



# **Flex-G and Flex-GT $\alpha$ : a comparison of test results**

**4th Meeting of the GRSP Flex PLI Technical Evaluation Group  
Bergisch Gladbach, April 2nd, 2007**

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**Bundesanstalt für Straßenwesen**

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(Federal Highway Research Institute)

## **Euro NCAP results**

**Test programme Flex-G and Flex-GT $\alpha$**

**Test results Volkswagen Golf**

**Test results Mercedes A-Class**

**Examination of the influence of impact height**

**Repeatability (real car tests)**

**Certification test results**

**Results / open issues**



## Impact points on cars tested by Euro NCAP

### Mercedes A-Class



Green rated lower leg test area

L1a(a): -141,5 g / -3,4 mm / 8,6°  
L1b: -132,4 g / -3,1 mm / 8,6°  
L2a: -113,0 g / -2,7 mm / 11,5°  
L3b: -143,0 g / -3,7 mm / 8,4°

### VW Golf V



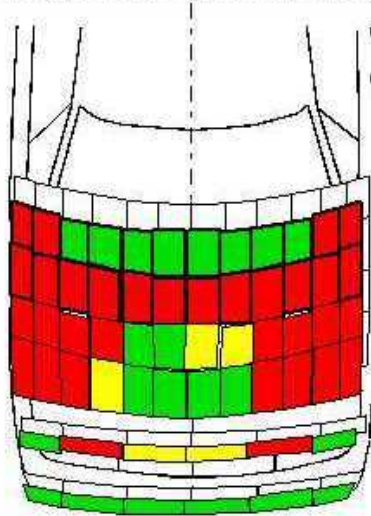
Borderline to green bumper area

L1b: -136,5 g / -2,4 mm / 15,7°  
L2a: -123,3 g / 2,9 mm / 13,1°  
L2b(b): -135,6 g / 2,7 mm / 13,4°



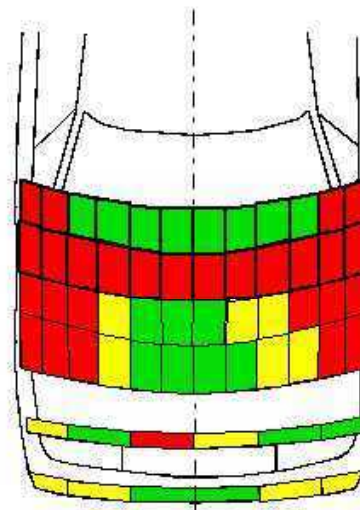
## Mercedes A-Class

Adult Headform assessment (sum)	4,00
Child Headform assessment (sum)	3,98
Upper Legform assessment (sum)	2,55
Legform assessment (Sum)	6,00
OVERALL PEDESTRIAN	16,52
ROUNDED OVERALL PEDESTRIAN	17
PEDESTRIAN PROTECTION STAR RATING	2



## VW Golf V

Adult Headform assessment (sum)	4,00
Child Headform assessment (sum)	4,93
Upper Legform assessment (sum)	4,46
Legform assessment (Sum)	5,44
TOTAL PEDESTRIAN	18,83
ROUNDED TOTAL SCORE	19,00
STAR RATING	3,00



**Euro NCAP results**

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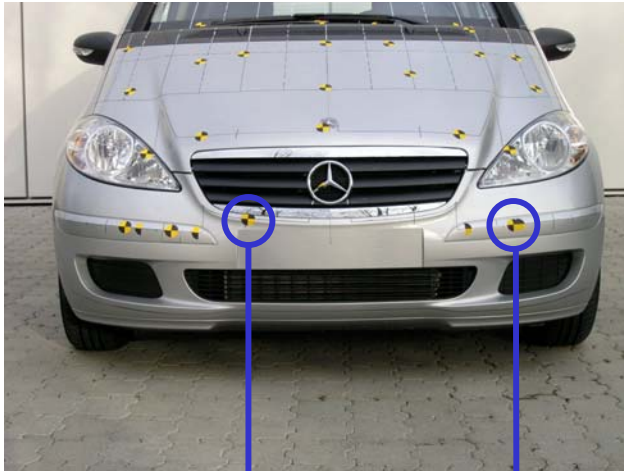
**Test results Mercedes A-Class**

**Examination of the influence of impact height**

**Repeatability (real car tests)**

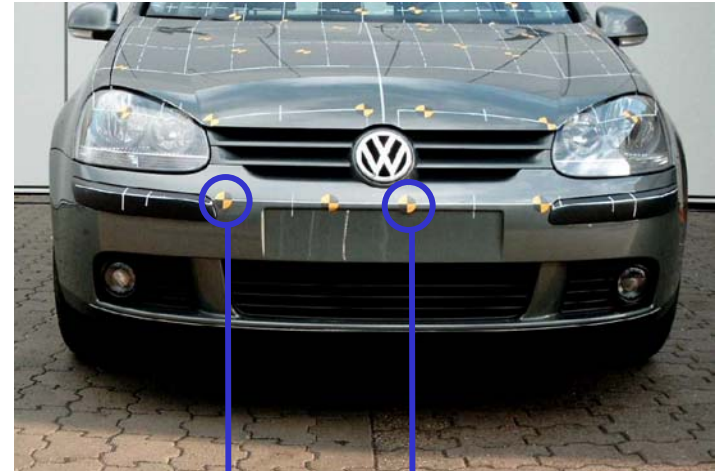
**Certification test results**

**Results / open issues**



L2a: (left end of number plate area)  
three tests with Flex-GT $\alpha$   
one mirrored test (L2b)  
one test with Flex-G

L3b: (left part of headlamp area)  
three tests with Flex-GT $\alpha$   
one test with Flex-G



L1b: (bumper vertical bracing rib)  
three tests with Flex-GT $\alpha$   
one mirrored test (L3a)  
one test with Flex-G

L2b: (manufacturer's emblem)  
three tests with Flex-GT $\alpha$   
one test with Flex-G



- tests on series production cars (Golf and A-Class)
- Flex-G tests performed at an impact speed of 24 km/h only  
(reduced test programme - one single test on each car model only)
- Flex-GT $\alpha$  tests performed at regular impact speed of 40 km/h  
(full test programme)
- impact height 25 mm above ground level due to comparability reasons

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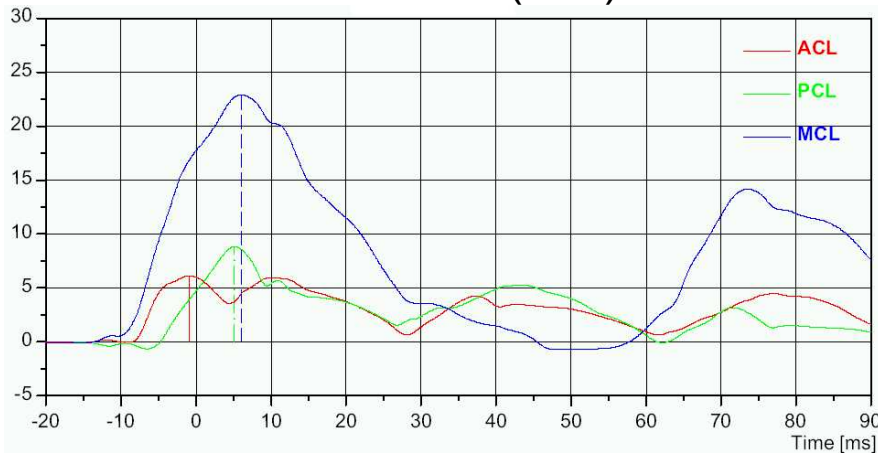
# Test results Golf - Tibia BM (25 mm)



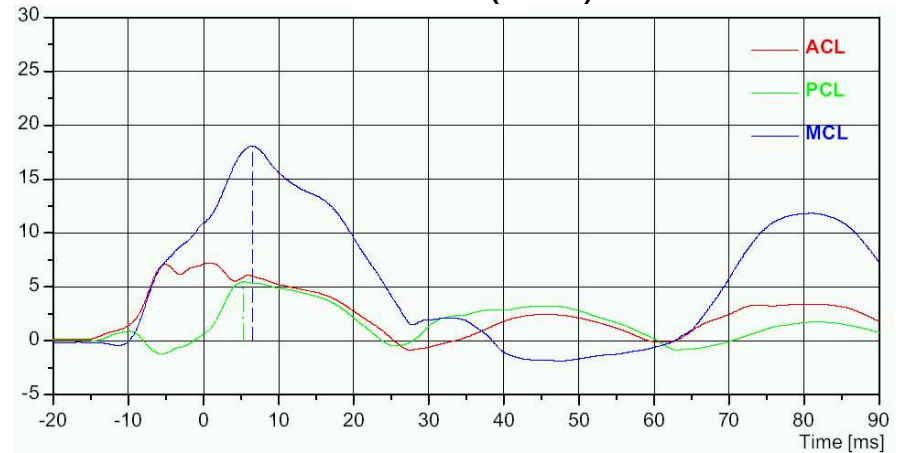
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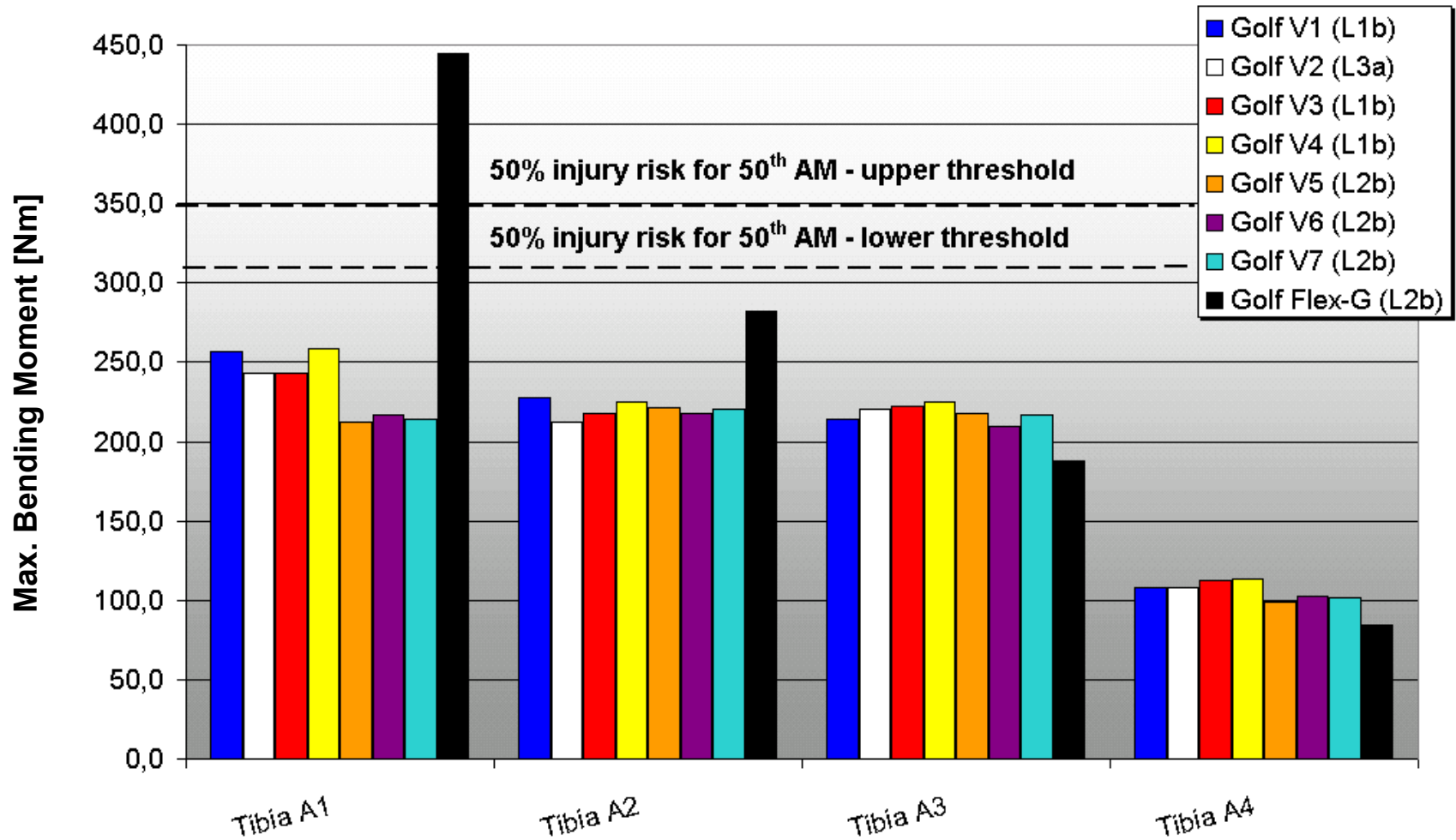
Golf V1 (L1b)



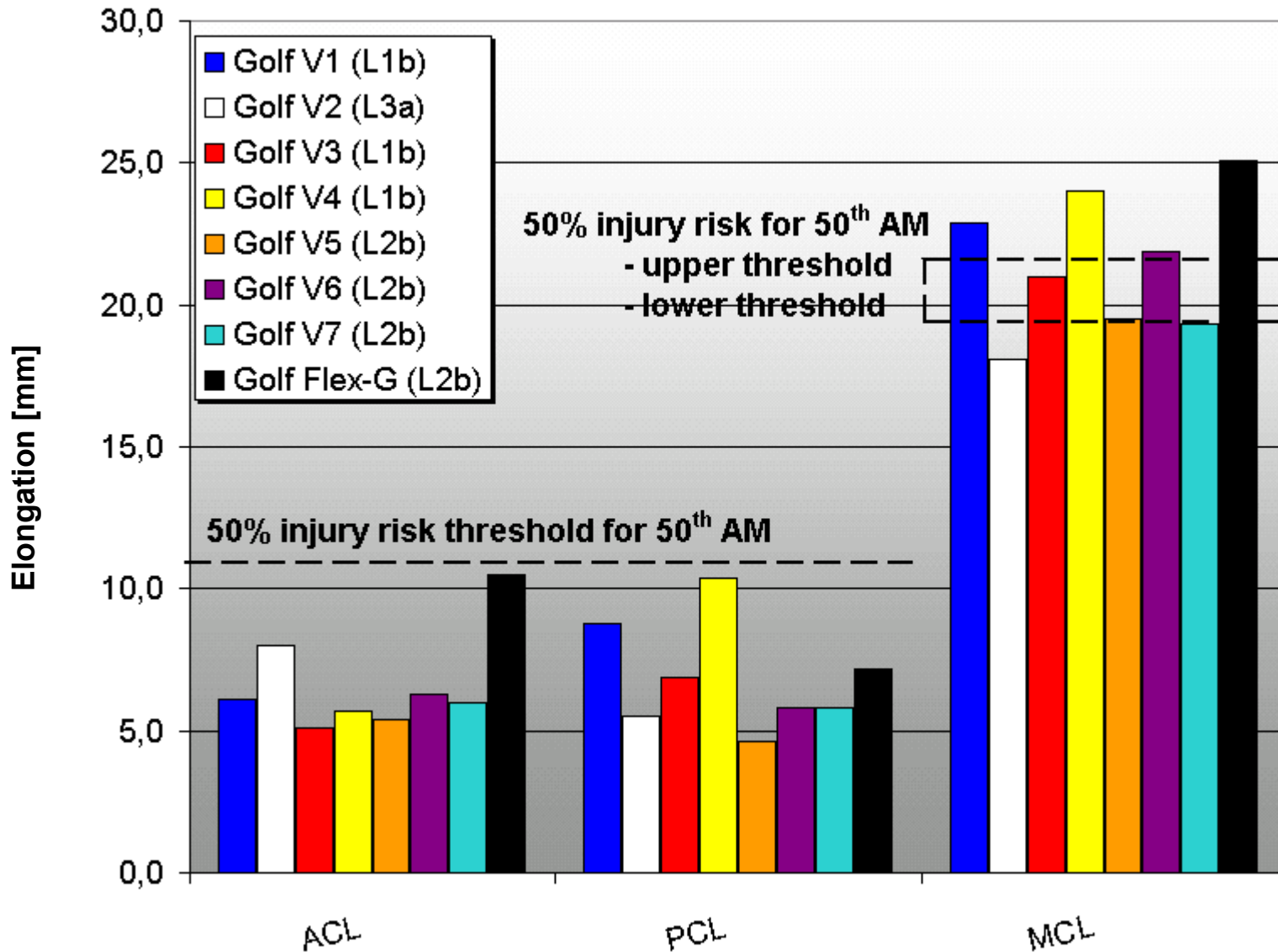
Golf V2 (L3a)



# Test results Golf - Tibia BM (25 mm)



# Test results Golf - Knee EL (25 mm)



- all three impact locations met the proposed tibia and ACL and PCL knee injury criteria with Flex-GT $\alpha$
- MCL thresholds exceeded in 4 tests
- in three of the tests all requirements were met
- tibia (same behaviour in tests on symmetrical identical points), ACL and PCL peak results (opposite behaviour in tests on symmetrical identical points) seem to confirm the symmetrie of the impact point in test #2, but: ACL peak elongation occurred at a different time
- test results with Flex-G sometimes significantly higher (two tibia strain gauges and ACL, PCL, MCL) despite the reduced impact speed (24 km/h)
- good test results according to Euro NCAP can be confirmed by Flex-GT $\alpha$ -tests

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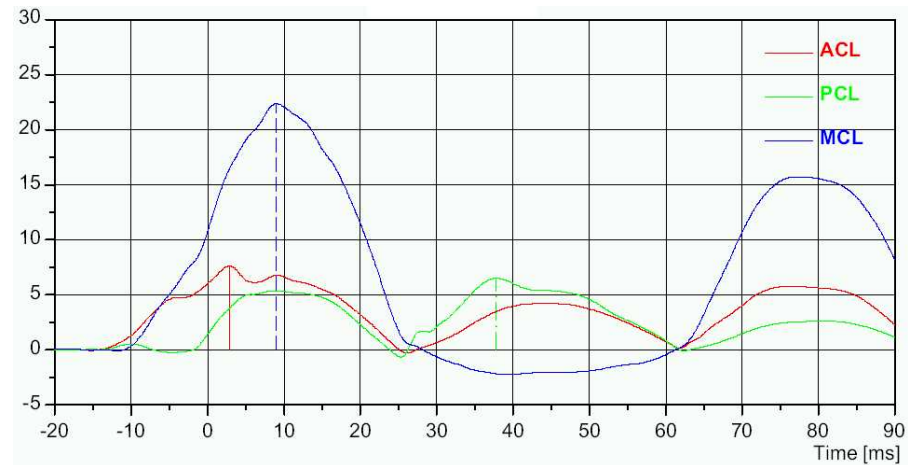
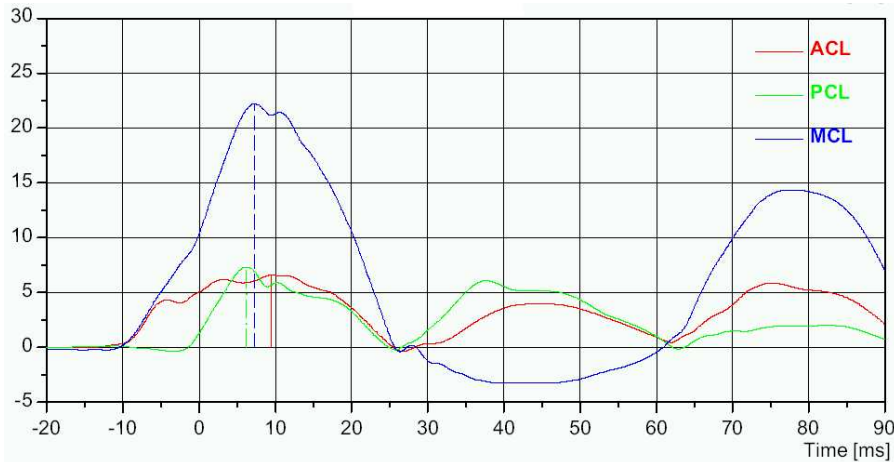
# Test results A-Class - Tibia BM (25 mm)



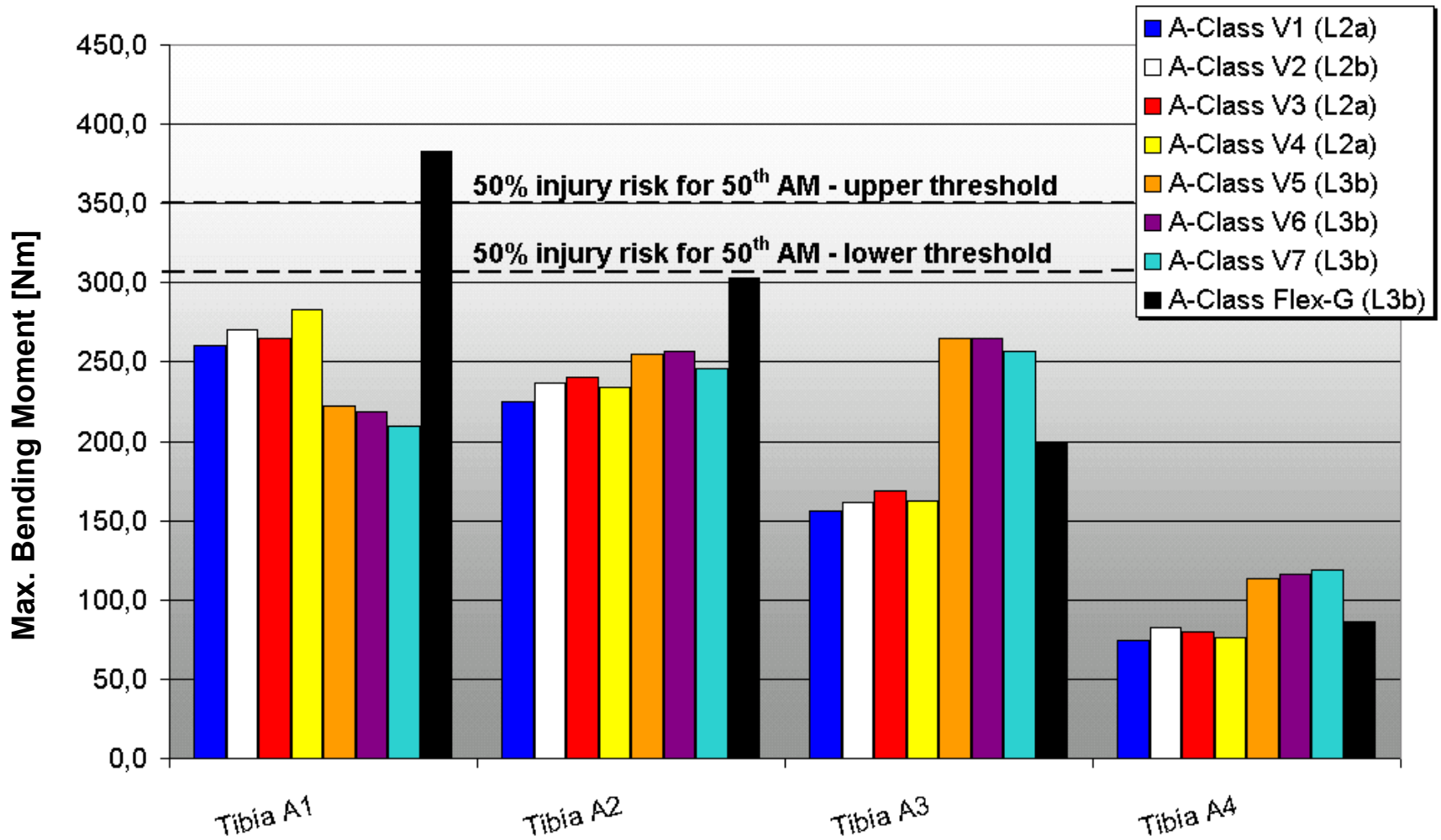
A-Class V3 (L2a)



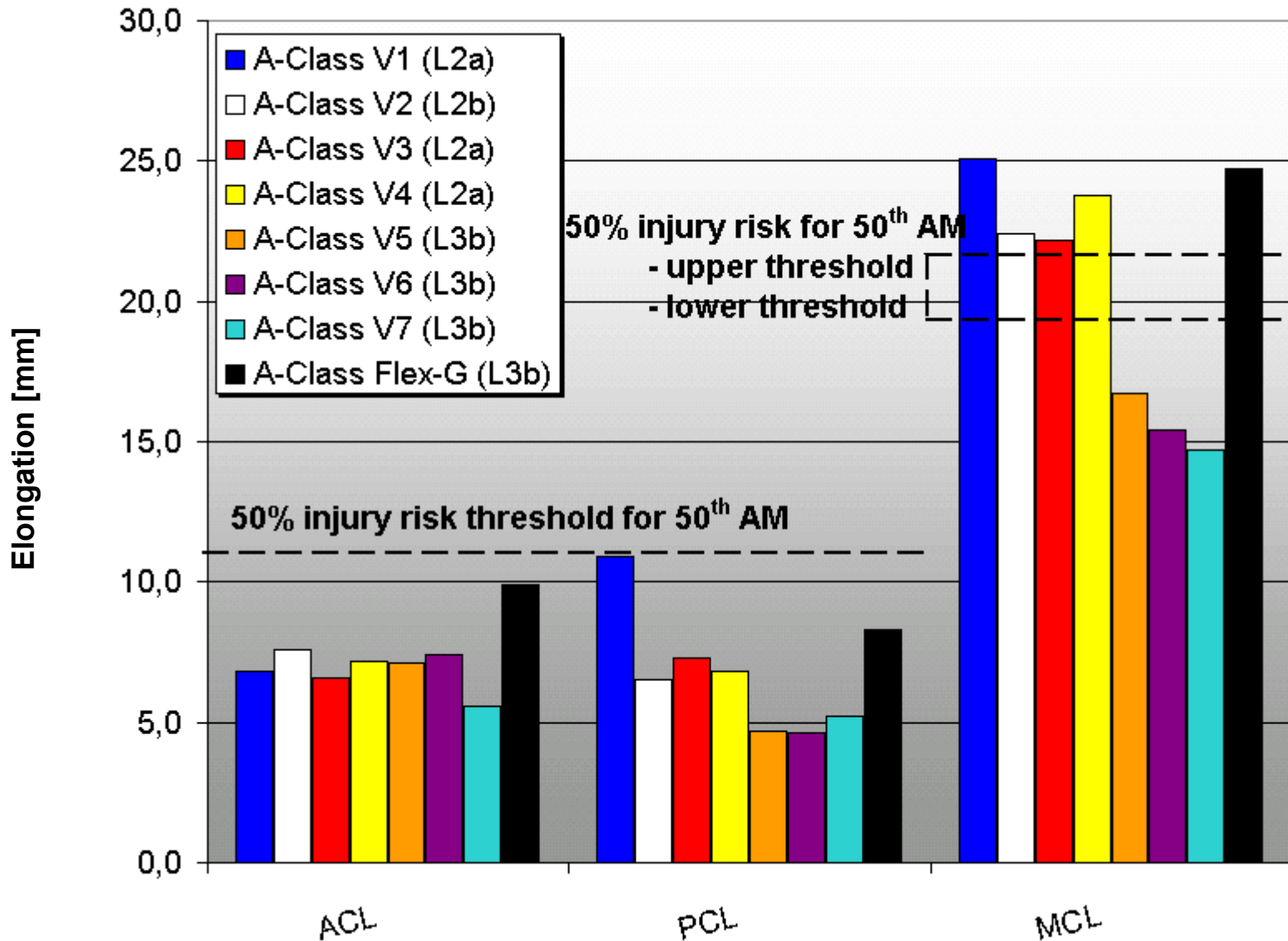
A-Class V2 (L2b)



# Test results A-Class - Tibia BM (25 mm)



# Test results A-Class - Knee EL (25 mm)







- again, all three impact locations met the proposed tibia and ACL and PCL knee injury criteria with Flex-GT $\alpha$
- MCL thresholds exceeded in 4 tests
- ACL and PCL peak results don't show any tendency confirming the symmetry of the impact point in test #2, but: more homogeneous outer structure beneath the impact points L2a, L2b
- tibia bending moments don't show any sensitivity towards mirrored test points
- impact location L3b met in all three of the tests all requirements
- test results with Flex-G sometimes significantly higher (two tibia strain gauges and ACL, PCL, MCL) despite the reduced impact speed (24 km/h)
- good test results according to Euro NCAP can be confirmed by Flex-GT $\alpha$ -tests

**Euro NCAP results**

**Test programme Flex-G and Flex-GT $\alpha$**

**Test results Volkswagen Golf**

**Test results Mercedes A-Class**

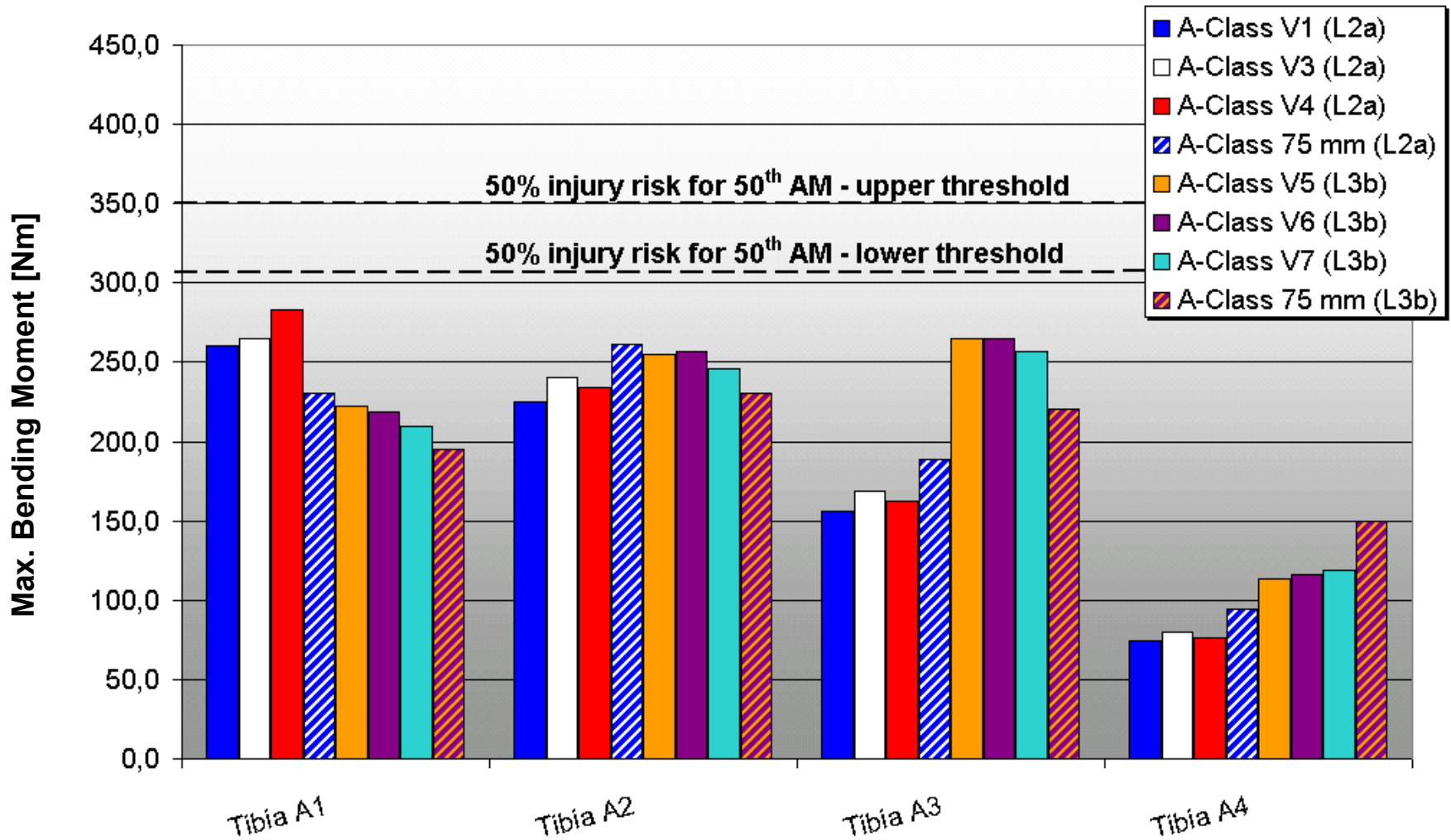
**Examination of the influence of impact height**

**Repeatability (real car tests)**

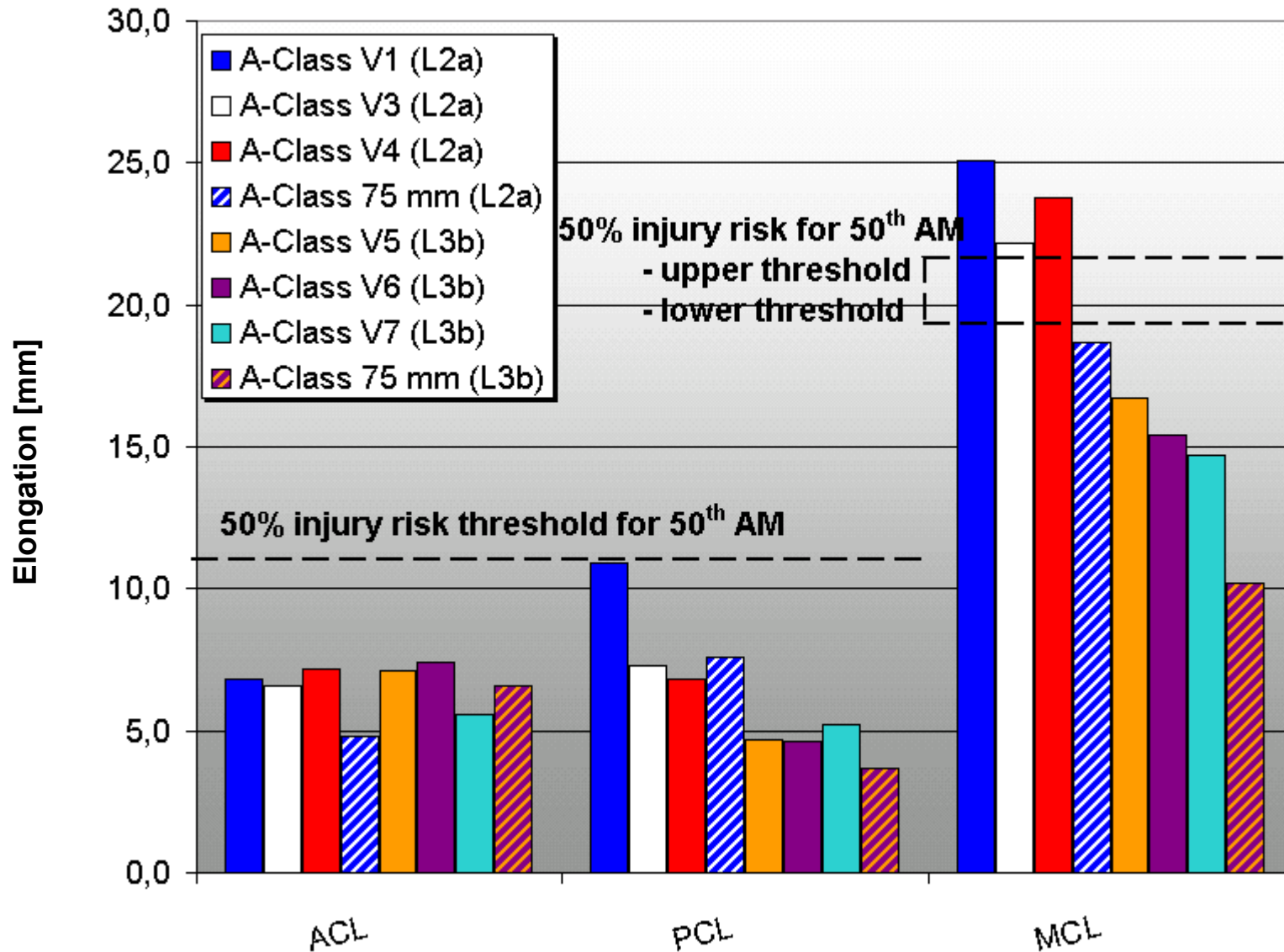
**Certification test results**

**Results / open issues**

# Influence of impact height (A-Class)



# Influence of impact height (A-Class)





- no clear tendency can be stated for the tibia sections
- the ACL and PCL loads seem to get lower with an increased impact height
- significantly smaller MCL loads with an increased impact height
- influence of impact height clearly depends on the car impact height, the shape of the environment of the impact point and the corresponding legform measuring point
- further tests at 75 mm on different car fronts and shapes would be beneficial

**Euro NCAP results**

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**Test results Mercedes A-Class**

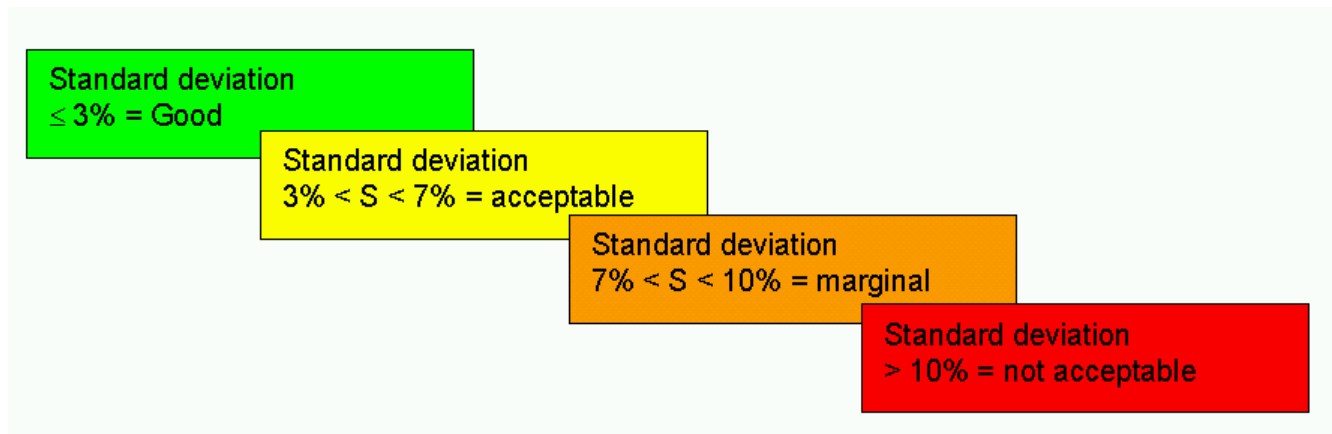
**Examination of the influence of impact height**

**Repeatability (real car tests)**

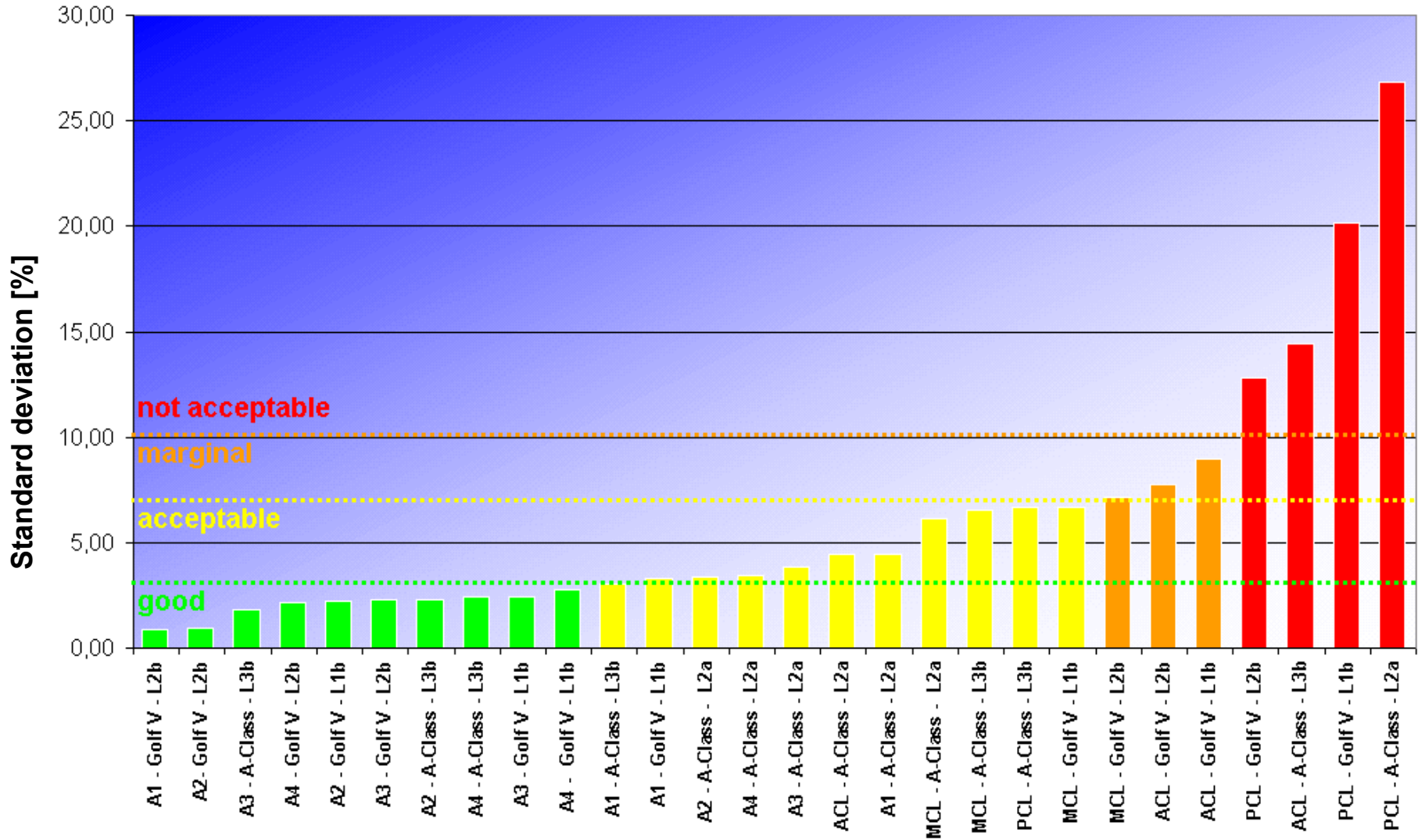
**Certification test results**

**Results / open issues**

- test results of all four impact points being tested three times were taken into account (i.e. mirrored test points were not included)
- assessment of the repeatability of test results for all four tibia strain gauges and the ACL, PCL and MCL elongations
- assessment of the standard deviation according to the requirements for dummies (best practice):



# Repeatability (real car tests)







- maximum tibia bending moments: SD between good and acceptable at all impact locations
- knee elongation: SD still acceptable in five cases (hereof three MCL results)
- repeatability for tibia sections significantly higher than for the knee ligaments
- additional tests under idealised impact conditions revealed a high sensitivity of the knee ligaments towards even marginally changed impact conditions (impact height, rotation)
- further research on the variation of impact parameters needed

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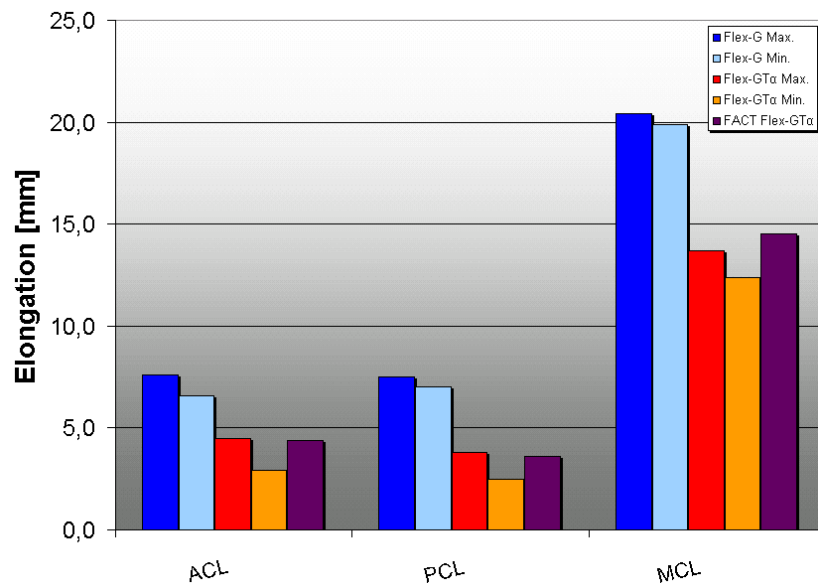
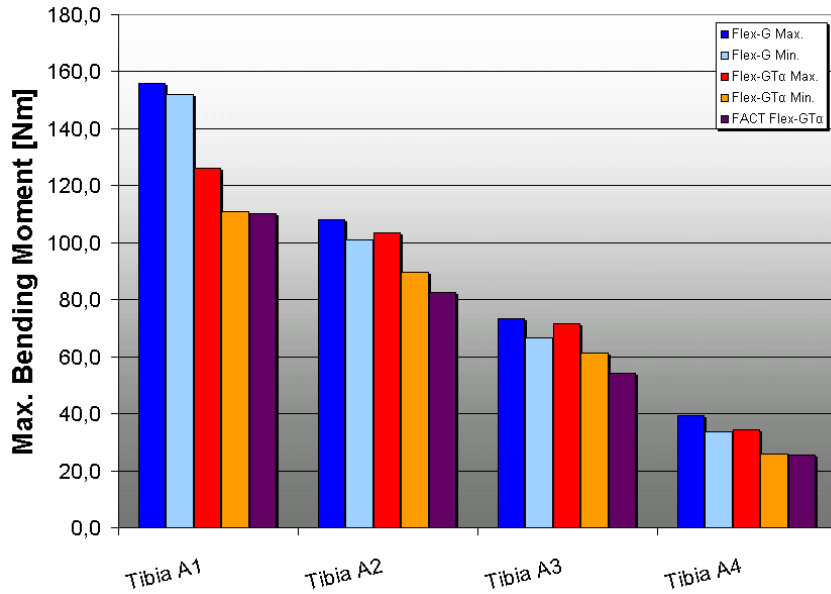
**Results / open issues**



Flex-GT $\alpha$  certification



Flex-GT $\alpha$  knee detail



Flex-G certification tests (5)  
 Flex-GT $\alpha$  certification tests (21)  
 Flex-GT $\alpha$  full assembly certification test (1)

Standard Deviation [%]:

Flex-G:

1,25 / 2,73 / 3,63 / 7,02 (tibia A1 - A4)  
 7,05 / 2,69 / 1,03 (ACL / PCL / MCL)

Flex-GT $\alpha$ :

3,82 / 3,53 / 3,53 / 6,75 (tibia A1-A4)  
 10,44 / 10,48 / 3,14 (ACL / PCL / MCL)

- lower performance of Flex-GT $\alpha$  in dynamic certification test in comparison with Flex-G
- dynamic certification tests showed a high scatter within the Flex-GT $\alpha$  test results especially for the ACL and PCL knee ligaments [SD > 10%]
- higher knee sensitivity of Flex-GT $\alpha$  can be stated
- a Flex-GT $\alpha$  full assembly certification test (with flesh and skin) showed a comparatively similar behaviour with marginally higher ligament results due to a higher knee stiffness caused by the application of the rubber sheets over the whole impactor length
- tests reveal a high z-rotation caused by an insufficient suspension method and the knee clearance
- certification method needs to be revised

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## General

- Flex-GT $\alpha$  robust enough to be tested at regular impact speed
- good handling and usability under mechanical aspects
- no expendables (foam, ligaments) needed

## Comparison EEVC WG 17 PLI and Flex-GT $\alpha$ test results

- good test results according to Euro NCAP can be confirmed by Flex-GT $\alpha$ -tests (taking into account the currently proposed tentative injury thresholds)

## Influence of impactor impact height

- clearly depends on the car impact height, the shape of the impact point environment and the corresponding legform measuring point
- significantly smaller MCL loads with an increased impact height



## Repeatability / sensitivity of the knee

- repeatability for tibia sections significantly higher than for the knee ligaments
- sensitivity of the knee high towards a variation of impact parameters and (minor) modifications of the car front shape
- additional tests under idealised impact conditions revealed a high sensitivity of the knee ligaments towards even marginally changed impact conditions (impact height, rotation)

## Dynamic certification test

- dynamic certification tests showed a high scatter within the Flex-GT $\alpha$  test results especially for the ACL and PCL knee ligaments [SD > 10%]
- certification tests reveal a high z-rotation caused by an insufficient suspension method and the knee clearance





- further tests at 75 mm on different car fronts and shapes would be beneficial
- further research on the variation of impact parameters (as impact height, z-rotation) needed
- dynamic certification method needs to be revised
- transfer function between knee bending angle and ligament elongation ?
- a study on injury thresholds for the anterior and posterior cruciate ligaments needs to be carried out (currently no injury risk curve available due to the comparatively low priority given to ACL and PCL injury risk during an accident)

Thank you for your attention !

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