



Comparison of FlexPLI Performance in Vehicle Tests with Prototype and Series Production Legforms

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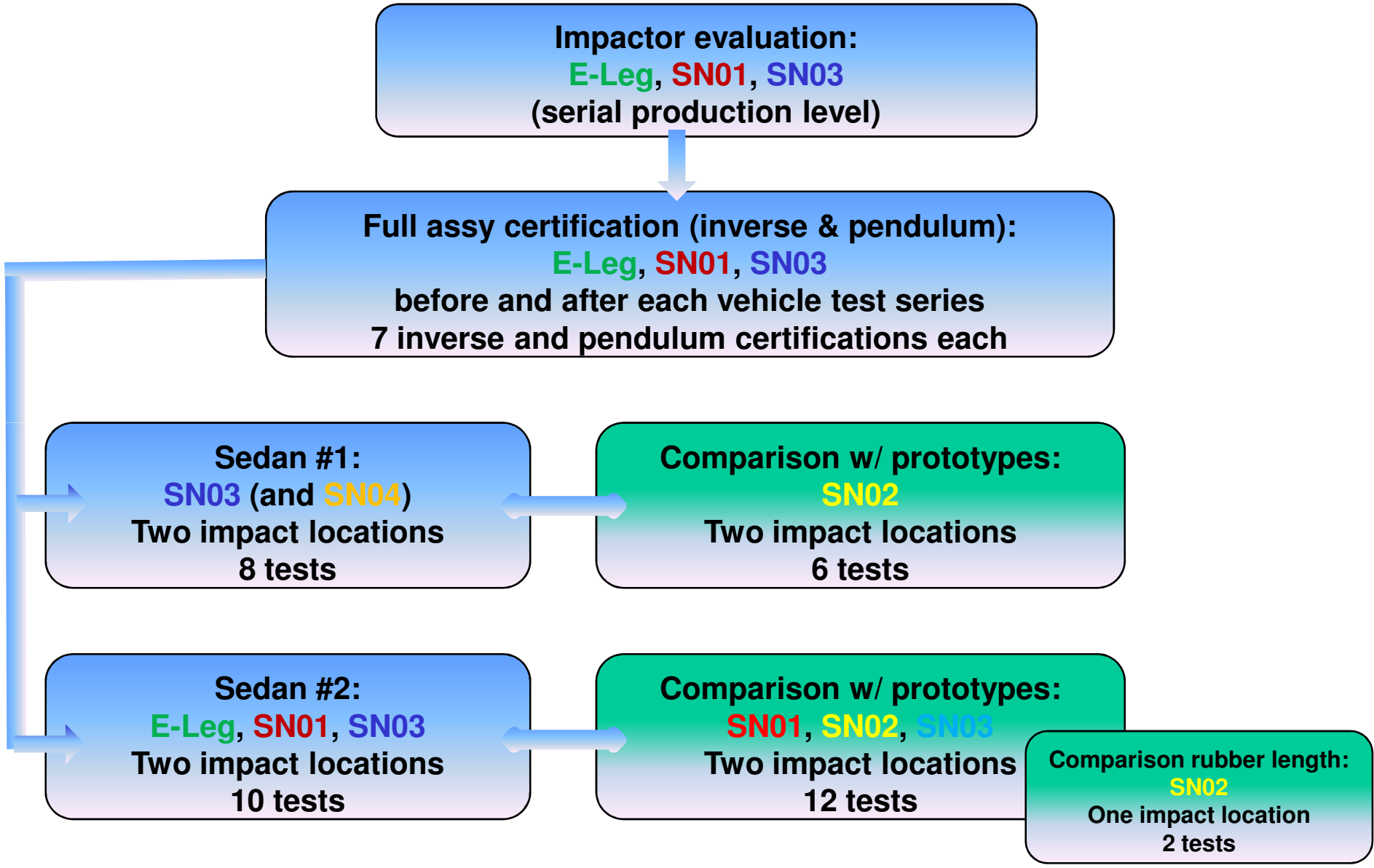
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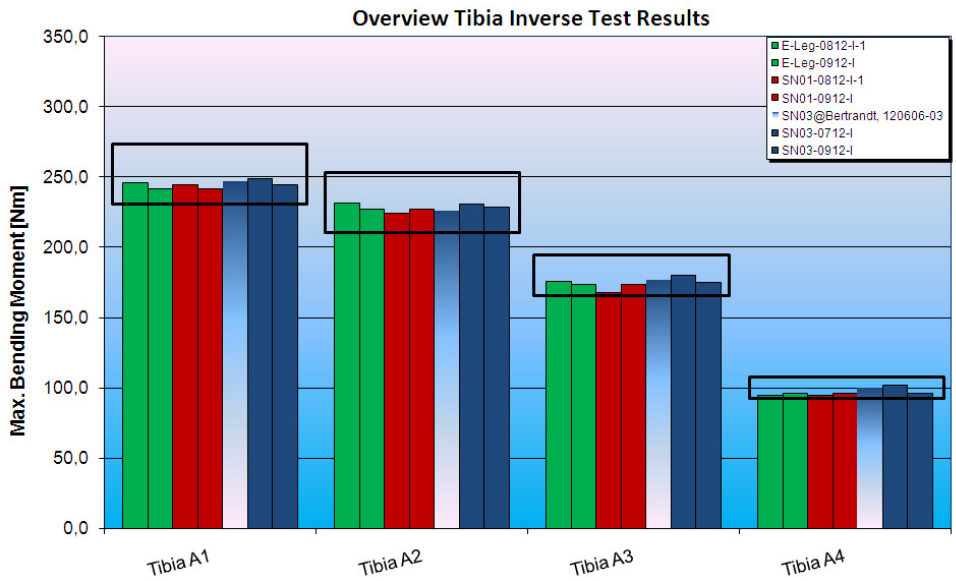
- **At the 3rd meeting of the Informal Group GTR9 Phase 2 a draft proposal for a future work plan regarding the further FlexPLI evaluation by means of vehicle tests was presented by BAST (Doc GTR9-3-06).**
- **This draft work plan suggested testing vehicles from different categories with ideally the series production legforms (SN01, SN03 and E-Leg) whose test results had been previously used for the definition of updated full assembly inverse and pendulum certification corridors (Doc TF-RUCC-4-04).**
- **BAST contributed to the round robin vehicle tests carrying out tests on frontends that had been previously tested against prototype impactors (SN01, SN02 and SN03).**
- **To ensure the impactors being in appropriate conditions, inverse and pendulum certification tests were carried out with the three series production impactors before and after each vehicle test series.**
- **The test results were afterwards compared to prototype test results that had been carried out on identical impact locations (ESV paper 09-0277).**



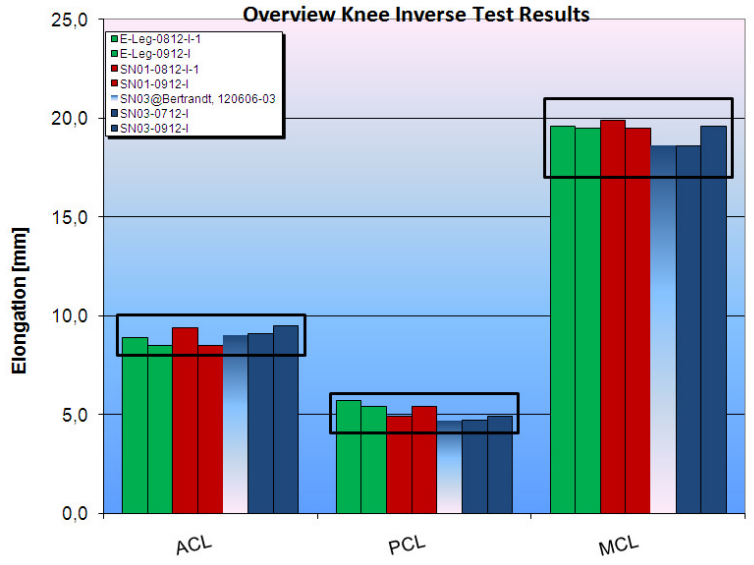
Flow Chart



Inverse certification test results



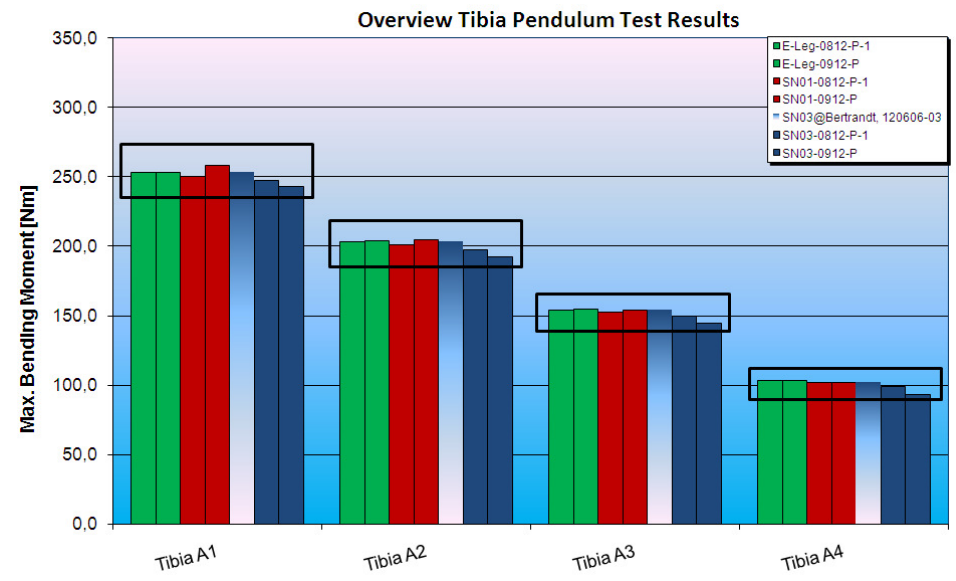
- All tibia results within new TF-RUCC draft corridors
- Tibia 4 results partly low in corridor



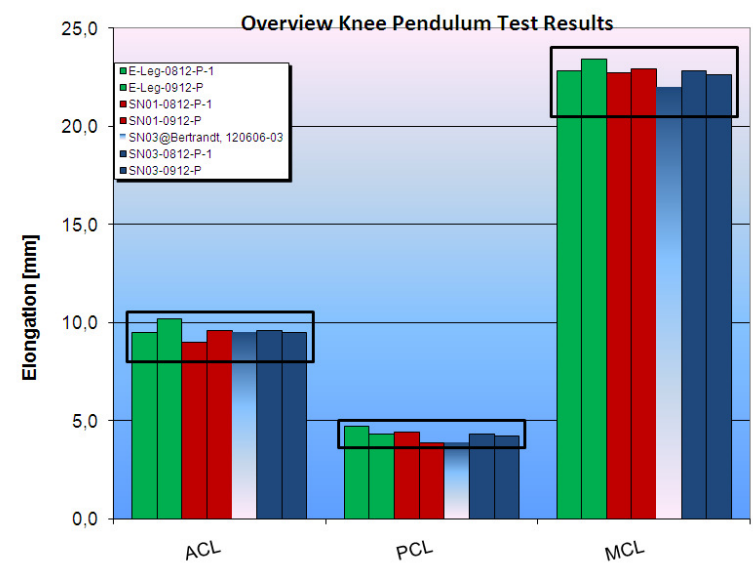
- All knee results well within new TF-RUCC draft corridors



Pendulum certification test results

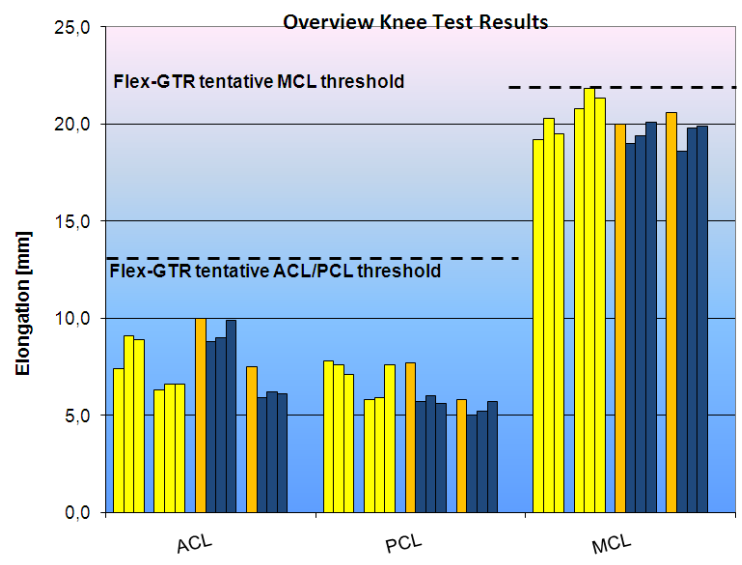
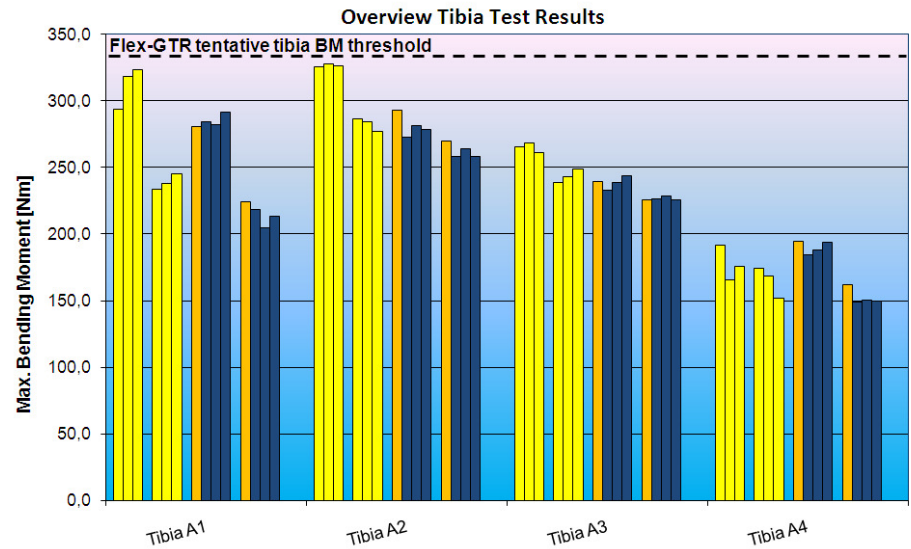


- All tibia results well within new TF-RUCC draft corridors



- All knee results within new TF-RUCC draft corridors

Sedan #1 test results - Overview



- Two impact locations
- One prototype impactor (SN02) – 6 tests
- One serial production impactor (SN03) – 6 tests
- Comparative tests with SN04 – 2 tests
- All requirements (tentative tibia and knee threshold values) met in all tests

■ Sedan #1 V1* (L1b) - SN02 - Proto
■ Sedan #1 V2 (L1b) - SN02 - Proto
■ Sedan #1 V3 (L1b) - SN02 - Proto
■ Sedan #1 V4* (L2b) - SN02 - Proto
■ Sedan #1 V5 (L2b) - SN02 - Proto
■ Sedan #1 V6 (L2b) - SN02 - Proto
■ Sedan #1 V5 (L1b) - SN04 - 'Serial'
■ Sedan #1 V6 (L1b) - SN03 - Serial
■ Sedan #1 V7 (L1b) - SN03 - Serial
■ Sedan #1 V8 (L1b) - SN03 - Serial
■ Sedan #1 V1 (L2b) - SN04 - 'Serial'
■ Sedan #1 V2 (L2b) - SN03 - Serial
■ Sedan #1 V3 (L2b) - SN03 - Serial
■ Sedan #1 V4 (L2b) - SN03 - Serial

Sedan #1 test results - Repeatability



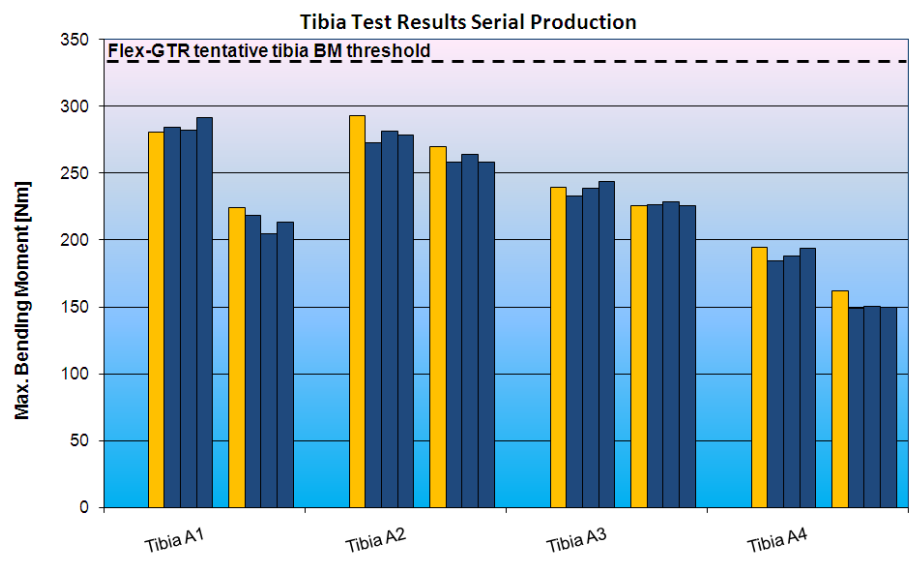
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Coefficients of variation – Sedan #1 tests:

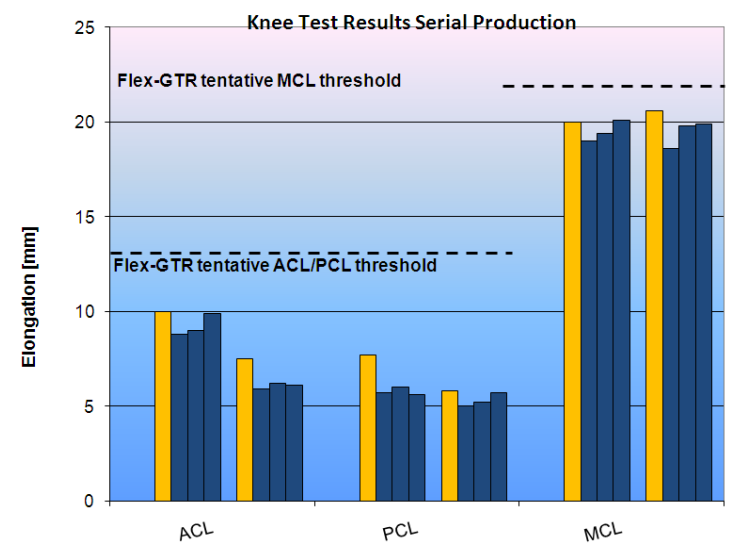
Setup	Tibia 1	Tibia 2	Tibia 3	Tibia 4	ACL	PCL	MCL
Sedan #1 P1 SN02 Proto	5.05	0.34	1.43	7.43	10.97	4.81	2.89
Sedan #1 P2 SN02 Proto	2.45	1.75	2.10	7.08	2.66	15.72	2.35
Sedan #1 P1 SN03 Serial	1.76	1.55	2.24	2.51	6.35	3.61	2.86
Sedan #1 P2 SN03 Serial	3.28	1.33	0.69	0.44	2.52	6.80	3.72

- Scatter of prototype test results partly marginal or even unacceptable
- Serial production leg shows an improved repeatability
- All coefficients of variation of the serial production leg in an acceptable range

Sedan #1 test results - Ser. Prod.

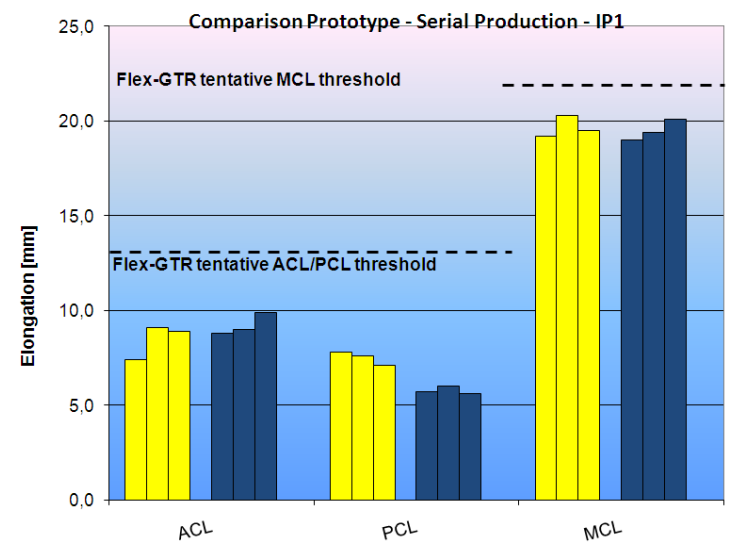
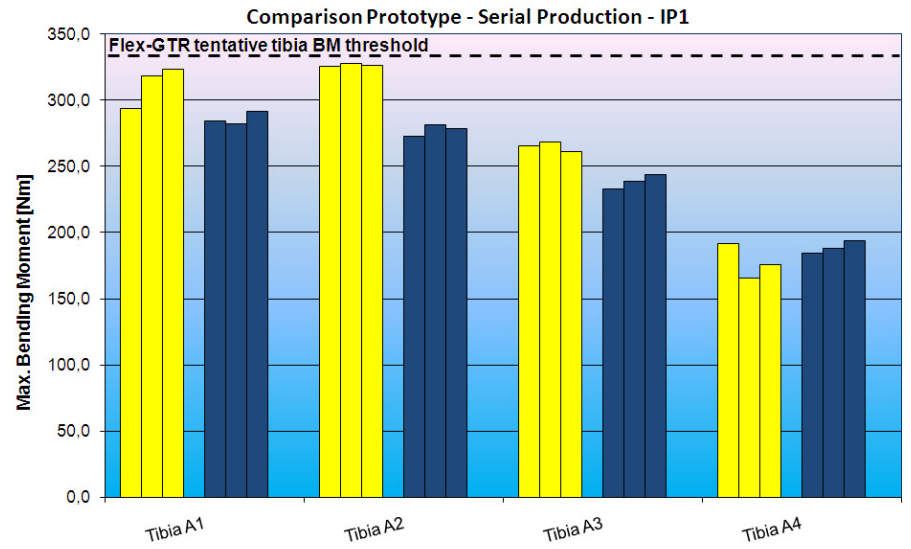


- Two impact locations
- One serial production impactor (SN03) - 6 tests
- Comparative tests with SN04 - 2 tests
- All requirements (tentative tibia and knee threshold values) clearly met in all tests



■	Sedan #1 V5 (L1b) - SN04 - 'Serial'
■	Sedan #1 V6 (L1b) - SN03 - Serial
■	Sedan #1 V7 (L1b) - SN03 - Serial
■	Sedan #1 V8 (L1b) - SN03 - Serial
■	Sedan #1 V1 (L2b) - SN04 - 'Serial'
■	Sedan #1 V2 (L2b) - SN03 - Serial
■	Sedan #1 V3 (L2b) - SN03 - Serial
■	Sedan #1 V4 (L2b) - SN03 - Serial

Sedan #1 test results – Proto vs Ser. Prod. #1

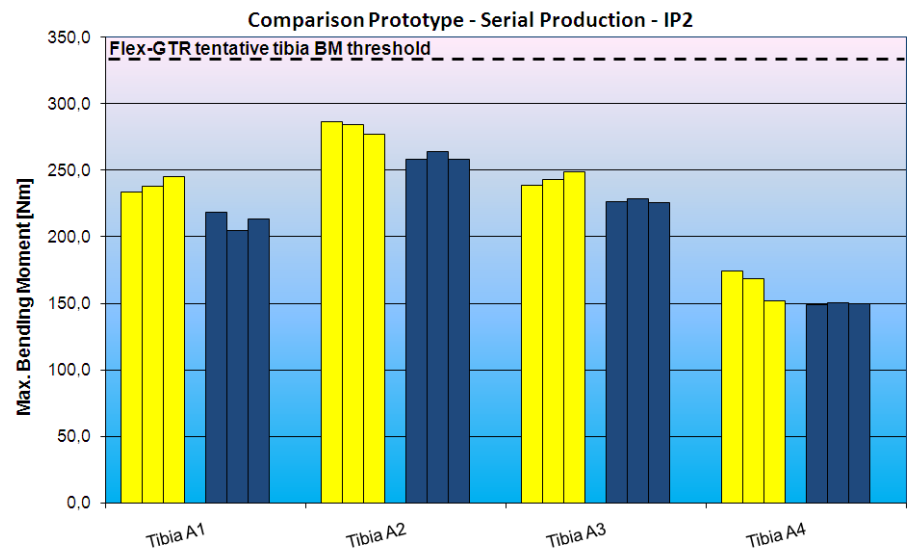


- Impact location #1
- Prototype impactor SN02 & Serial production impactor SN03
- 6 tests
- Tibia 1-3 and PCL results lower with serial production impactor
- Tibia 4 and ACL results slightly higher with serial production impactor

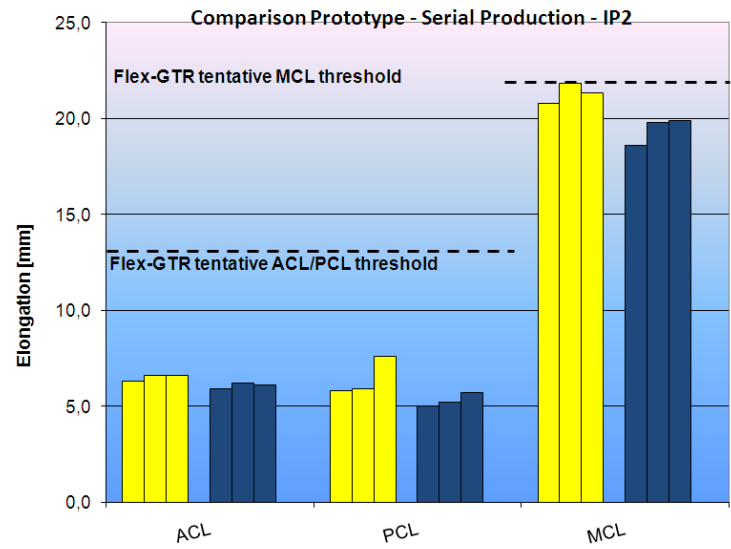
	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
MV SN02	311,83	326,33	264,87	177,50	8,47	7,50	19,67
MV SN03	285,97	277,47	238,63	188,87	9,23	5,77	19,50
Dev. [%]	-8,30	-14,97	-9,90	6,40	9,06	-23,11	-0,85

- Sedan #1 V1' (L1b) - SN02 - Proto
- Sedan #1 V2 (L1b) - SN02 - Proto
- Sedan #1 V3 (L1b) - SN02 - Proto
- Sedan #1 V6 (L1b) - SN03 - Serial
- Sedan #1 V7 (L1b) - SN03 - Serial
- Sedan #1 V8 (L1b) - SN03 - Serial

Sedan #1 test results – Proto vs Ser. Prod. #2



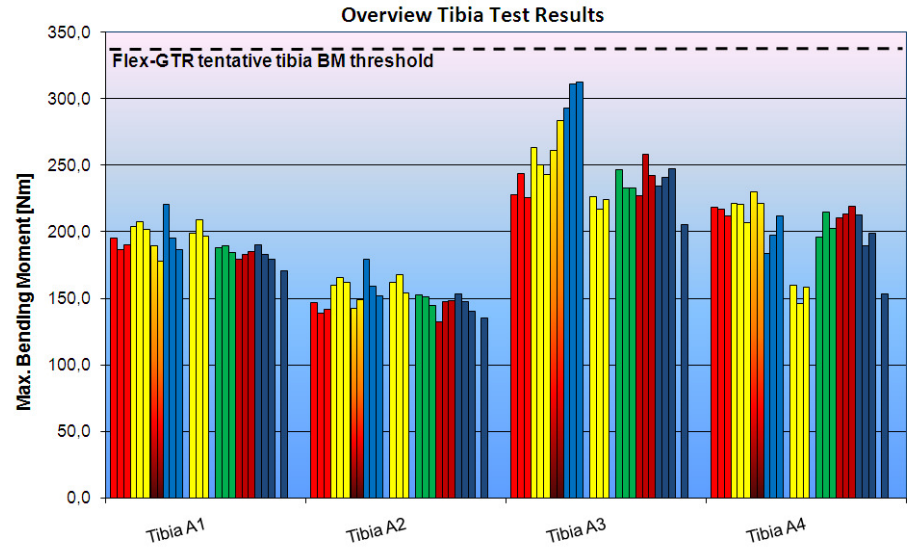
- Impact location #2
- Prototype impactor SN02 & Serial production impactor SN03
- 6 tests
- All results lower with serial production impactor



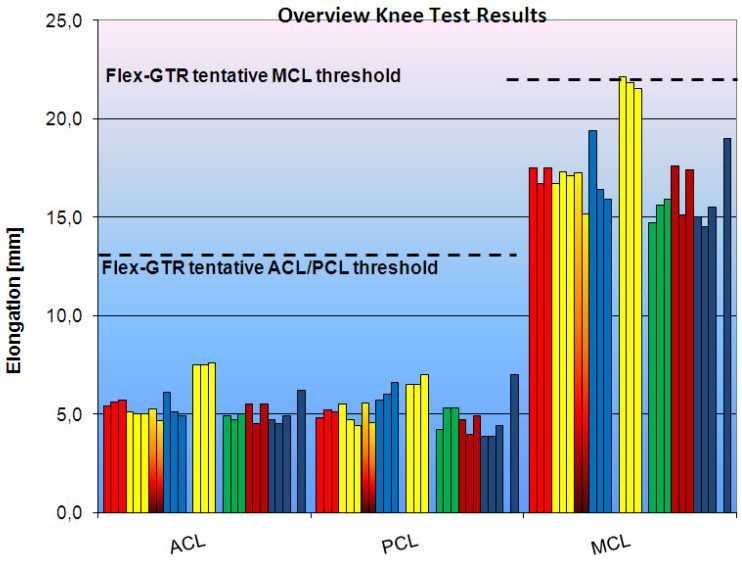
	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
MV SN02	239,07	282,27	243,50	164,97	6,50	6,43	21,30
MV SN03	212,20	260,00	227,03	149,77	6,07	5,30	19,43
Dev. (%)	-11,24	-7,89	-6,76	-9,21	-6,67	-17,62	-8,76

- Sedan #1 V4' (L2b) - SN02 - Proto
- Sedan #1 V5 (L2b) - SN02 - Proto
- Sedan #1 V6 (L2b) - SN02 - Proto
- Sedan #1 V2 (L2b) - SN03 - Serial
- Sedan #1 V3 (L2b) - SN03 - Serial
- Sedan #1 V4 (L2b) - SN03 - Serial

Sedan #2 test results - Overview



- Two impact locations
- Three „original“ prototype impactors (SN01, SN02 and SN03) – 12 tests
- One „modified“ prototype impactor (SN02), i.e. with long rubber sheets – 2 tests
- Three serial production impactors (E-Leg, SN01 and SN03) – 10 tests



- All (except one prototype) tests passed the tentative tibia and knee threshold values)
- Only MCL requirement failed once with SN02 prototype

■	Sedan #2 V7 (P1) - SN01 - Proto
■	Sedan #2 V8 (P1) - SN01 - Proto
■	Sedan #2 V9 (P1) - SN01 - Proto
■	Sedan #2 V4 (P1) - SN02 - Proto
■	Sedan #2 V5 (P1) - SN02 - Proto
■	Sedan #2 V6 (P1) - SN02 - Proto
■	Sedan #2 V10 (P1) - SN02LR - Proto
■	Sedan #2 V11 (P1) - SN02LR - Proto
■	Sedan #2 V1 (P1) - SN03 - Proto
■	Sedan #2 V2 (P1) - SN03 - Proto
■	Sedan #2 V3 (P1) - SN03 - Proto
■	Sedan #2 V1 (P2) - SN02 - Proto
■	Sedan #2 V2 (P2) - SN02 - Proto
■	Sedan #2 V3 (P2) - SN02 - Proto
■	Sedan # 2 V1 (P1) - Eleg - Serial
■	Sedan # 2 V2 (P1) - Eleg - Serial
■	Sedan # 2 V3 (P1) - Eleg - Serial
■	Sedan # 2 V4 (P1) - SN01 - Serial
■	Sedan # 2 V5 (P1) - SN01 - Serial
■	Sedan # 2 V6 (P1) - SN01 - Serial
■	Sedan # 2 V7 (P1) - SN03 - Serial
■	Sedan # 2 V8 (P1) - SN03 - Serial
■	Sedan # 2 V9 (P1) - SN03 - Serial
■	Sedan # 2 V10 (P2) - SN03 - Serial

Sedan #2 test results - Repeatability



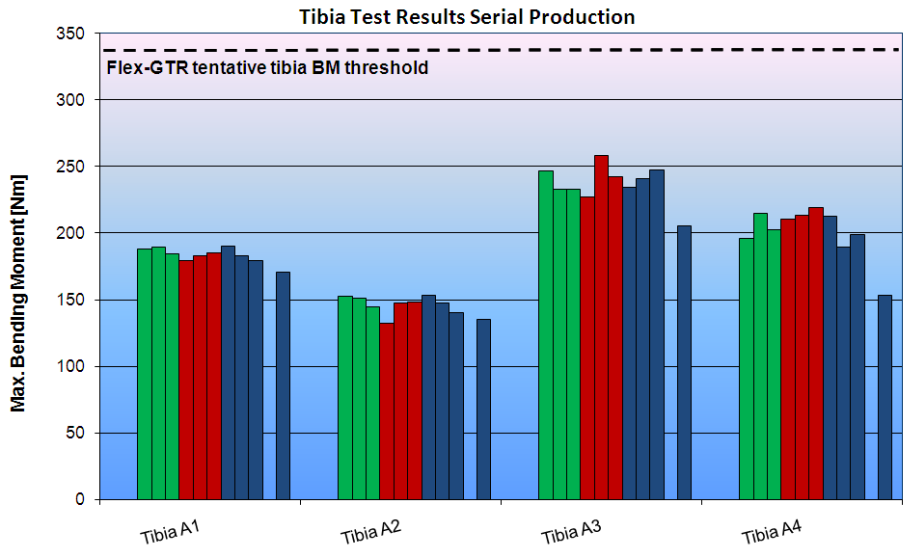
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Coefficients of variation – Sedan #2 tests:

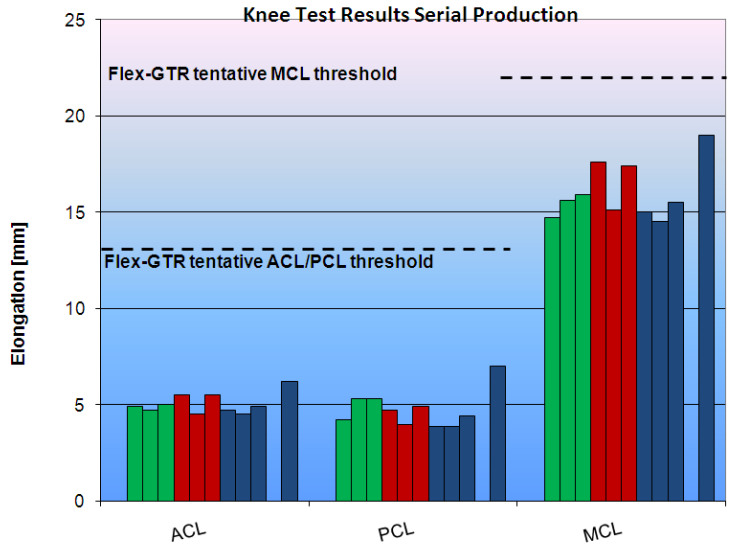
Setup	Tibia 1	Tibia 2	Tibia 3	Tibia 4	ACL	PCL	MCL
Sedan #2 P1 SN01 Proto	2,18	2,78	4,18	1,59	2,74	4,14	2,68
Sedan #2 P1 SN02 Proto	1,40	1,82	4,01	3,69	1,15	11,68	1,79
Sedan #2 P1 SN03 Proto	8,74	8,83	3,57	7,09	11,98	7,51	10,98
Sedan #2 P2 SN02 Proto	3,36	4,23	2,38	4,87	0,77	4,33	1,38
Sedan #2 P1 Eleg Serial	1,28	2,78	3,36	4,64	3,14	12,87	4,06
Sedan #2 P1 SN01 Serial	1,74	6,33	6,45	2,10	11,17	10,42	8,32
Sedan #2 P1 SN03 Serial	2,99	4,47	2,64	5,83	4,26	7,10	3,33

- Comparison of repeatability between prototype and serial production impactors shows inconsistent results
- Repeatability of ACL/PCL partly still unacceptable
- Tibia repeatability improved (all CV's acceptable)
- Increased scatter in knee results

Sedan #2 test results – Ser. Prod.

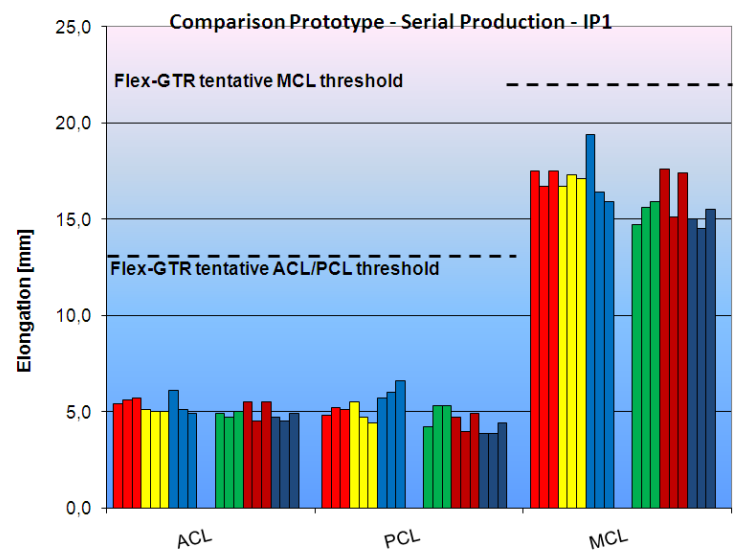
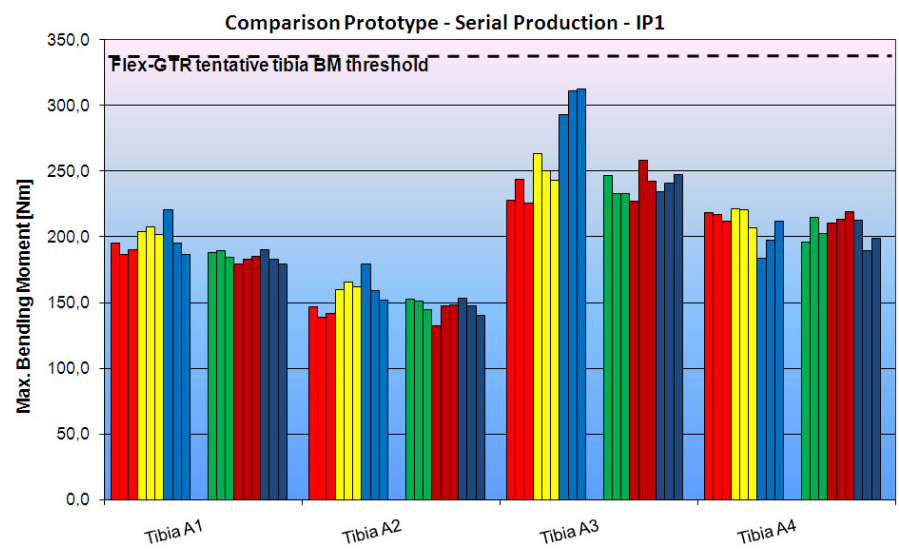


- Two impact locations
- Three serial production impactors (E-Leg, SN01 and SN03) – 10 tests
- All requirements (tentative tibia and knee threshold values) clearly met in all tests



█	Sedan #2 V1 (P1) - Eleg - Serial
█	Sedan #2 V2 (P1) - Eleg - Serial
█	Sedan #2 V3 (P1) - Eleg - Serial
█	Sedan #2 V4 (P1) - SN01 - Serial
█	Sedan #2 V5 (P1) - SN01 - Serial
█	Sedan #2 V6 (P1) - SN01 - Serial
█	Sedan #2 V7 (P1) - SN03 - Serial
█	Sedan #2 V8 (P1) - SN03 - Serial
█	Sedan #2 V9 (P1) - SN03 - Serial
█	Sedan #2 V10 (P2) - SN03 - Serial

Sedan #2 test results – Proto vs Ser. Prod. #1

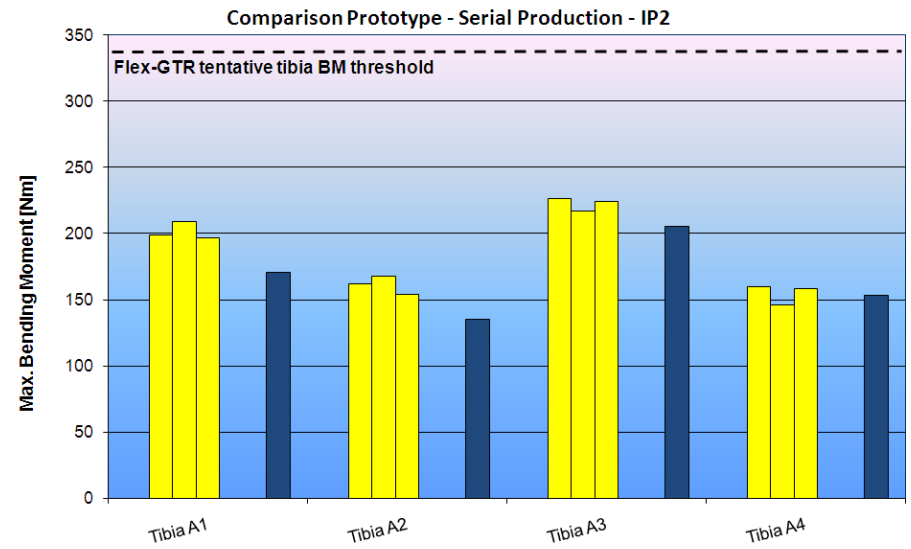


- Impact location #1
- Prototype impactors SN01, SN02 and SN03
- Serial production impactors E-Leg, SN01 and SN03
- 18 tests
- Again, test results lower with serial production impactors

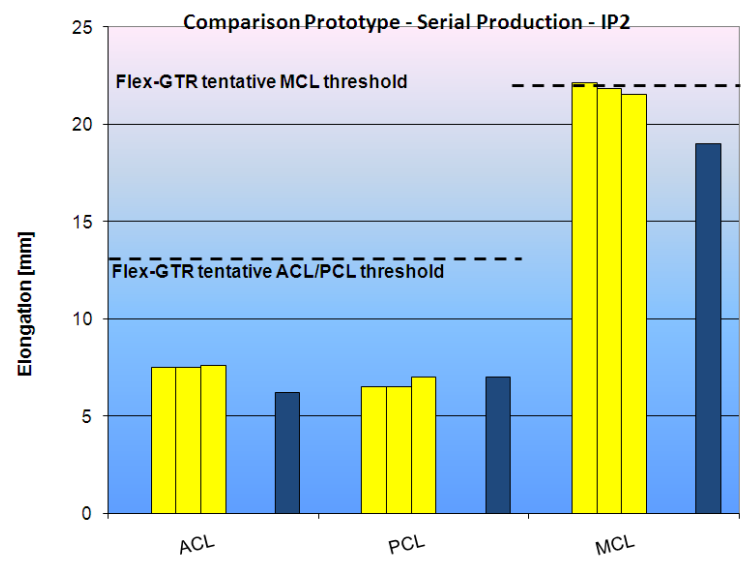
	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
MV SN01-SN02-SN03	198,58	156,21	263,31	209,81	5,32	5,33	17,17
MV E-Leg-SN01-SN03	184,66	146,40	240,29	206,29	4,91	4,51	15,70
Dev. (%)	-7,01	-6,28	-8,74	-1,68	-7,72	-15,42	-8,54

- Sedan #2 V7 (P1) - SN01 - Proto
- Sedan #2 V8 (P1) - SN01 - Proto
- Sedan #2 V9 (P1) - SN01 - Proto
- Sedan #2 V4 (P1) - SN02 - Proto
- Sedan #2 V5 (P1) - SN02 - Proto
- Sedan #2 V6 (P1) - SN02 - Proto
- Sedan #2 V1 (P1) - SN03 - Proto
- Sedan #2 V2 (P1) - SN03 - Proto
- Sedan #2 V3 (P1) - SN03 - Proto
- Sedan #2 V1 (P1) - Eleg - Serial
- Sedan #2 V2 (P1) - Eleg - Serial
- Sedan #2 V3 (P1) - Eleg - Serial
- Sedan #2 V4 (P1) - SN01 - Serial
- Sedan #2 V5 (P1) - SN01 - Serial
- Sedan #2 V6 (P1) - SN01 - Serial
- Sedan #2 V7 (P1) - SN03 - Serial
- Sedan #2 V8 (P1) - SN03 - Serial
- Sedan #2 V9 (P1) - SN03 - Serial

Sedan #2 test results – Proto vs Ser. Prod. #2



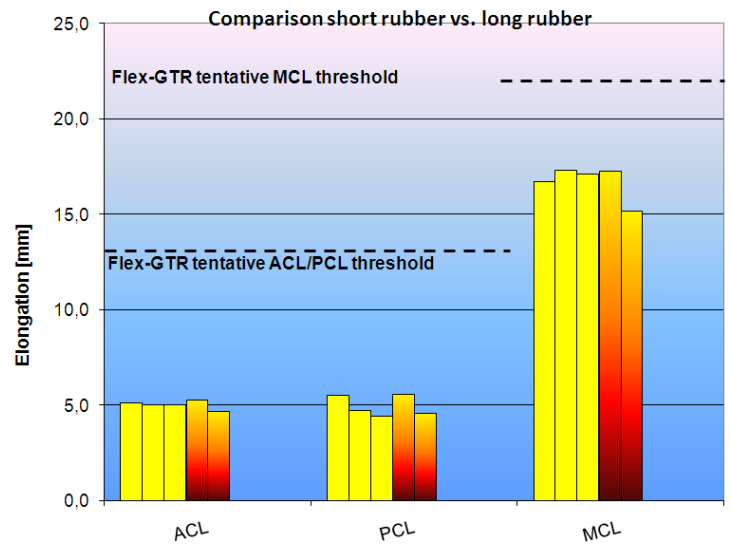
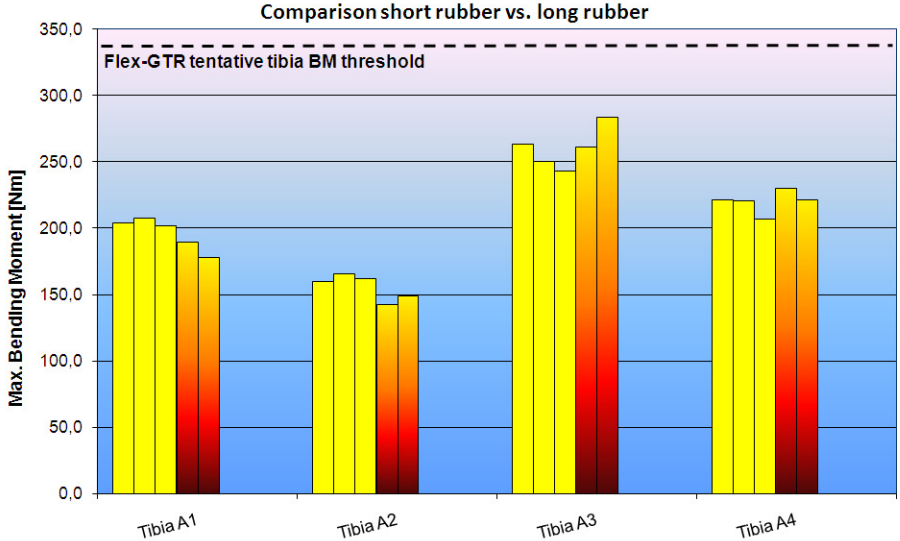
- Impact location #2
- Prototype impactor SN02
- Serial production impactor SN03
- Only one test performed with serial production impactor
- 4 tests
- Most results (except PCL) lower with serial production impactor



	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
MV SN02	201,40	161,37	222,57	154,87	7,53	6,67	21,80
Single Test SN03	170,30	135,40	205,20	153,20	6,20	7,00	19,00
Dev. (%)	-15,44	-16,09	-7,80	-1,08	-17,70	5,00	-12,84

- Sedan #2 V1 (P2) - SN02 - Proto
- Sedan #2 V2 (P2) - SN02 - Proto
- Sedan #2 V3 (P2) - SN02 - Proto
- Sedan # 2 V10 (P2) - SN03 - Serial

Influence of rubber length



- Sedan #2 vehicle tests
- Impact location #1
- Prototype impactor SN02
- 3 tests with long rubber sheets
- 2 tests with short rubber sheets
- Inconsistent influence of rubber length depending on location of particular load paths

	Tibia A1	Tibia A2	Tibia A3	Tibia A4	ACL	PCL	MCL
MV SN02 SR	204,47	162,67	252,20	216,10	5,03	4,87	17,03
MV SN02 LR	184,3	146,0	272,8	226,1	5,0	5,1	16,3
Dev. (%)	-9,89	-10,25	8,17	4,60	-0,66	4,79	-4,60

- Sedan #2 V4 (P1) - SN02 - Proto
- Sedan #2 V5 (P1) - SN02 - Proto
- Sedan #2 V6 (P1) - SN02 - Proto
- Sedan #2 V10 (P1) - SN02LR - Proto
- Sedan #2 V11 (P1) - SN02LR - Proto

Summary



- **18 impactor tests with three different serial production impactors (E-Leg, SN01 and SN03) on two different vehicles were carried out at BAST.**
- **The impactors have been successfully inverse and pendulum certified according to the TF-RUCC corridor proposal before and after each vehicle test series.**
- **All test results entirely met the tentative FlexPLI thresholds for tibia bending moments as well as ligament elongations according to ECE-TRANS-WP29-GRSP-2011-13e.**
- **A comparison of the serial production impactor test results with prototype results on identical impact locations shows that the serial production impactors are producing in most cases lower output values than the prototypes. This observation is in line with the inverse certification tests (Doc TF-RUCC-4-04).**
- **The repeatability of vehicle test results shows an improvement regarding the tibia segments while the scatter in the knee is partly increased.**
- **The influence of the length of the rubber sheet on the test results is inconsistent and seems to depend on the location of the particularly impacted load paths.**



Thank you !