Round Robin Test Result [E-Leg]

Dec. 5-7, 2012

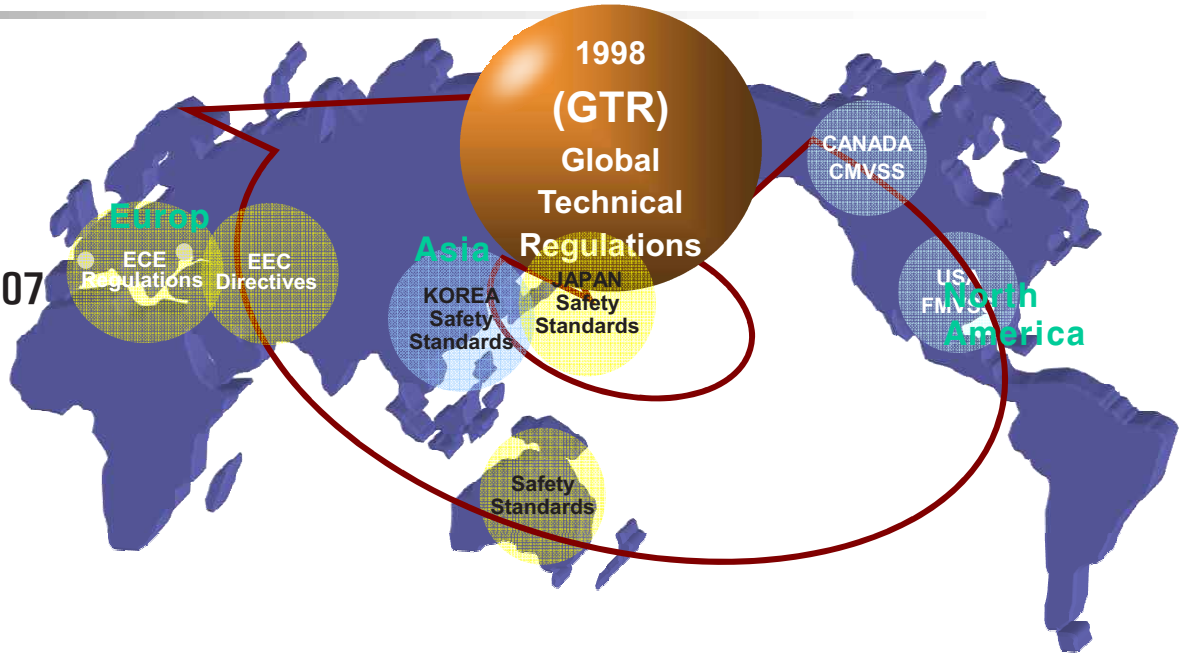
Ministry of Land, Transport and Maritime Affairs (MLTM)
Korea Automobile Testing and Research Institute (KATRI)

MLTM Ministry of Land, Transport and Maritime Affairs
TS Korea Transportation Safety Authority

Background

Regulation & K-NCAP

- Pedestrian protection (K-NCAP)
  - ✓ Headform test had been Started since 2007
  - ✓ Legform test was added since 2008
- Pedestrian protection (KMVSS)
  - ✓ New vehicle (2013)
  - ✓ Old vehicle (2018)



Round Robin Test for Flex-PLi

- Test is conducted by KATRI as a part of Round Robin Test for Flex-PLi (E-Leg)
- The purpose of test is to assess repeatability and reproducibility for Flex-PLi
- Test was composed by real vehicle impacts and dynamic calibration (Pendulum)

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Acquisition of Master Leg(E-Leg)

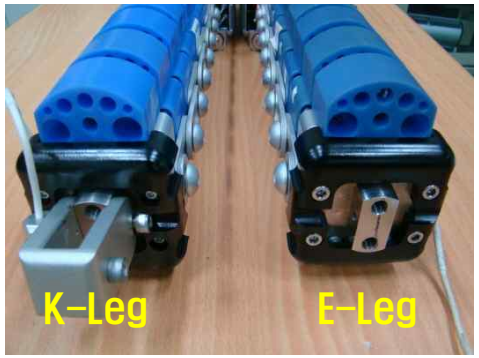
- Date of acquisition : Monday 19 November 2012
- Sending by Germany (HUMANETICS)
- Composition
  - E Leg, Skins, Rubber, DAS and cables etc.

- Date of acquisition : Monday 19 November 2012
- Sending by Japan (HUMANETICS)
- Composition
  - Ballast femur, Femur brocket

Comparison of E-Leg Vs K-Leg

- E-Leg Vs K-Leg : Basically There are no difference
- E-Leg is more stable than K-Leg

Where,
E-Leg : Master leg for Round Robin Test
K-Leg : KATRI possession leg



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Introduction of Test Vehicles and Method

Test Vehicles

- Test Vehicles meet the criteria of GTR No.9 for TRL LFI
- Test Vehicles were rated completely green in the TRL LFI to tests of KNCAP in 2012
- 1 sedan and 1 SUV

Test Method

Impactor type	Flex-PLi(E-Leg) & Flex-PLi(K-Leg)
Impact velocity	11.1±0.2m/s
Impact point	L1, L2, L3 (both of sedan & SUV)
Impact method	(E-Leg)_sedan & SUV 2 impacts at each of L1,L2,L3
	(K-Leg)_only SUV 1 impacts at each of L1,L2,L3
Impact Height	75mm (From ground level)

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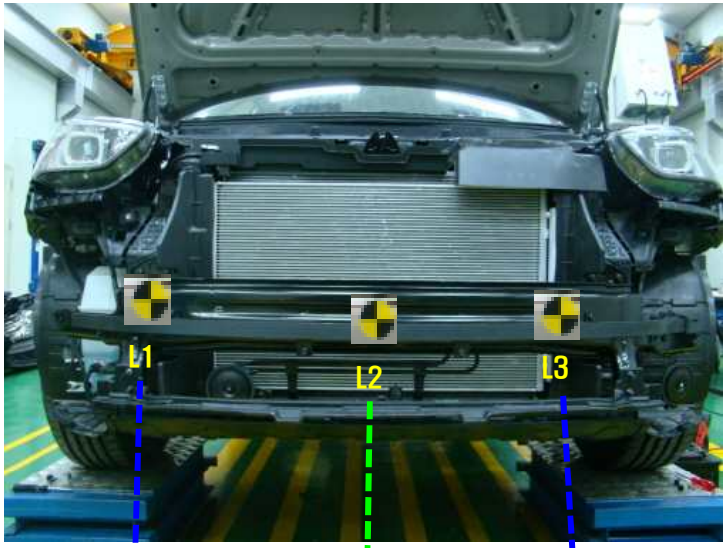
Vehicle Impact Test Process



L2 : 1 impact per 1 bumper

L1 & L3 : 2 impacts per 1 bumper

Impact : L2

Bumper replace

Impact : L1 Impact : L3

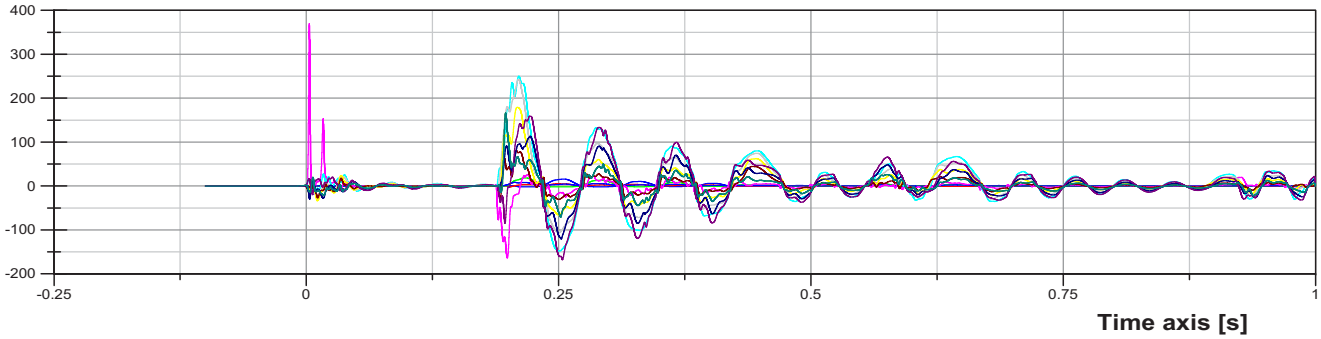
Bumper replace

Bumper replace parts
- Impact beam
- Facer
- Energy absorber
- Lower stiffener

Vehicle Impact Test Result (L2, E-Leg, SUV)

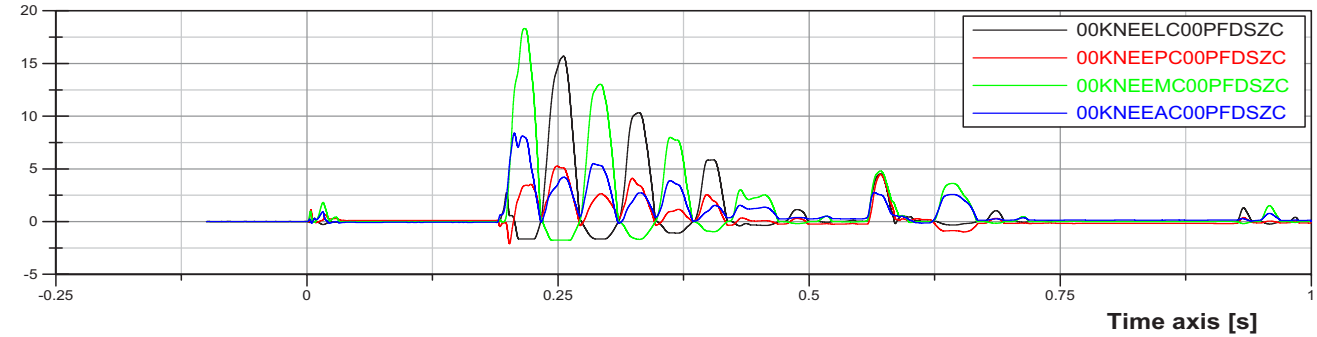
Pedestrian Lower Legform Impact Test - Flex PLI

KATRI



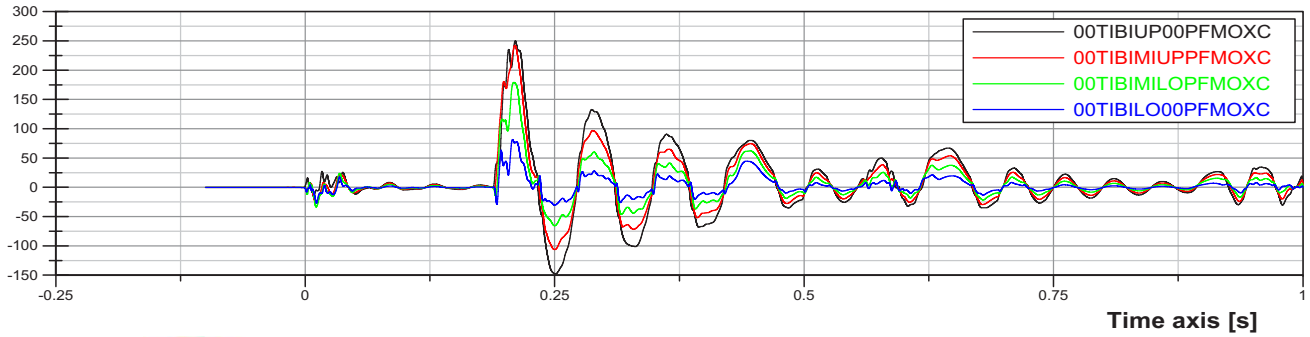
 # Test Information

Date : 2012-11-23
Test Name : RRT -L2-T2
Vehicle Name :
Impact Speed : 40.03



 # Knee Elongation(mm) / CFC_180

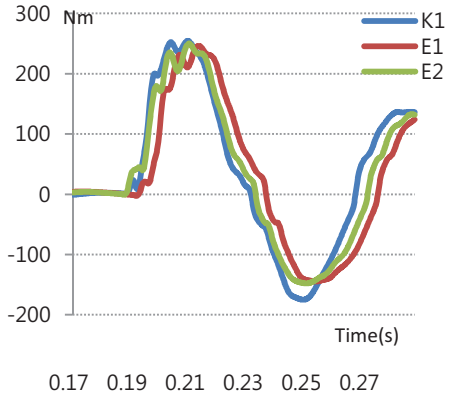
LCL : 15.70 mm
PCL : 5.27 mm
MCL : 18.31 mm
ACL : 8.40 mm
Max : 18.31 mm



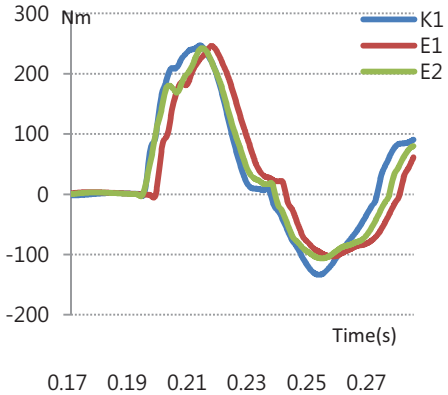
 # Tibia BM(Nm) / CFC_180

T1-BM : 250.11 Nm
T2-BM : 242.42 Nm
T3-BM : 179.10 Nm
T4-BM : 81.56 Nm
Max : 250.11 Nm

Vehicle Impact Test Result (L2, E/K-Leg, SUV)



Tibia 1



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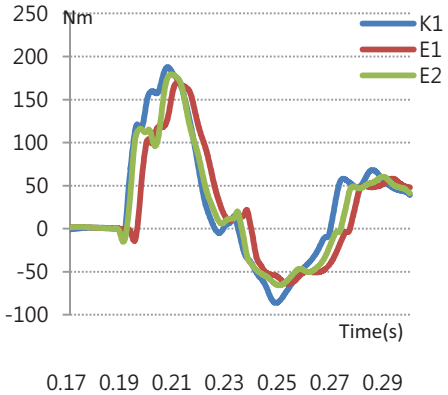
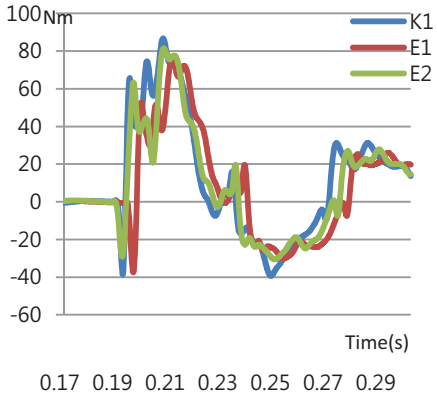
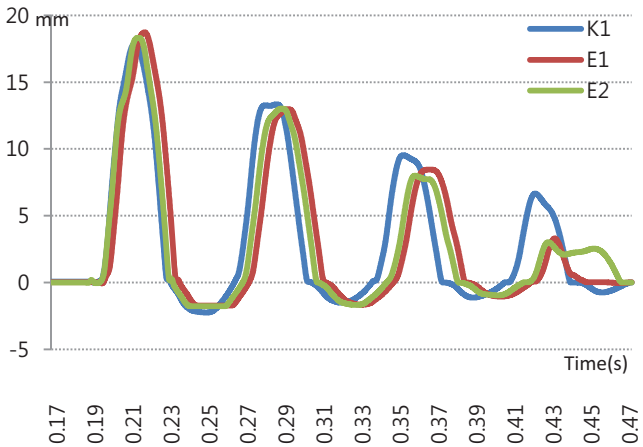


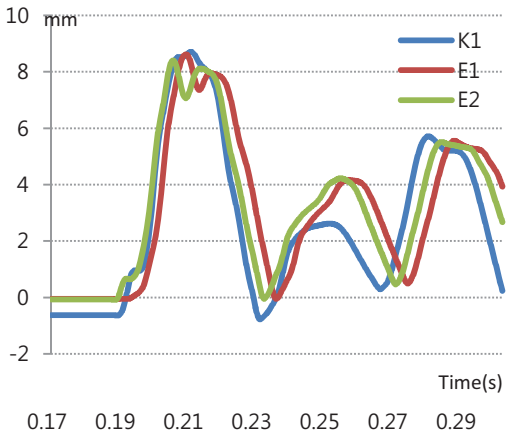
Tibia 3



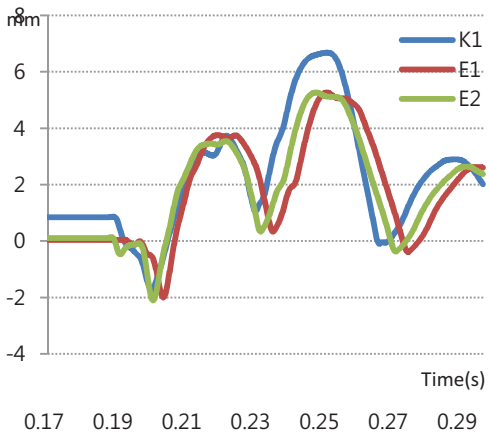
Tibia 4



MCL

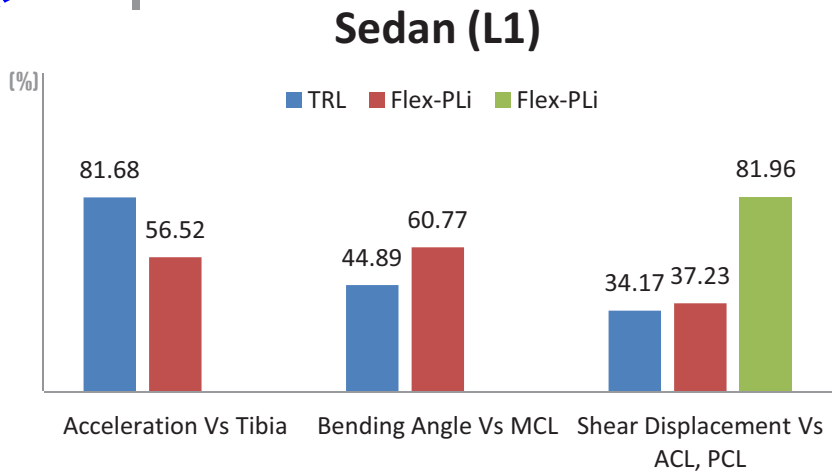


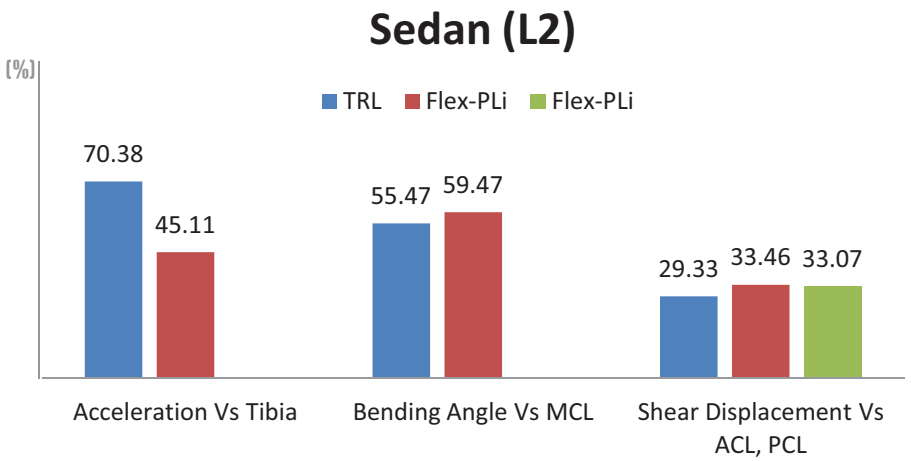
ACL

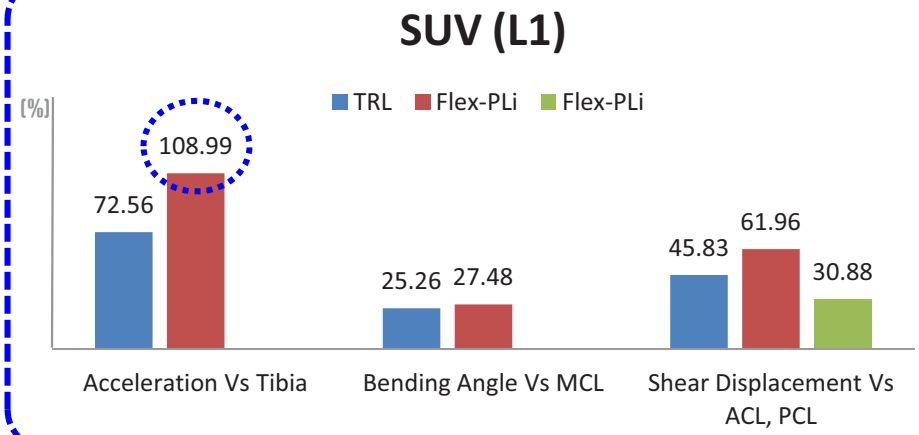


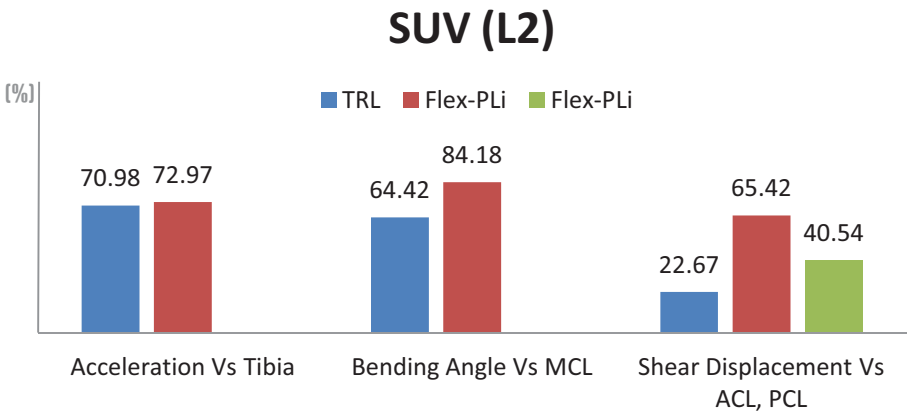
PCL

Comparison Injury Assessment between TRL Vs Flex-PLi









Tibia Acceleration limitation of 170g
-> Tibia Bending moment : 340Nm

Bending limitation of 19 deg.
-> MCL Elongation : 22mm

Shear displacement limitation of 6mm
-> ACL/PCL Elongation : 13mm

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Repeatability E-Leg (Sedan)

		TIBIA 1	TIBIA 2	TIBIA 3	TIBIA 4	MCL	ACL	PCL
L1	TEST-1	138.2	143.2	147.2	202.9	13.9	4.6	10.6
	TEST-2	164.1	180.1	181.5	165.9	12.9	5.1	10.7
	MEAN	151.15	161.65	164.35	184.4	13.4	4.85	10.65
	ST.DEV	18.314	26.092	24.254	26.163	0.7071	0.3536	0.0707
	C.V	0.1212	0.1614	0.1476	0.1419	0.0528	0.0729	0.0066
	C.V(%)	12.12	16.14	14.76	14.19	5.28	7.29	0.66
L2		TIBIA 1	TIBIA 2	TIBIA 3	TIBIA 4	MCL	ACL	PCL
	TEST-1	136.3	149.4	123.6	116	13.3	4.7	4.6
	TEST-2	114.5	157.4	139.6	127.7	12.9	4	4
	MEAN	125.4	153.4	131.6	121.85	13.1	4.35	4.3
	ST.DEV	15.415	5.6569	11.314	8.2731	0.2828	0.495	0.4243
	C.V	0.1229	0.0369	0.086	0.0679	0.0216	0.1138	0.0987
	C.V(%)	12.29	3.69	8.60	6.79	2.16	11.38	9.87
L3		TIBIA 1	TIBIA 2	TIBIA 3	TIBIA 4	MCL	ACL	PCL
	TEST-1	190.5	185.8	150.8	123.9	16.7	7	6.8
	TEST-2	204.4	177.5	165.3	126	17.6	7.8	5.7
	MEAN	197.45	181.65	158.05	124.95	17.15	7.4	6.25
	ST.DEV	9.8288	5.869	10.253	1.4849	0.6364	0.5657	0.7778
	C.V	0.0498	0.0323	0.0649	0.0119	0.0371	0.0764	0.1245
	C.V(%)	4.98	3.23	6.49	1.19	3.71	7.64	12.45

CV = 3%	3% < CV = 7%	7% < CV = 10%	CV > 10
good	acceptable	marginal	not acceptable

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Repeatability E-Leg (SUV)

		TIBIA 1	TIBIA 2	TIBIA 3	TIBIA 4	MCL	ACL	PCL
L1	TEST-1	251.8	361.8	302.5	122.3	6.8	7.9	4.6
	TEST-2	252.4	379.3	356.5	138	5.4	8.2	3.5
	MEAN	252.1	370.55	329.5	130.15	6.1	8.05	4.05
	ST.DEV	0.4243	12.374	38.184	11.102	0.9899	0.2121	0.7778
	C.V	0.0017	0.0334	0.1159	0.0853	0.1623	0.0264	0.1921
	C.V(%)	0.17	3.34	11.59	8.53	16.23	2.64	19.21
L2		TIBIA 1	TIBIA 2	TIBIA 3	TIBIA 4	MCL	ACL	PCL
	TEST-1	246	246.1	169.8	77.1	18.7	8.6	5.3
	TEST-2	250.1	242.4	179.1	81.6	18.3	8.4	5.2
	MEAN	248.05	244.25	174.45	79.35	18.5	8.5	5.25
	ST.DEV	2.8991	2.6163	6.5761	3.182	0.2828	0.1414	0.0707
	C.V	0.0117	0.0107	0.0377	0.0401	0.0153	0.0166	0.0135
	C.V(%)	1.17	1.07	3.77	4.01	1.53	1.66	1.35
L3		TIBIA 1	TIBIA 2	TIBIA 3	TIBIA 4	MCL	ACL	PCL
	TEST-1	257.5	311.4	226.9	105.4	16.8	6.9	4.7
	TEST-2	228	299	289.4	122.5	12.5	6.5	4
	MEAN	242.75	305.2	258.15	113.95	14.65	6.7	4.35
	ST.DEV	20.86	8.7681	44.194	12.092	3.0406	0.2828	0.495
	C.V	0.0859	0.0287	0.1712	0.1061	0.2075	0.0422	0.1138
	C.V(%)	8.59	2.87	17.12	10.61	20.75	4.22	11.38

CV = 3%	3% < CV = 7%	7% < CV = 10%	CV > 10
good	acceptable	marginal	not acceptable

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Repeatability E-Leg Vs K-Leg (SUV)

		TIBIA 1	TIBIA 2	TIBIA 3	TIBIA 4	MCL	ACL	PCL
L1	E-Leg	252.1	370.6	329.5	130.2	6.1	8.1	4
	K-Leg	240.73	352	340.83	146.51	3.72	6.61	3
	MEAN	246.42	361.3	335.17	138.36	4.91	7.355	3.5
	ST.DEV	8.0398	13.152	8.0115	11.533	1.6829	1.0536	0.7071
	C.V	0.0326	0.0364	0.0239	0.0834	0.3428	0.1432	0.202
	C.V(%)	3.26	3.64	2.39	8.34	34.28	14.32	20.20
		TIBIA 1	TIBIA 2	TIBIA 3	TIBIA 4	MCL	ACL	PCL
L2	E-Leg	248	246.8	174.4	79.3	18.5	8.5	5.2
	K-Leg	254.5	246.89	178.63	86.75	17.83	8.7	6.68
	MEAN	251.25	246.85	176.52	83.025	18.165	8.6	5.94
	ST.DEV	4.5962	0.0636	2.9911	5.2679	0.4738	0.1414	1.0465
	C.V	0.0183	0.0003	0.0169	0.0635	0.0261	0.0164	0.1762
	C.V(%)	1.83	0.03	1.69	6.35	2.61	1.64	17.62
		TIBIA 1	TIBIA 2	TIBIA 3	TIBIA 4	MCL	ACL	PCL
L3	E-Leg	242.7	305.2	258.2	113.9	14.6	6.7	4.4
	K-Leg	245.7	278.1	277.2	134.1	14.4	6.5	4.45
	MEAN	244.2	291.65	267.7	124	14.5	6.6	4.425
	ST.DEV	2.1213	19.163	13.435	14.284	0.1414	0.1414	0.0354
	C.V	0.0087	0.0657	0.0502	0.1152	0.0098	0.0214	0.008
	C.V(%)	0.87	6.57	5.02	11.52	0.98	2.14	0.80

CV = 3%	3% < CV = 7%	7% < CV = 10%	CV > 10
good	acceptable	marginal	not acceptable

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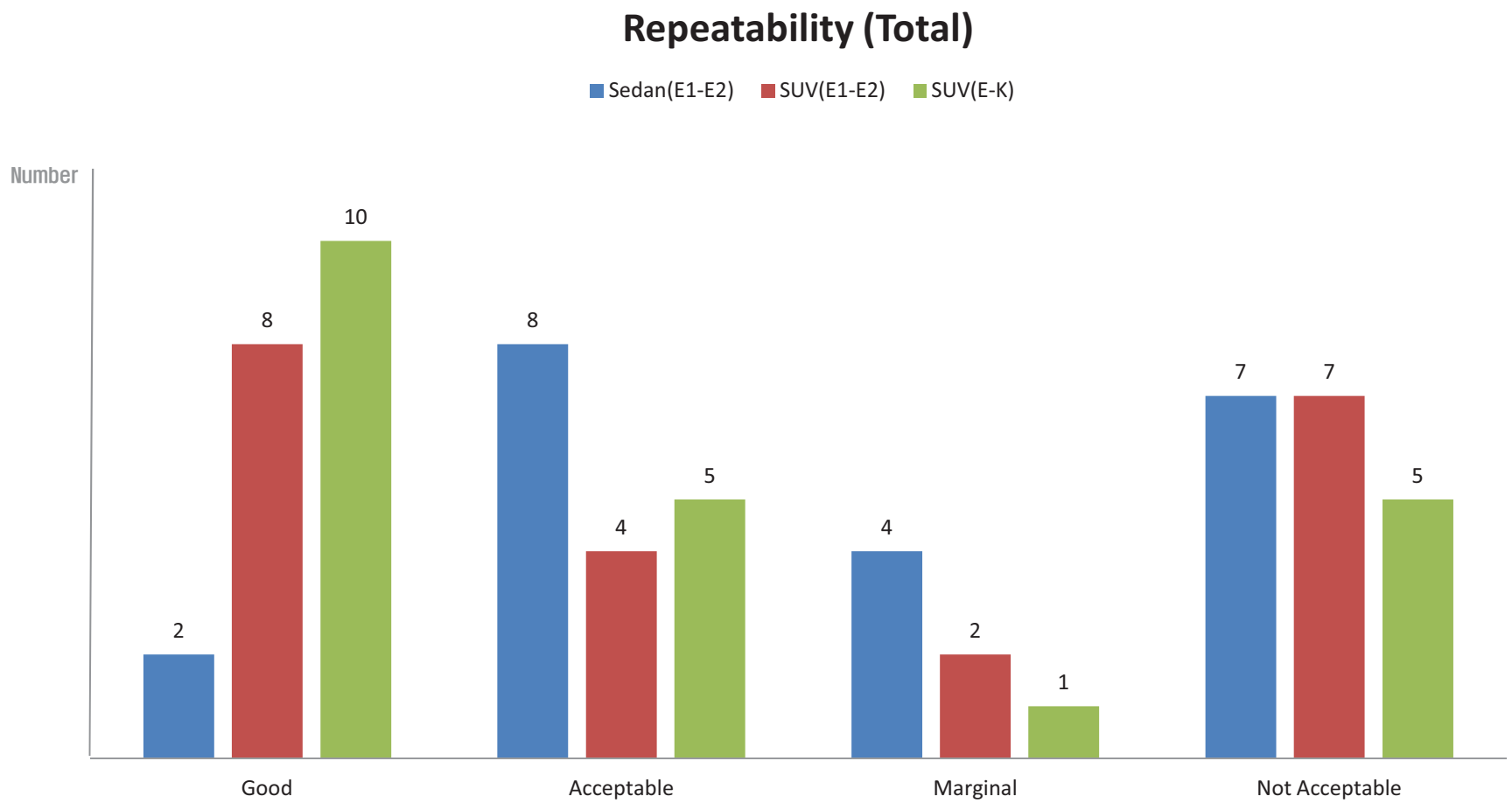
Repeatability (Overall)



CV = 3%	3% < CV = 7%	7% < CV = 10%	CV > 10
good	acceptable	marginal	not acceptable

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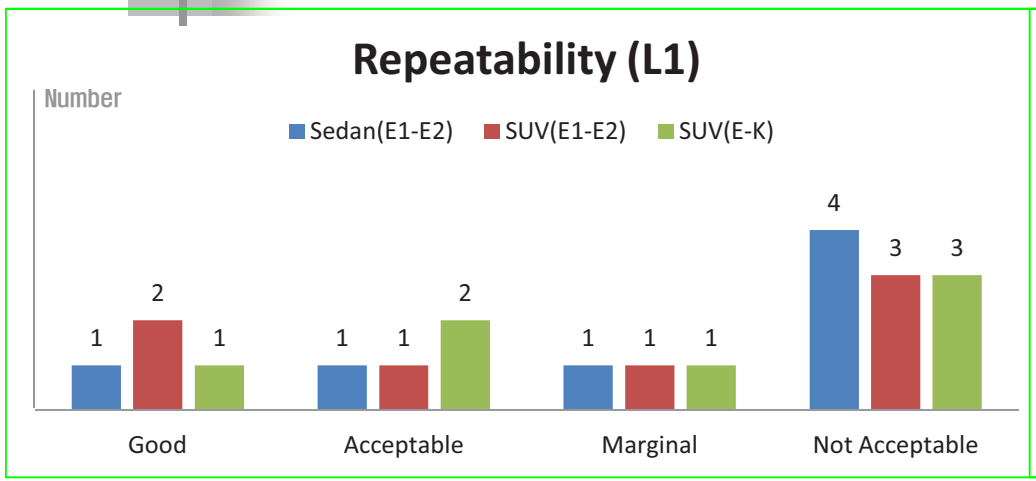
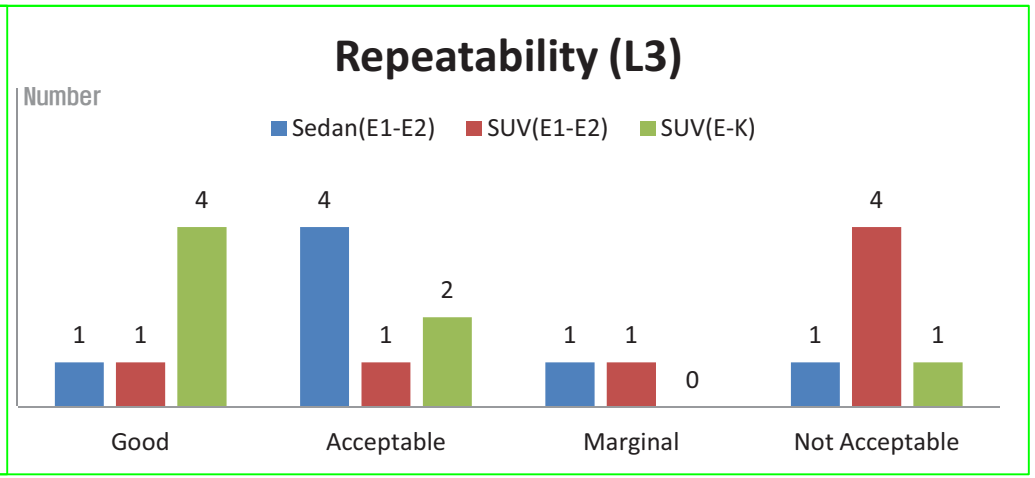
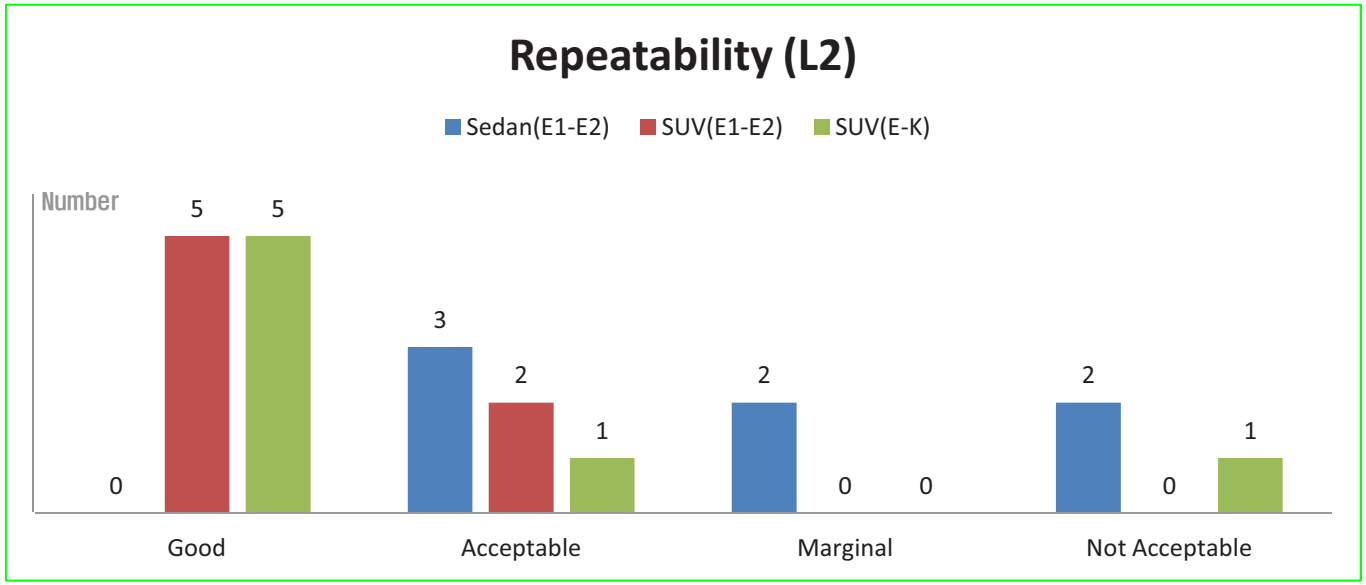
Repeatability (L1/L2/L3)







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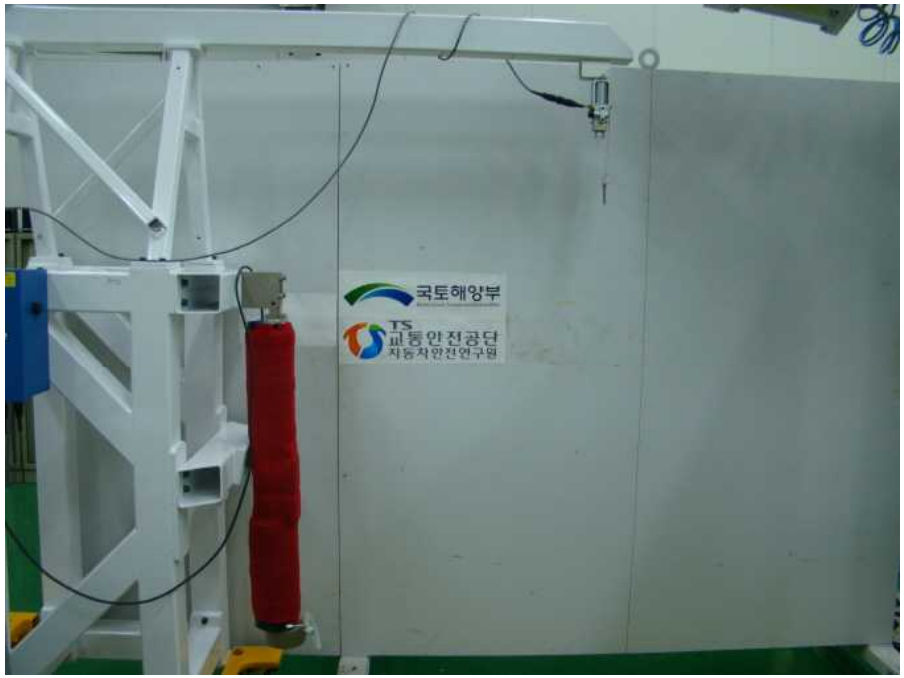
CV = 3%	3% < CV = 7%	7% < CV = 10%	CV > 10
good	acceptable	marginal	not acceptable

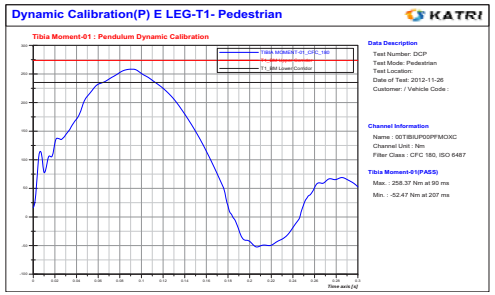
Dynamic Calibration (Pendulum) Test

Pre-Test

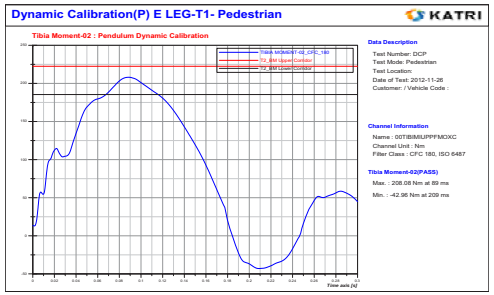


Post-Test

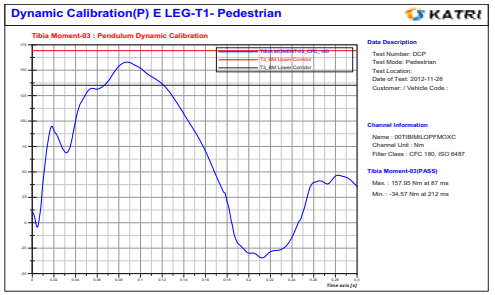
Dynamic Calibration Test result (E-Leg test-1)



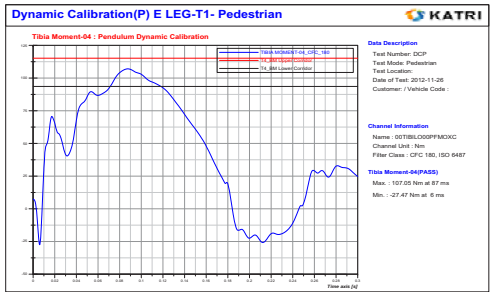
Tibia 1



Tibia 2



Tibia 3



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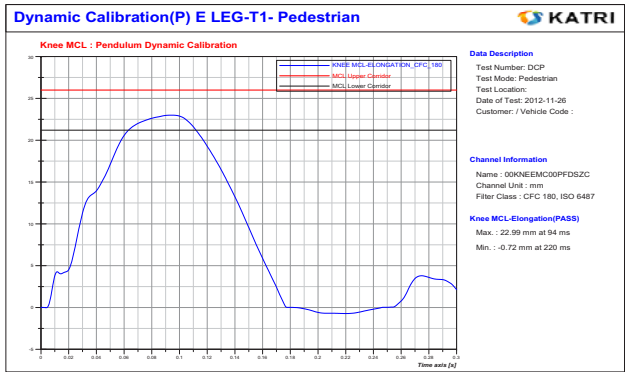
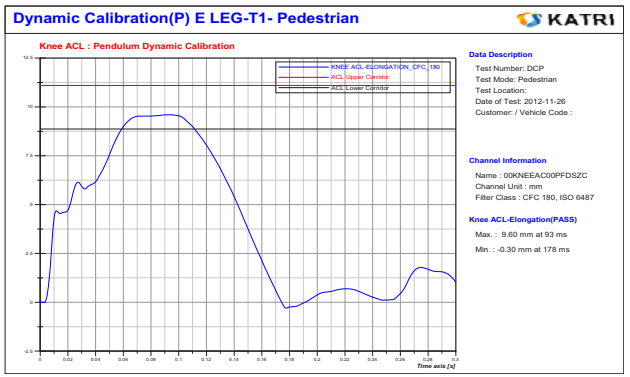
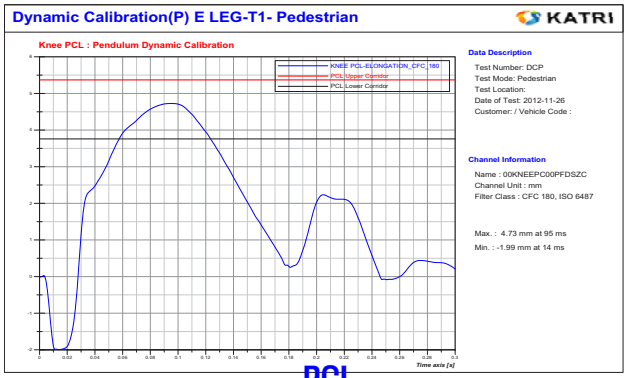


MCL



ACL



PCL

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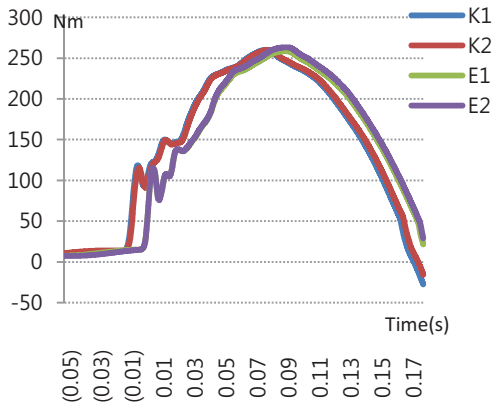
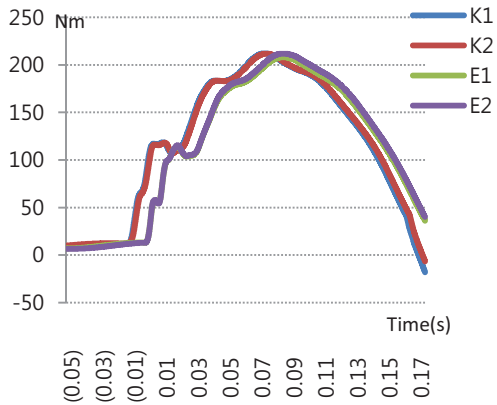
Dynamic Calibration Test result (E-Leg & K-Leg)



Tibia 1



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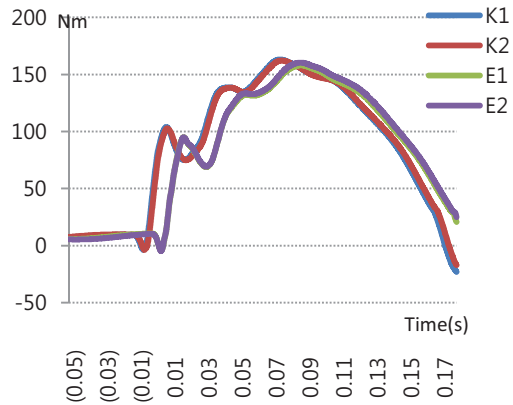

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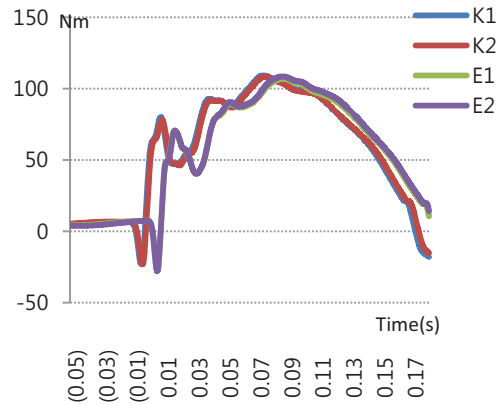
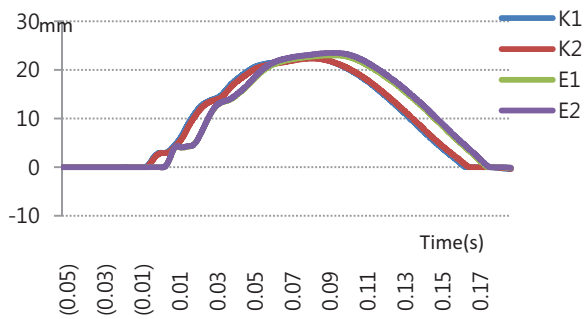
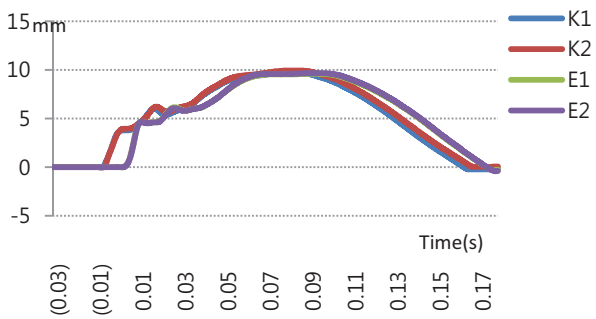


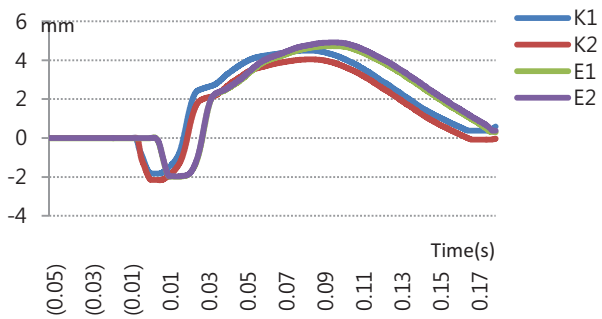
Tibia 4



MCL



ACL



PCL

Repeatability E-Leg Vs K-Leg (Dynamic calibration)

		TIBIA 1	TIBIA 2	TIBIA 3	TIBIA 4	MCL	ACL	PCL
E Leg	TEST-1	258.37	208.08	157.95	107.05	22.99	9.6	4.73
	TEST-2	263.26	211.85	160.27	108.56	23.49	9.68	4.91
	MEAN	260.82	209.97	159.11	107.81	23.24	9.64	4.82
	ST.DEV	3.4578	2.6658	1.6405	1.0677	0.3536	0.0566	0.1273
	C.V	0.0133	0.0127	0.0103	0.0099	0.0152	0.0059	0.0264
	C.V(%)	1.33	1.27	1.03	0.99	1.52	0.59	2.64
K Leg		TIBIA 1	TIBIA 2	TIBIA 3	TIBIA 4	MCL	ACL	PCL
	TEST-1	260.03	212.18	163.06	109.31	22.46	9.74	4.49
	TEST-2	259.97	211.82	162.17	108.43	22.28	9.94	4.04
	MEAN	260	212	162.62	108.87	22.37	9.84	4.265
	ST.DEV	0.0424	0.2546	0.6293	0.6223	0.1273	0.1414	0.3182
	C.V	0.0002	0.0012	0.0039	0.0057	0.0057	0.0144	0.0746
	C.V(%)	0.02	0.12	0.39	0.57	0.57	1.44	7.46
E Vs K		TIBIA 1	TIBIA 2	TIBIA 3	TIBIA 4	MCL	ACL	PCL
	E-Leg	260.82	209.97	159.11	107.81	23.24	9.64	4.82
	K-Leg	260	212	162.62	108.87	22.37	9.84	4.265
	MEAN	260.41	210.98	160.86	108.34	22.805	9.74	4.5425
	ST.DEV	0.5763	1.439	2.4784	0.7531	0.6152	0.1414	0.3924
	C.V	0.0022	0.0068	0.0154	0.007	0.027	0.0145	0.0864
	C.V(%)	0.22	0.68	1.54	0.70	2.70	1.45	8.64

CV = 3%	3% < CV = 7%	7% < CV = 10%	CV > 10
good	acceptable	marginal	not acceptable

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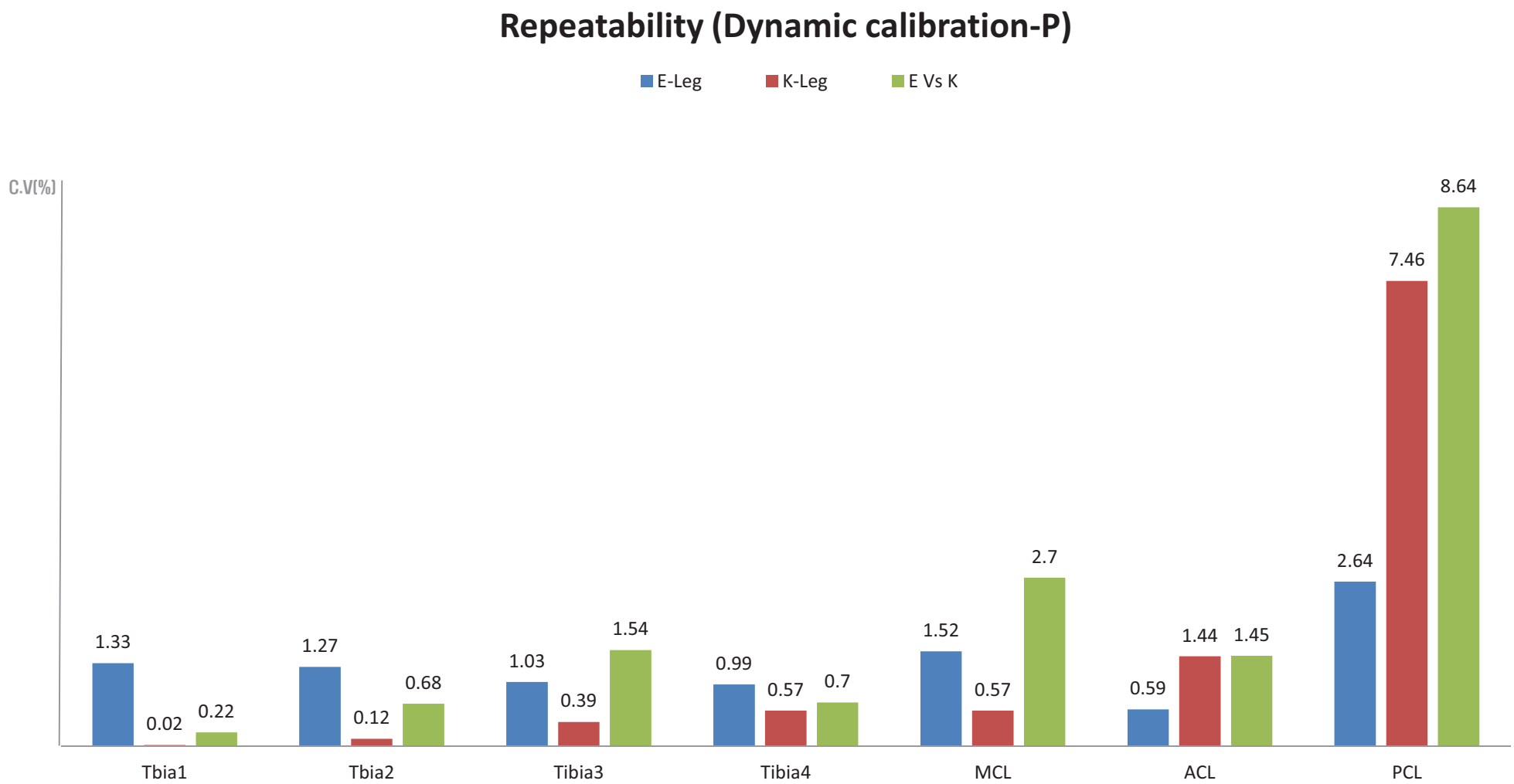
Repeatability E-Leg Vs K-Leg (Dynamic calibration)



CV = 3%	3% < CV = 7%	7% < CV = 10%	CV > 10
good	acceptable	marginal	not acceptable

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Summary-1

KATRI have conducted the round robin test and Findings up to now are as follows,

- Comparison for injury assessment between TRL and Flex-PLi (sedan & SUV)
  - ✓ Vehicles meet the criteria of TRL LFI almost also meet Flex-PLi (except for 1 Tibia value)
  - ✓ This result should not apply for every vehicle but only result for relevant this test vehicles
- Comparison for repeatability of vehicles impact test (sedan & SUV)
  - ✓ Sedan : Repeatability is almost not good result
    - – The cause is basically not stiff enough, so some deformation of FEM(H/L) was happened
    - – Bumper Replace times (L2 : 1 impact per 1 bumper, L1/L3 : 2 impacts per 1 bumper)
      - ※ First impact of L1/L3 area had an effect on rest impact point (ex, Lower stiffener bending)
  - ✓ SUV : Repeatability (L2) is good result, but other points are not good result
    - – The cause is impact per 1 bumper, and shape of bumper is simple and flat (L2)
    - – Bumper replace times (L2 : 1 impact per 1 bumper, L1/L3 : 2 impacts per 1 bumper)
      - ※ First impact of L1/L3 area had an effect on rest impact point (ex, Lower stiffener bending)
    - – Bumper shape of L1/L3 area is more complex relatively than L2 area

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Summary-2

- **Comparison for repeatability of dynamic calibration (Pendulum)**
  - ✓ Both of E-Leg and K-Leg are almost good repeatability for dynamic calibration
  - ✓ Repeatability of E-Leg is good result (ALL of injury items are good value, cv%)
  - ✓ Repeatability of K-Leg is good result except for PCL (PCL is marginal value, cv%)

- **Durability and Usability**
  - ✓ No serious issues on the durability and usability

- **Some improvements are needed**
  - ✓ As for spare parts : Zipper and zipper hook are not enough strong
  - ✓ As for connector : More hardness is needed to protect connector from damage and to download data safely

Thank you for your attention