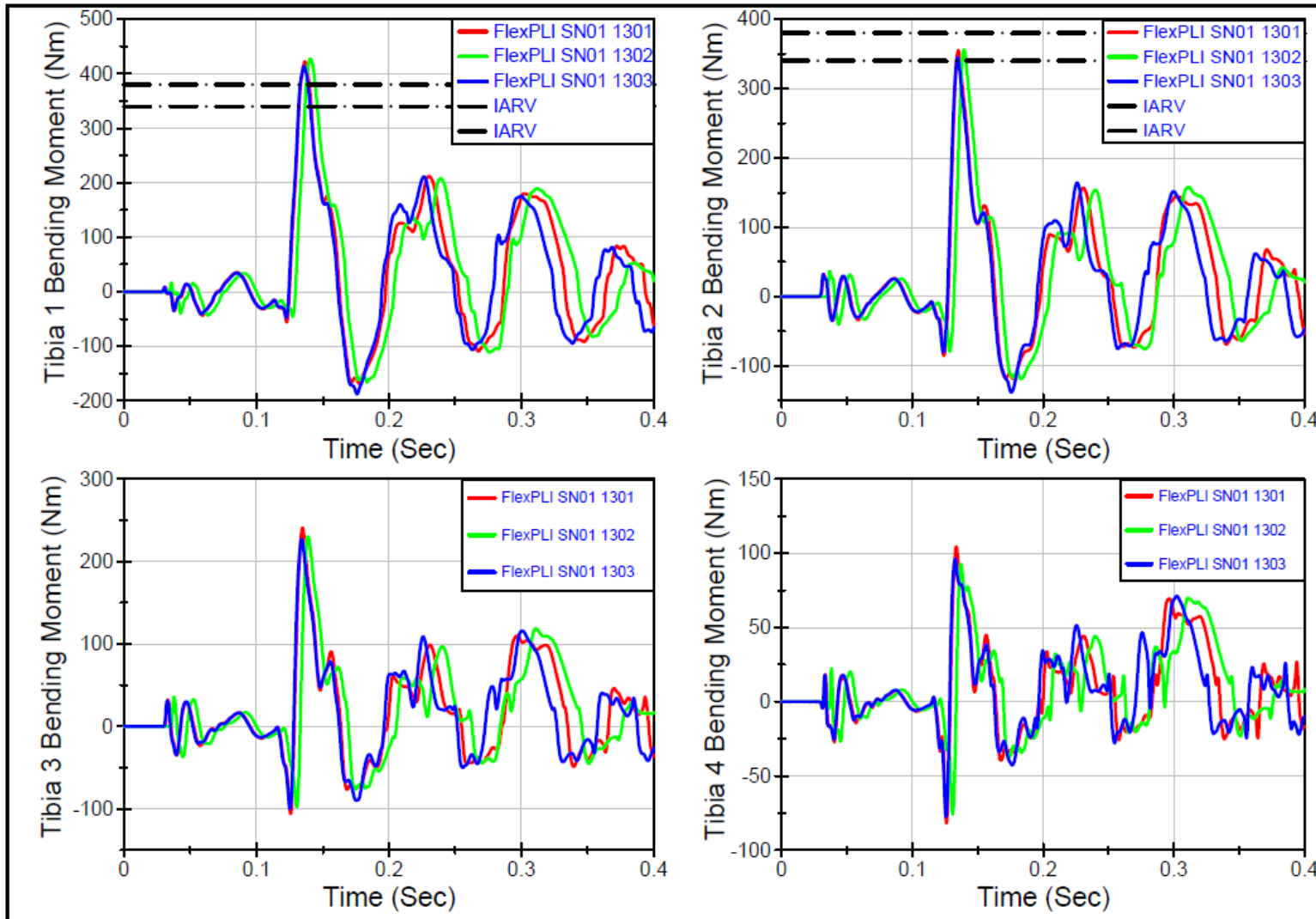
- Pendulum certification
 - Pre vs post for non-GTR applicable vehicles
 - Reproducibility

Repeatability 2011 Jeep Cherokee (SN01)

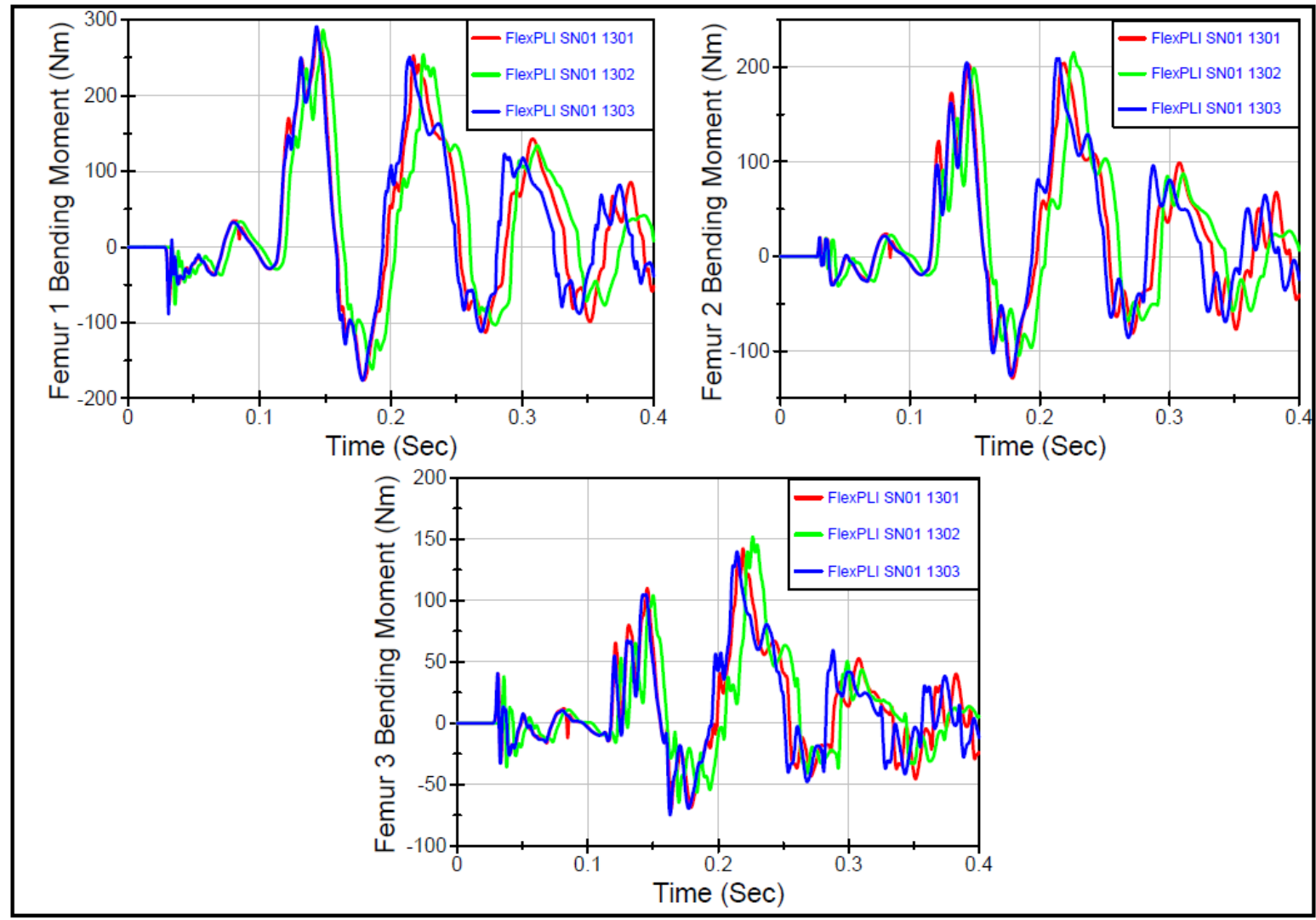


Repeatability

2011 Jeep Cherokee

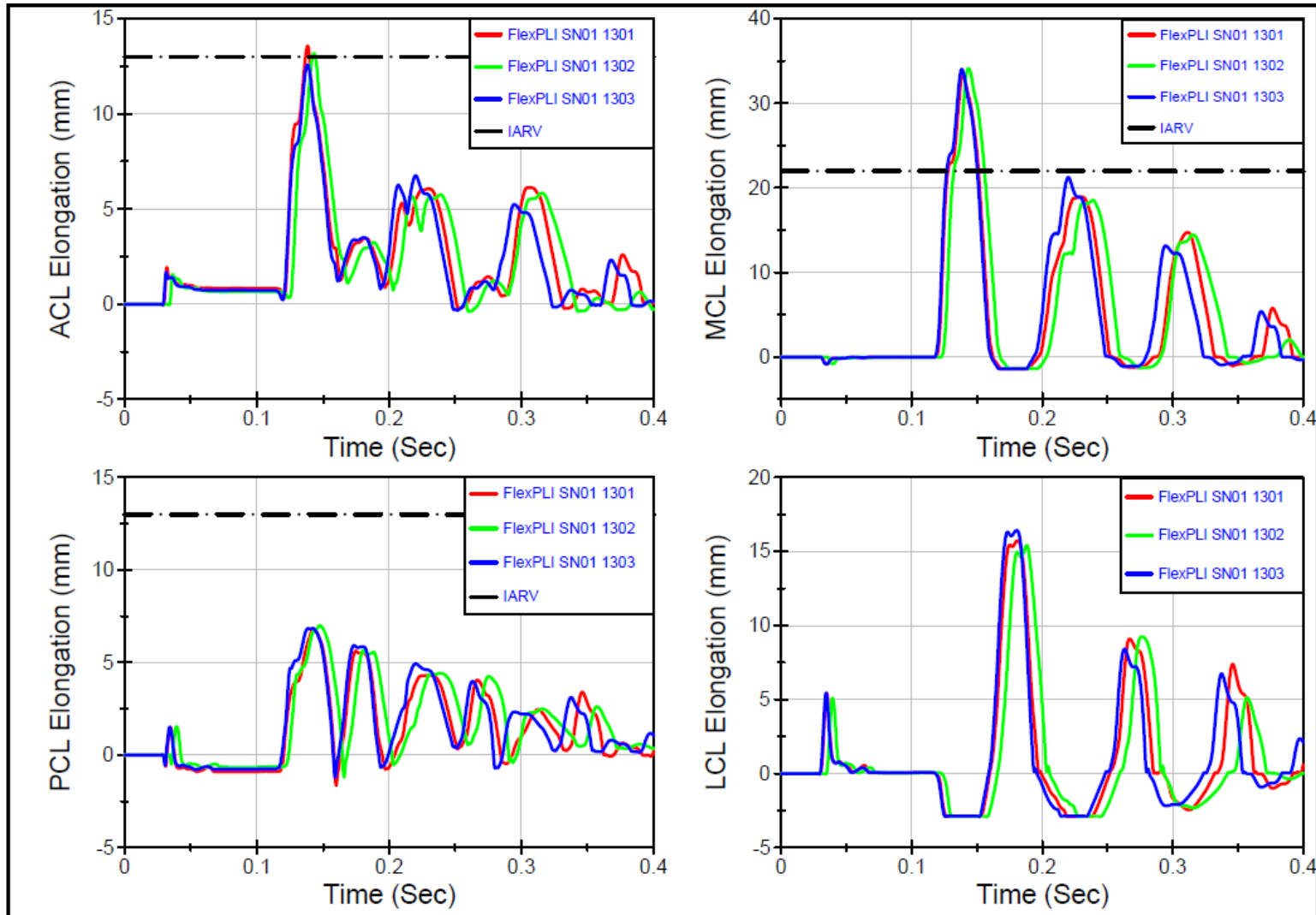


Repeatability 2011 Jeep Cherokee



Repeatability

2011 Jeep Cherokee



Repeatability

2011 Jeep Cherokee

| Injury Measurement | | IARV | 2011 Jeep Grand Cherokee | | | | | |
|-------------------------|---------------------|--------------------|--------------------------|--------|--------|--------|-------|------|
| | | | Center Impact | | | | | |
| | | | Legform SN01 | | | | | |
| | | | #1301 | #1302 | #1303 | Mean | STDEV | CV |
| Femur Moment (Nm) | Femur 3 (Upper) | -- | 142 | 152 | 140 | 145 | 6.4 | 4.4% |
| | Femur 2 (Middle) | | 204 | 215 | 209 | 209 | 5.5 | 2.6% |
| | Femur 1 (Lower) | | 287 | 287 | 290 | 288 | 1.7 | 0.6% |
| Tibia Moment (Nm) | Tibia 1 (Upper) | 340 Nm (380 Nm) | 422 | 427 | 413 | 421 | 7.1 | 1.7% |
| | Tibia 2 (Mid Upper) | | 355 | 356 | 344 | 352 | 6.7 | 1.9% |
| | Tibia 3 (Mid Lower) | | 241 | 230 | 227 | 233 | 7.4 | 3.2% |
| | Tibia 4 (Lower) | | 104 | 93 | 96 | 98 | 5.7 | 5.8% |
| MCL Elongation (mm) | | 22 mm | 33.4 | 34.1 | 34.0 | 33.8 | 0.4 | 1.1% |
| ACL Elongation (mm) | | 13 mm | 29.8 | 29.6 | 29.6 | 29.7 | 0.1 | 0.4% |
| PCL Elongation (mm) | | 13 mm | 6.9 | 7.0 | 6.8 | 6.9 | 0.1 | 1.4% |
| LCL Elongation (mm) | | -- | 15.7 | 15.4 | 16.4 | 15.8 | 0.5 | 3.2% |
| Velocity (m/s) | | -- | 11.181 | 11.190 | 11.225 | 11.199 | 0.023 | 0.2% |

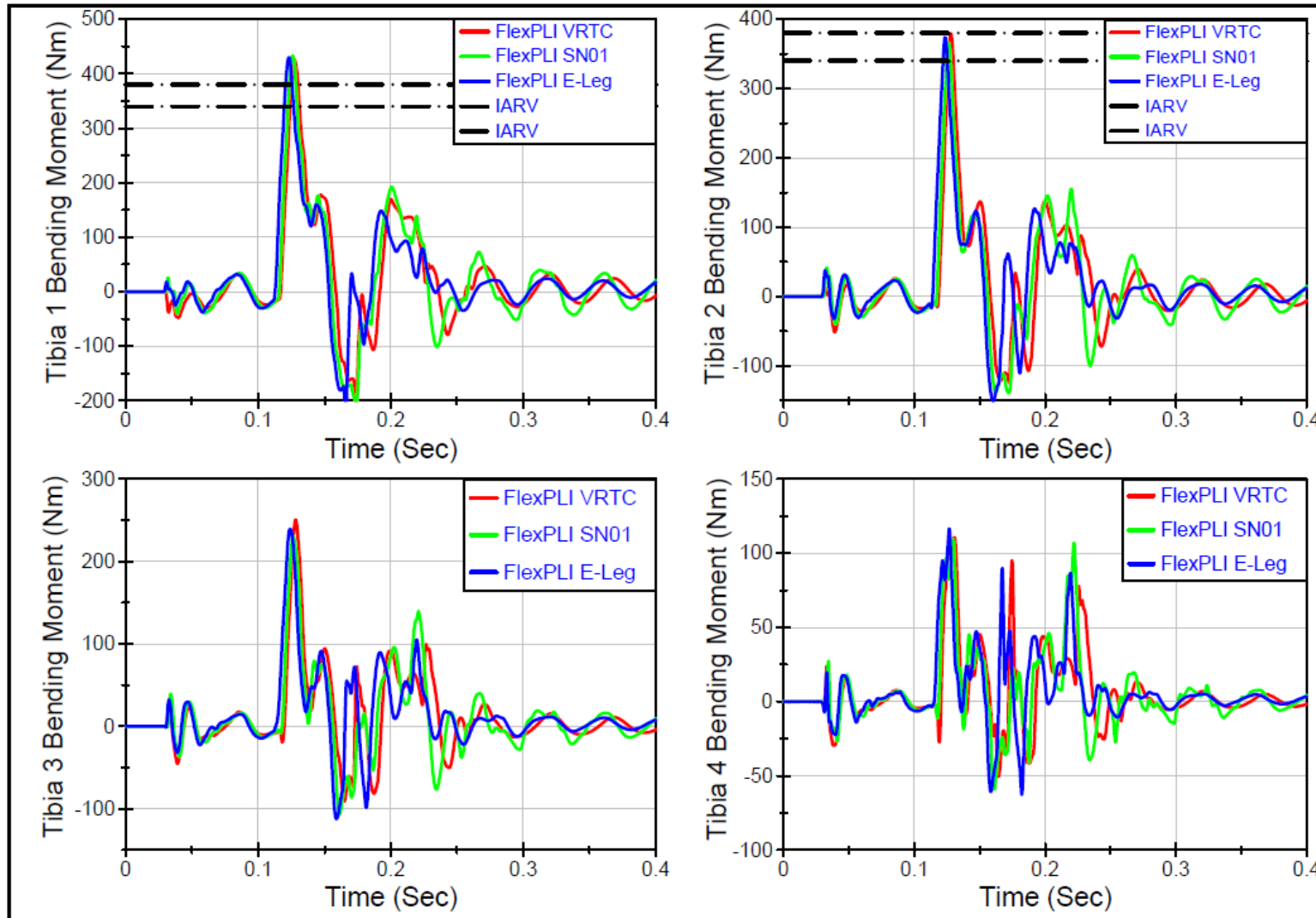
Reproducibility

2006 Volkswagen Passat (VRTC, SN01, E-Leg)



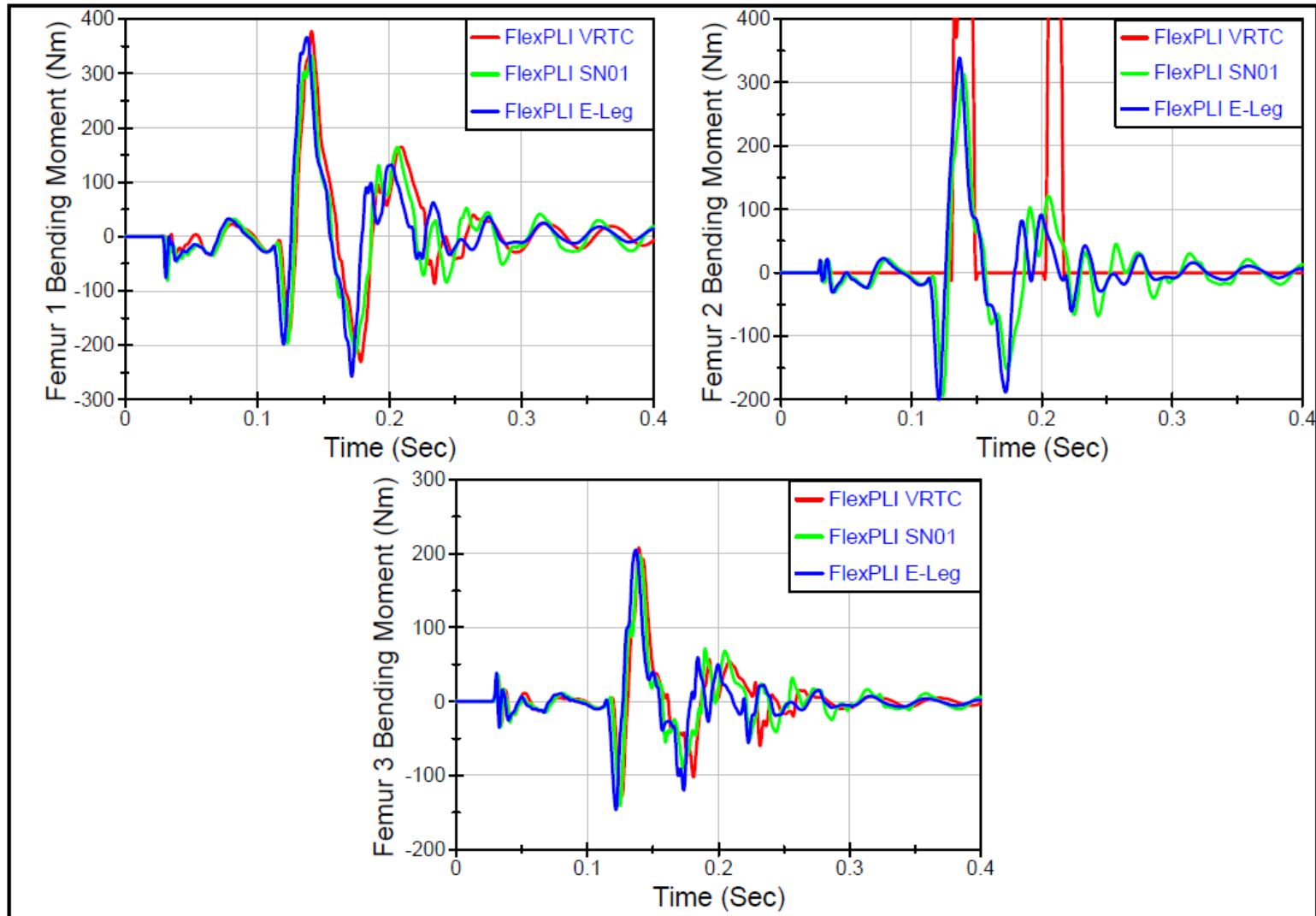
Reproducibility

2006 Volkswagen Passat



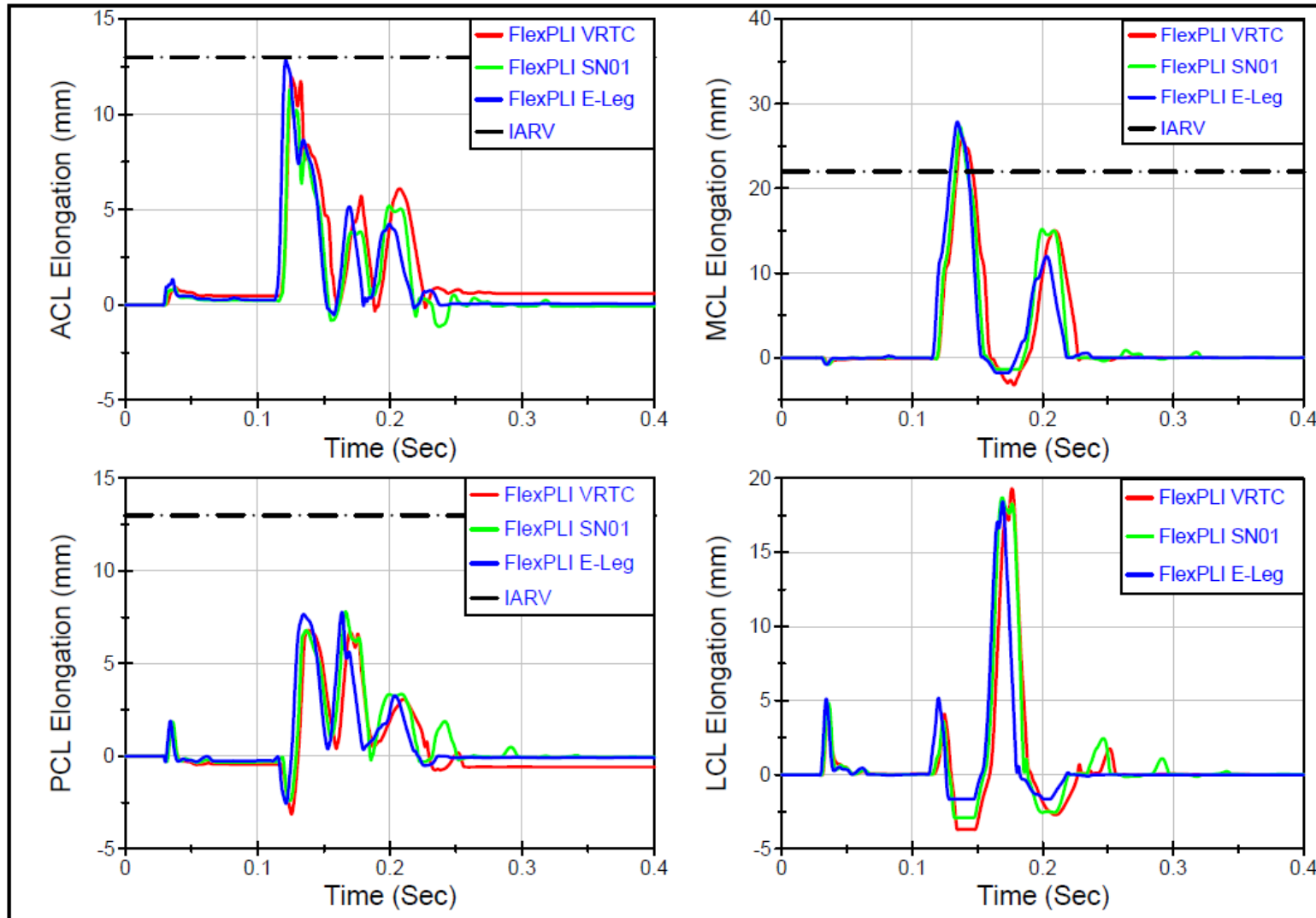
Reproducibility

2006 Volkswagen Passat



Reproducibility

2006 Volkswagen Passat



Reproducibility

2006 Volkswagen Passat

| Injury Measurement | | IARV | 2006 Volkswagen Passat | | | | | |
|-------------------------|---------------------|--------------------|------------------------|--------|--------|--------|-------|------|
| | | | Center Impact | | | | | |
| | | | VRTC* | SN01 | E-Leg | Mean | STDEV | CV |
| Femur Moment (Nm) | Femur 3 (Upper) | -- | 207 | 197 | 205 | 203 | 5.3 | 2.6% |
| | Femur 2 (Middle) | | 484** | 313 | 339 | 326 | 18.4 | 5.6% |
| | Femur 1 (Lower) | | 333 | 333 | 366 | 344 | 19.1 | 5.5% |
| Tibia Moment (Nm) | Tibia 1 (Upper) | 340 Nm (380 Nm) | 426 | 433 | 430 | 430 | 3.5 | 0.8% |
| | Tibia 2 (Mid Upper) | | 379 | 366 | 374 | 373 | 6.6 | 1.8% |
| | Tibia 3 (Mid Lower) | | 251 | 231 | 239 | 240 | 10.1 | 4.2% |
| | Tibia 4 (Lower) | | 111 | 109 | 116 | 112 | 3.6 | 3.2% |
| MCL Elongation (mm) | | 22 mm | 26.1 | 27.3 | 27.9 | 27.1 | 0.9 | 3.4% |
| ACL Elongation (mm) | | 13 mm | 11.9 | 11.3 | 12.8 | 12.0 | 0.8 | 6.3% |
| PCL Elongation (mm) | | 13 mm | 6.8 | 7.8 | 7.8 | 7.5 | 0.6 | 7.7% |
| LCL Elongation (mm) | | -- | 19.3 | 18.7 | 18.4 | 18.8 | 0.5 | 2.4% |
| Velocity (m/s) | | -- | 11.019 | 11.188 | 11.247 | 11.151 | 0.118 | 1.1% |

*VRTC Legform data was presented at the 2012 SAE Government Industry (*NHTSA Evaluation of the Flex-GTR on US Vehicles*)

**The Femur 2 strain gauge of the VRTC legform was damaged during the test and was repaired

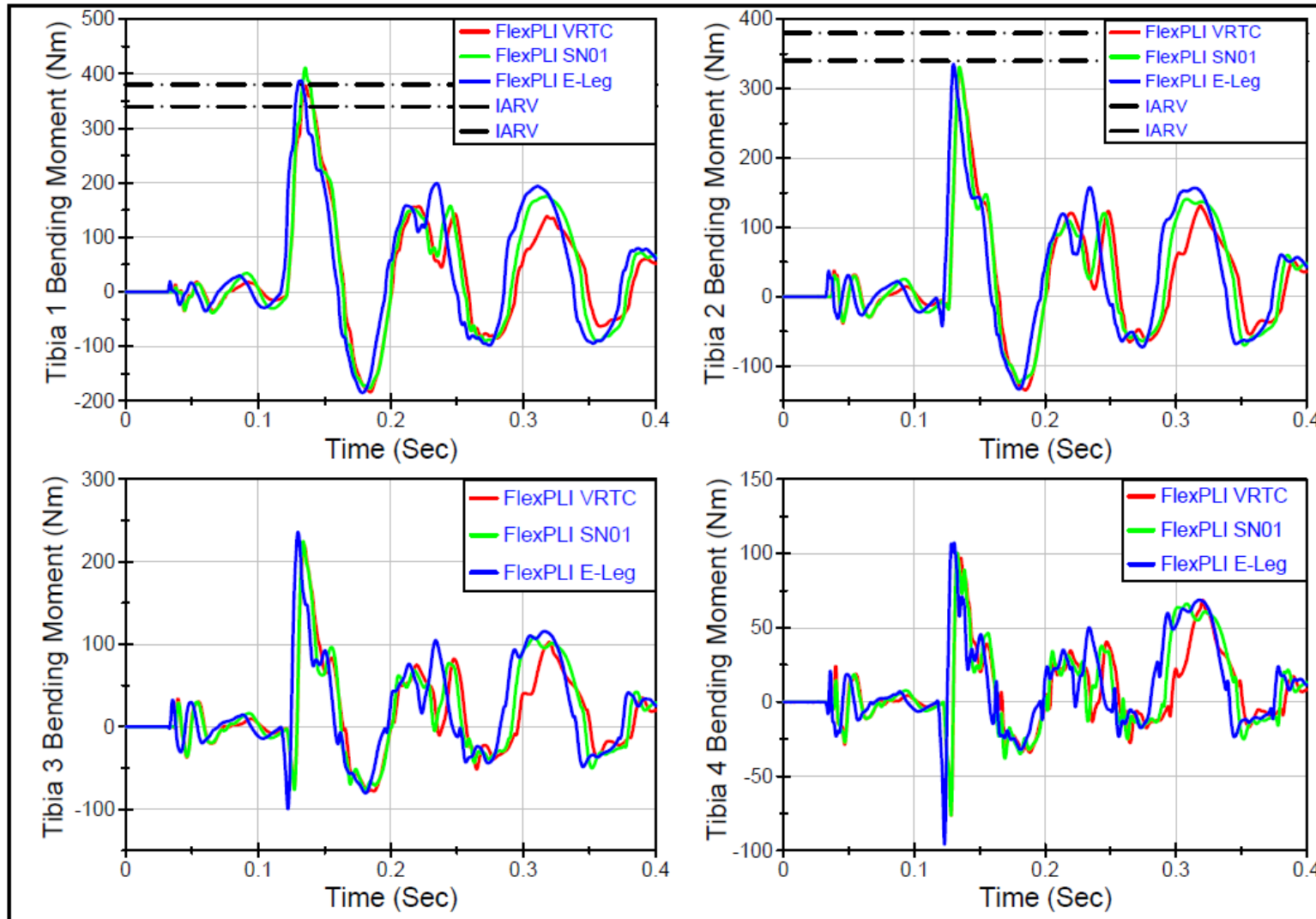
Reproducibility

2011 Hyundai Tucson (VRTC, SN01, E-Leg)



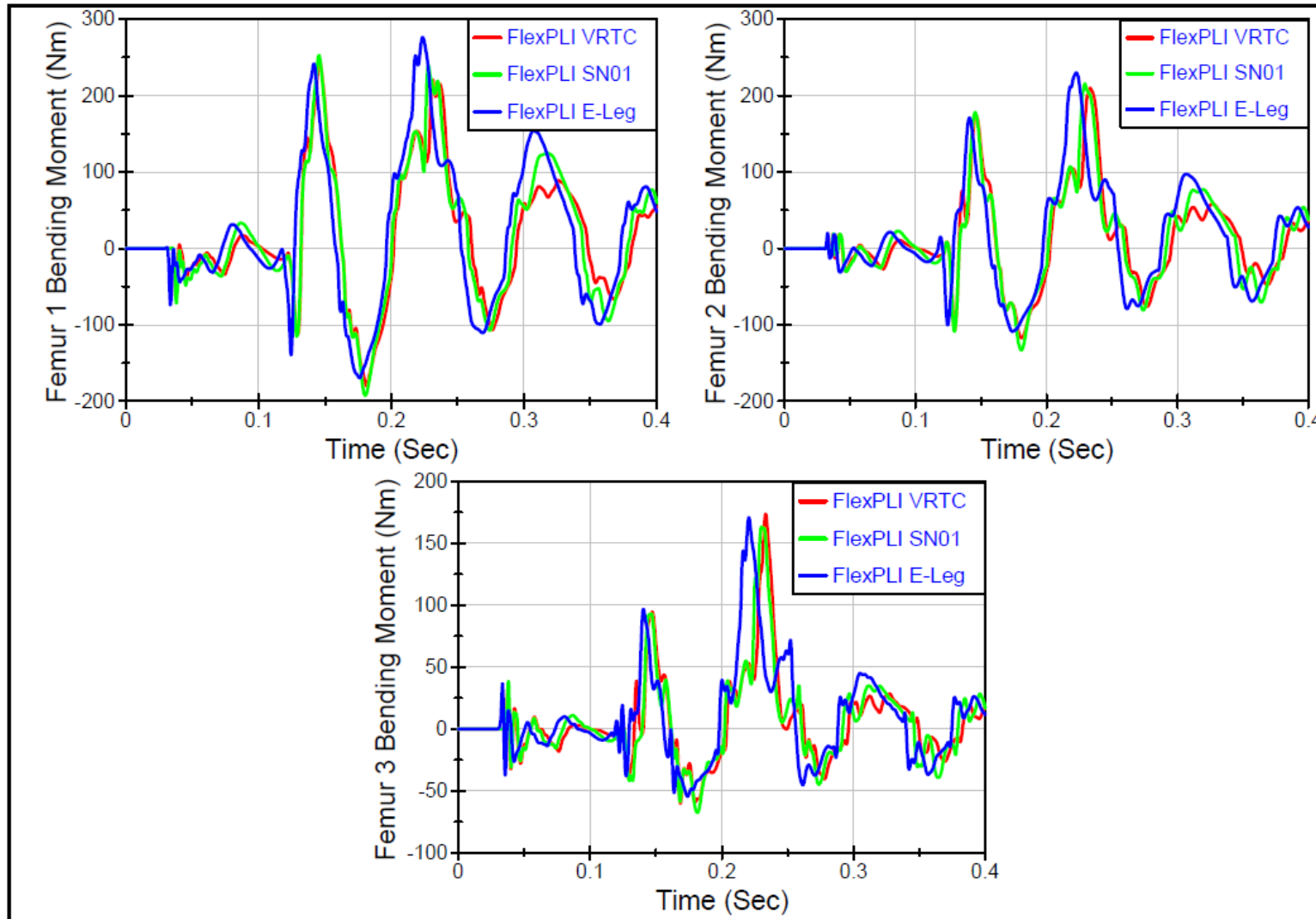
Reproducibility

2011 Hyundai Tucson



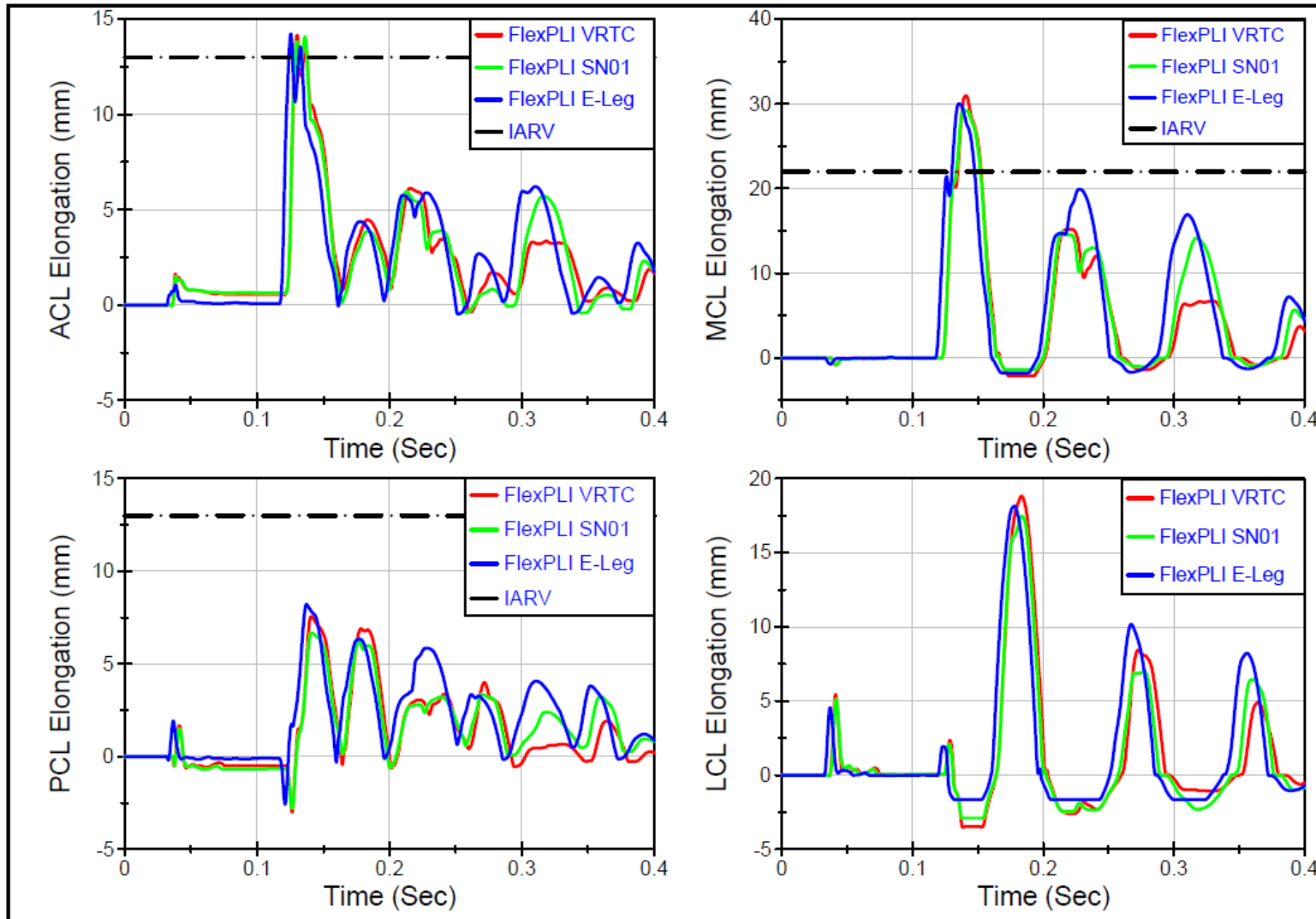
Reproducibility

2011 Hyundai Tucson



Reproducibility

2011 Hyundai Tucson

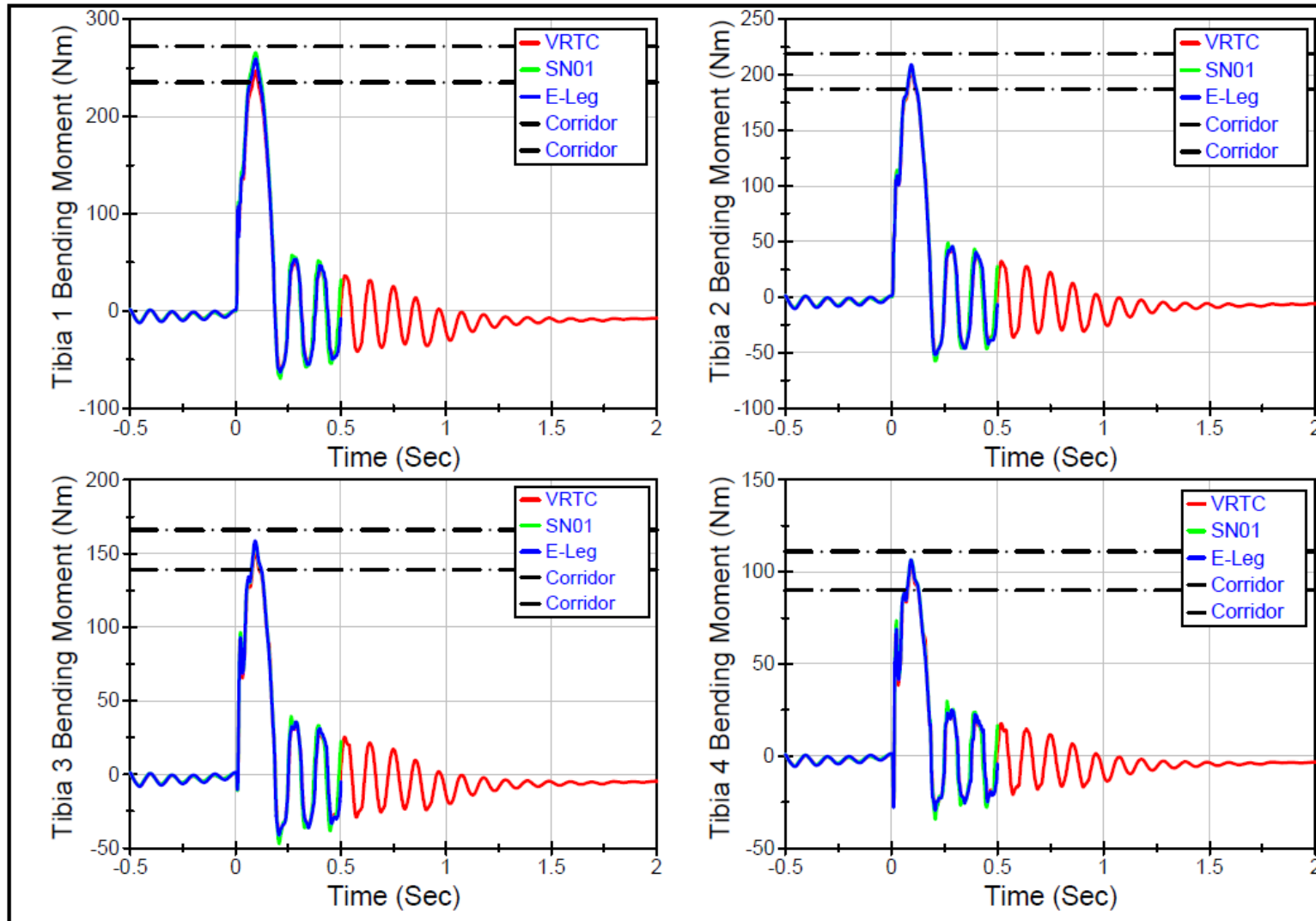


Reproducibility

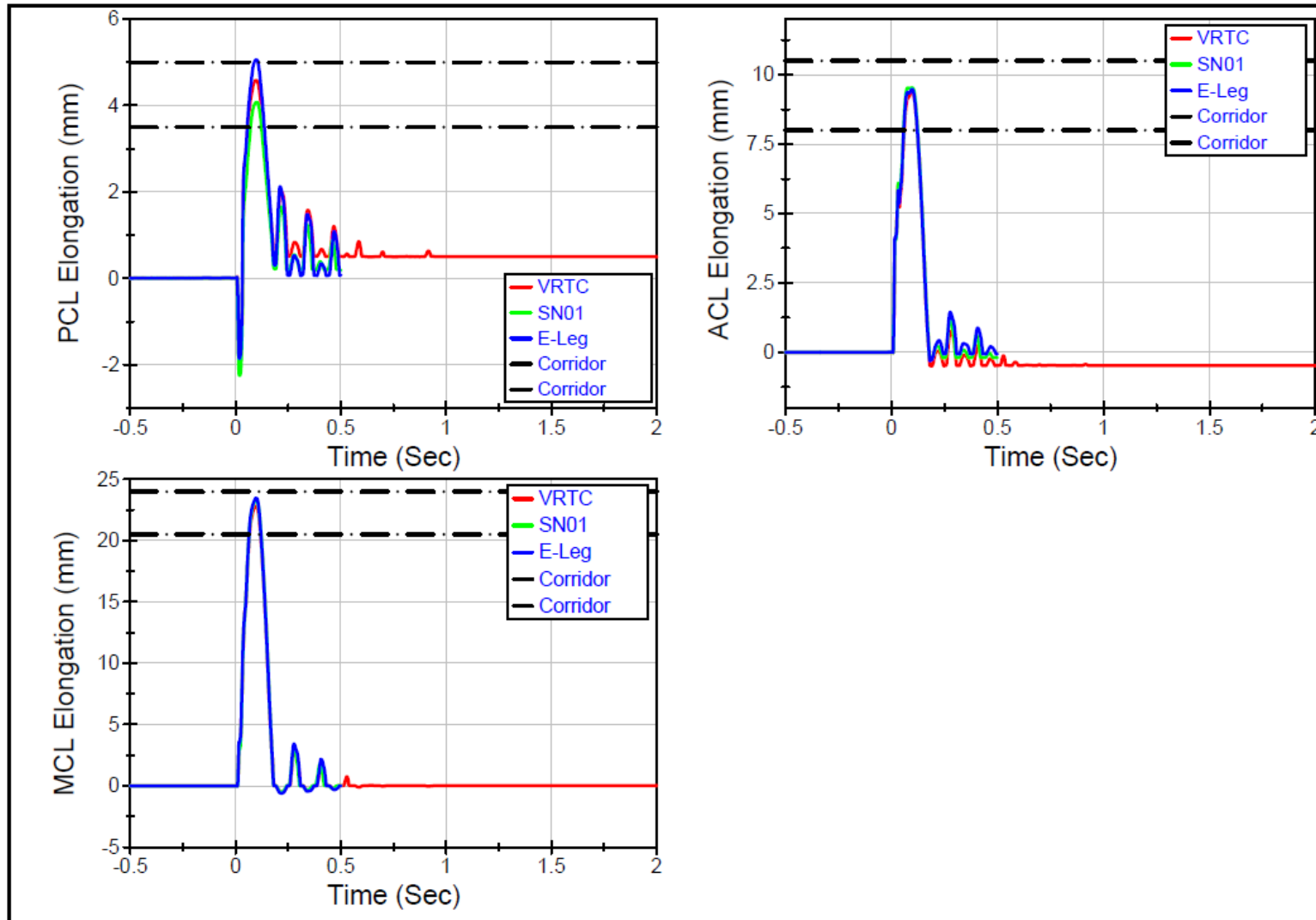
2011 Hyundai Tucson

| Injury Measurement | | IARV | 2011 Hyundai Tucson | | | | | |
|---------------------|---------------------|--------------------|---------------------|--------|--------|--------|-------|-------|
| | | | Center Impact | | | | | |
| | | | VRTC | SN01 | E-Leg | Mean | STDEV | CV |
| Femur Moment (Nm) | Femur 3 (Upper) | -- | 174 | 163 | 171 | 169 | 5.7 | 3.4% |
| | Femur 2 (Middle) | | 210 | 215 | 230 | 218 | 10.4 | 4.8% |
| | Femur 1 (Lower) | | 245 | 253 | 276 | 258 | 16.1 | 6.2% |
| Tibia Moment (Nm) | Tibia 1 (Upper) | 340 Nm (380 Nm) | 378 | 411 | 387 | 392 | 17.1 | 4.4% |
| | Tibia 2 (Mid Upper) | | 329 | 331 | 335 | 332 | 3.1 | 0.9% |
| | Tibia 3 (Mid Lower) | | 220 | 225 | 236 | 227 | 8.2 | 3.6% |
| | Tibia 4 (Lower) | | 100 | 100 | 107 | 102 | 4.0 | 3.9% |
| MCL Elongation (mm) | | 22 mm | 31.0 | 29.3 | 30.0 | 30.1 | 0.9 | 2.8% |
| ACL Elongation (mm) | | 13 mm | 14.1 | 14.1 | 14.2 | 14.1 | 0.1 | 0.4% |
| PCL Elongation (mm) | | 13 mm | 7.6 | 6.7 | 8.2 | 7.5 | 0.8 | 10.1% |
| LCL Elongation (mm) | | -- | 18.8 | 17.5 | 18.1 | 18.1 | 0.7 | 3.6% |
| Velocity (m/s) | | -- | 10.968 | 11.146 | 11.162 | 11.092 | 0.1 | 1.0% |

Pendulum Certification



Pendulum Certification



Pendulum Certification

Pre vehicle testing

| Injury Measurement | Corridor | | Pendulum Certification | | | | | |
|---------------------|----------|-------|------------------------|------------|-------------|------|-------|-------|
| | Lower | Upper | VRTC (Pre) | SN01 (Pre) | E-Leg (Pre) | Mean | STDEV | CV |
| Tibia 1 (Nm) | 235 | 272 | 247 | 266 | 259 | 257 | 9.55 | 3.7% |
| Tibia 2 (Nm) | 187 | 219 | 205 | 208 | 209 | 207 | 2.26 | 1.1% |
| Tibia 3 (Nm) | 139 | 166 | 153 | 157 | 159 | 156 | 2.76 | 1.8% |
| Tibia 4 (Nm) | 90 | 111 | 104 | 106 | 107 | 106 | 1.24 | 1.2% |
| MCL Elongation (mm) | 20.5 | 24 | 22.8 | 23.2 | 23.5 | 23.2 | 0.33 | 1.4% |
| ACL Elongation (mm) | 8 | 10.5 | 9.36 | 9.53 | 9.47 | 9.45 | 0.09 | 0.9% |
| PCL Elongation (mm) | 3.5 | 5 | 4.58 | 4.07 | 5.06 | 4.57 | 0.50 | 10.8% |

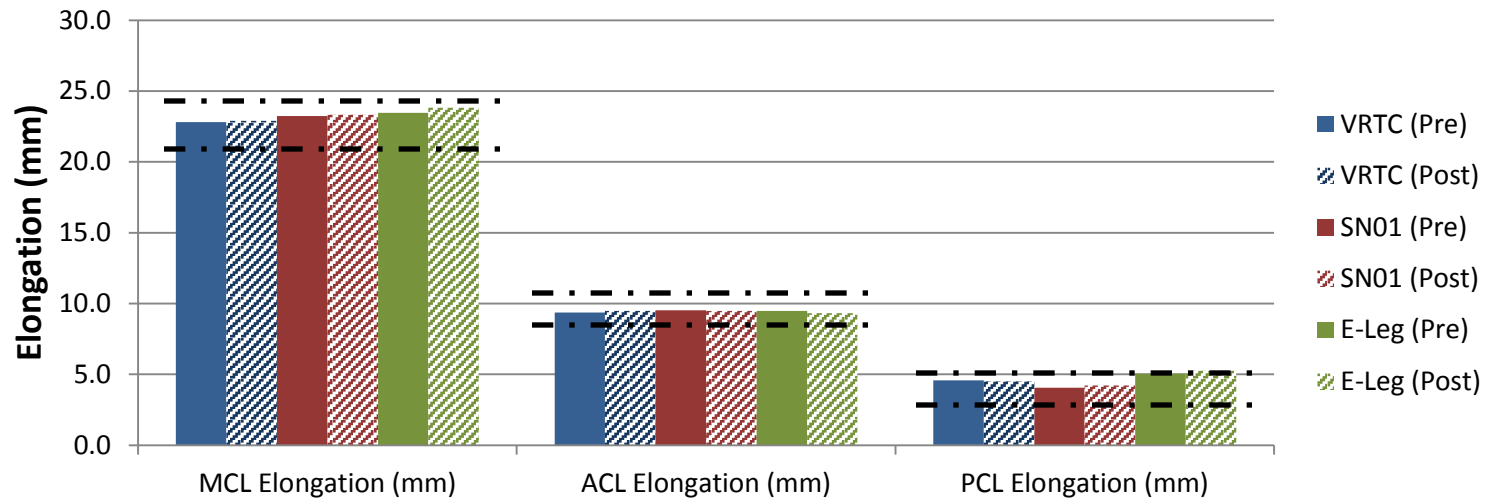
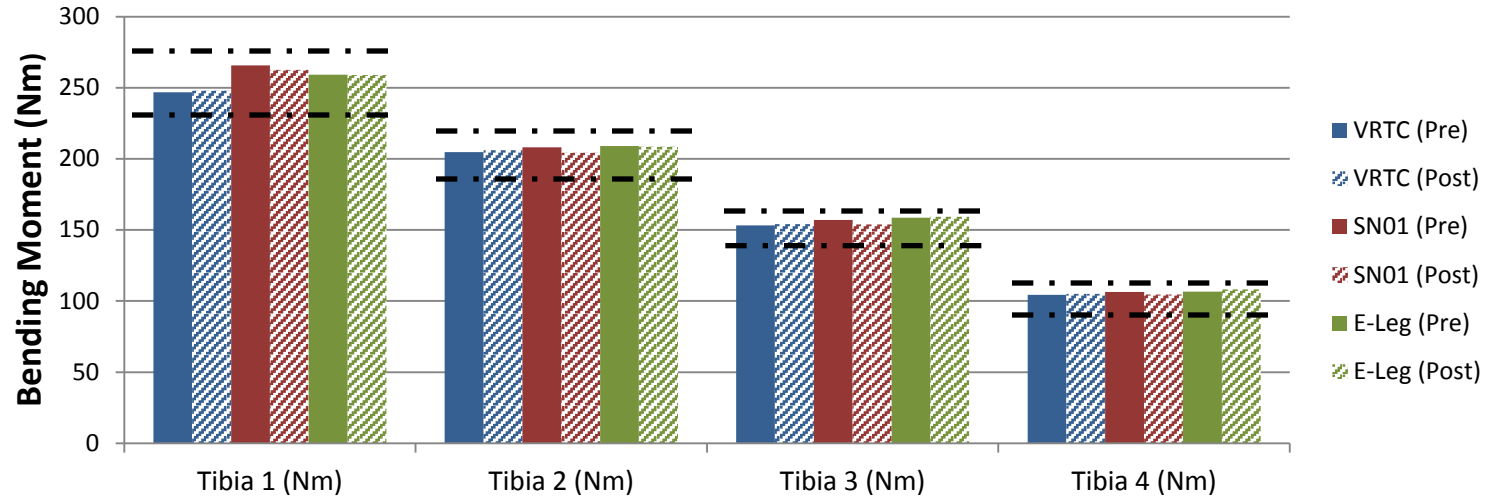
E-Leg PCL elongation did not meet the certification requirement

Post vehicle testing

| Injury Measurement | Corridor | | Pendulum Certification | | | | | |
|---------------------|----------|-------|------------------------|-------------|--------------|------|-------|-------|
| | Lower | Upper | VRTC (Post) | SN01 (Post) | E-Leg (Post) | Mean | STDEV | CV |
| Tibia 1 (Nm) | 235 | 272 | 248 | 263 | 259 | 257 | 7.61 | 3.0% |
| Tibia 2 (Nm) | 187 | 219 | 206 | 204 | 208 | 206 | 2.10 | 1.0% |
| Tibia 3 (Nm) | 139 | 166 | 154 | 154 | 159 | 156 | 3.04 | 2.0% |
| Tibia 4 (Nm) | 90 | 111 | 105 | 104 | 108 | 106 | 2.01 | 1.9% |
| MCL Elongation (mm) | 20.5 | 24 | 22.9 | 23.3 | 23.8 | 23.4 | 0.47 | 2.0% |
| ACL Elongation (mm) | 8 | 10.5 | 9.49 | 9.49 | 9.32 | 9.43 | 0.10 | 1.0% |
| PCL Elongation (mm) | 3.5 | 5 | 4.51 | 4.22 | 5.25 | 4.66 | 0.53 | 11.4% |

E-Leg PCL elongation did not meet the certification requirement

Pendulum Certification



Summary & Observations

- **Flex legforms exhibited very good repeatability & reproducibility on three vehicle classes & in pendulum certification tests**
 - %CV results take into account bumper replacement and test setup
- PCL channel in the E-Leg did not pass the pendulum certification requirements
- Masses of the three legforms are different but within tolerance – required different input pressures to meet speed:
 - VRTC: 13.096 kg
 - SN01: 13.260 kg
 - E-Leg: 13.13 kg
- Test notes:
 - The black protective end caps were not used during testing
 - Tape was used to hold the rubber sheets against the legform instead of the velcro straps
 - The legform hanger was tilted back (approx. 19 degrees) to prevent forward pitch
 - No major damage to the legform was observed
 - Damage to skin and zippers upon receipt of legforms
- Legform-SLICE connection issues
 - Connection issues due to low input voltage or super capacitor discharge
 - Damaged the cable connection that provides input power to the Base SLICE in the VRTC legform

Thank You