Injury Threshold for the Flex-PLI Medial Collateral Ligament (MCL) (JAMA proposal)

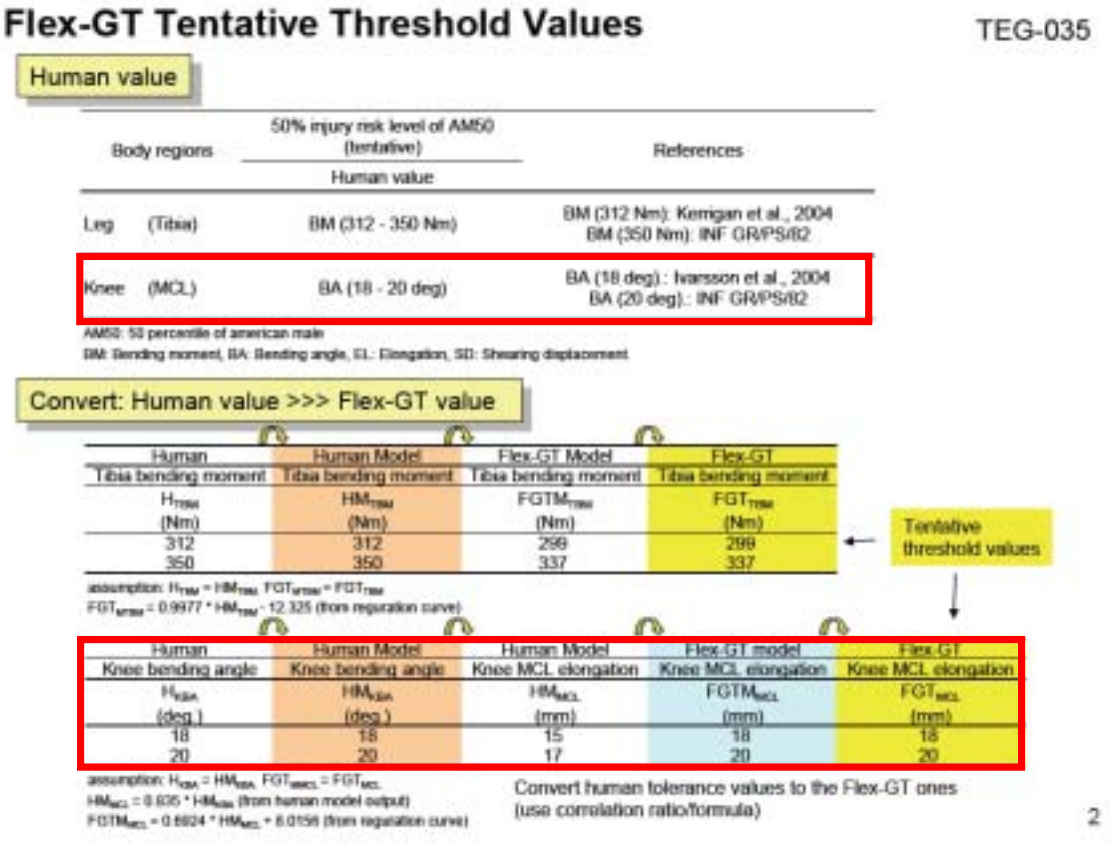
The Japan Automobile Manufacturers Association Inc.
Vehicle Safety subcommittee and Pedestrian Safety WG

Current Proposal

TEG-048
29 Nov. 2007
JAMA-JARI

Review of Injury Criteria and Injury Thresholds for Flex-PLI

Current Proposal



Flex-GT Tentative Threshold Values TEG-035

Human value

Body regions	50% injury risk level of AM50 (tentative) Human value	References
Leg (Tibia)	BM (312 - 350 Nm)	BM (312 Nm): Kerrigan et al., 2004 BM (350 Nm): INF GR/PS/82
Knee (MCL)	BA (18 - 20 deg)	BA (18 deg): Ivarsson et al., 2004 BA (20 deg): INF GR/PS/82

AM50: 50 percentile of american male
BM: Bending moment, BA: Bending angle, EL: Elongation, SD: Shearing displacement

Convert: Human value >>> Flex-GT value

Human Tibia bending moment	Human Model Tibia bending moment	Flex-GT Model Tibia bending moment	Flex-GT Tibia bending moment
H_{TBM} (Nm)	HM_{TBM} (Nm)	$FGTM_{TBM}$ (Nm)	FGT_{TBM} (Nm)
312	312	299	299
350	350	337	337

Tentative threshold values

assumption: $H_{TBM} = HM_{TBM}$, $FGT_{MTBM} = FGT_{TBM}$
$FGT_{MTBM} = 0.9977 * HM_{TBM} - 12.325$ (from regression curve)

Human Knee bending angle	Human Model Knee bending angle	Human Model Knee MCL elongation	Flex-GT model Knee MCL elongation	Flex-GT Knee MCL elongation
H_{KBA} (deg.)	HM_{KBA} (deg.)	HM_{MCL} (mm)	$FGTM_{MCL}$ (mm)	FGT_{MCL} (mm)
18	18	15	18	18
20	20	17	20	20

assumption: $H_{KBA} = HM_{KBA}$, $FGT_{MMCL} = FGT_{MCL}$
$HM_{MCL} = 0.835 * HM_{KBA}$ (from human model output)
$FGTM_{MCL} = 0.6824 * HM_{MCL} + 6.0156$ (from regression curve)

Convert human tolerance values to the Flex-GT ones (use correlation ratio/formula)

2

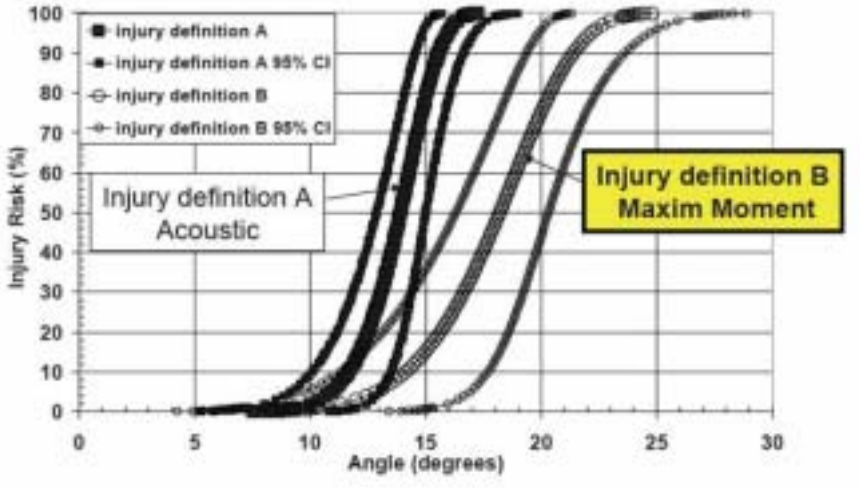
Based on the paper by Iversson et al. (2004) employed by IHRA, and the ESV paper by Konosu et al. (2001), the threshold values for MCL failure were set at 18 and 20 mm.

Current Proposal

References (referred contents)

Human value

Injury Risk Curve for Knee (Bending)



- Ivarsson, B.J., Lessley, D., Kerrigan, J.R., Bhalla, K.S., Bose, D., Crandall, J.R., Kent, R. (2004) Dynamic Response Corridors and Injury Thresholds of the Pedestrian Lower Extremities, Proc. International IRCOBI Conference on the Biomechanics of Impacts, pp. 179-191.

6

Injury risk curves for MCL failure from the IRCOBI paper by Iversson et al. (2004) employed by IHRA

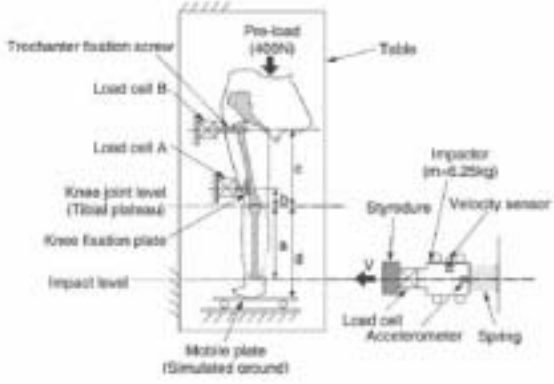
Current Proposal

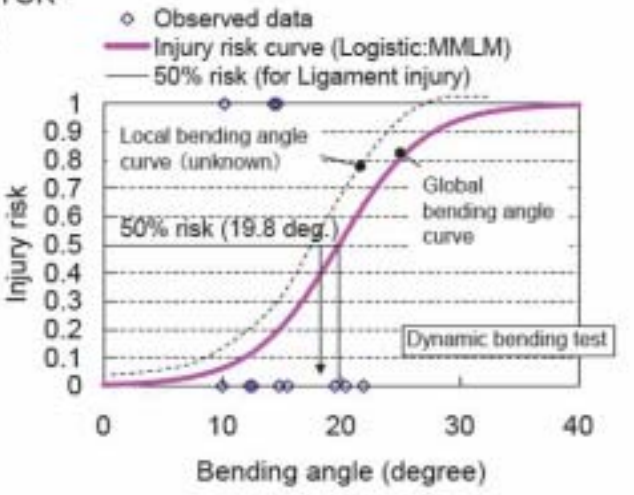
References (referred contents)

Human value

Injury Risk Curve for Knee (Bending)

RECONSIDERATION OF INJURY CRITERIA FOR PEDESTRIAN SUBSYSTEM LEGFORM TEST
- PROBLEMS OF RIGID LEGFORM IMPACTOR -
Konosu A. et al, 2001 (ESV, Paper No. 263)





Proposed injury threshold for Knee bending: 20 deg.

Local bending angle: Exclude Long Bone Bending Angle
Global bending angle: Include Long Bone Bending Angle

- ECE/TRANS/WP.29/GRSP/INF GR PS (2004) Discussion on Injury Threshold for Pedestrian Legform Test, INF/GR/PS/82, P. 2.

7

Injury risk curves for MCL failure from the ESV paper by Konosu et al. (2001)

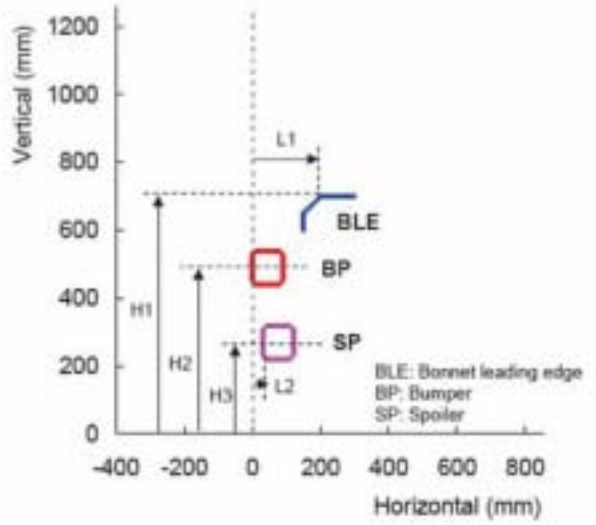
Current Proposal

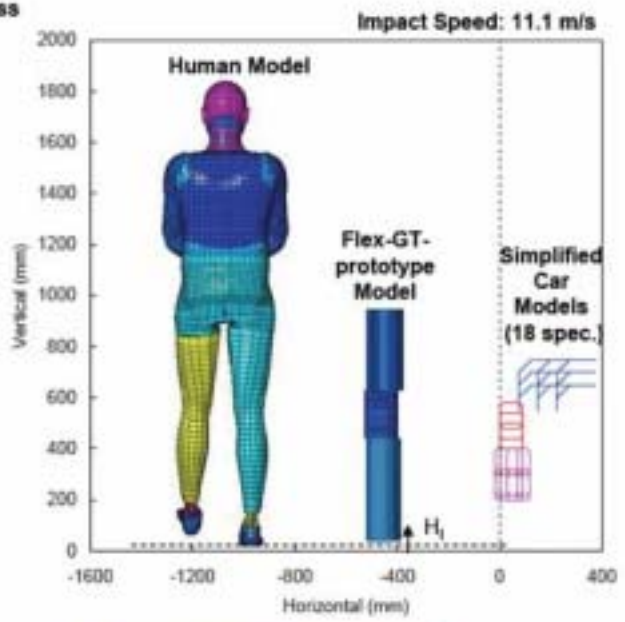
Computer Simulation Analysis

Simplified Car Model (Parameters)

Parameter	Unit	Level 1	Level 2	Level 3	
K1 (BLE stiffness*)	mm	0.4	0.6		Stiffness
K2 (BP stiffness**)	JC***	0.7	0.8	1.0	
K3 (SP stiffness**)	JC***	0.6	0.8	1.0	
H1 (BLE height)	mm	650	700	750	
H2 (BP height)	mm	450	490	530	Shape
H3 (SP height)	mm	250	270	350	
L1 (BLE lead)	mm	125	200	275	
L2 (SP lead)	mm	-20	0	30	

* Stiffness is changed by steel plate thickness.
** Stiffness is changed by joint characteristics.
*** JC: Joint characteristics



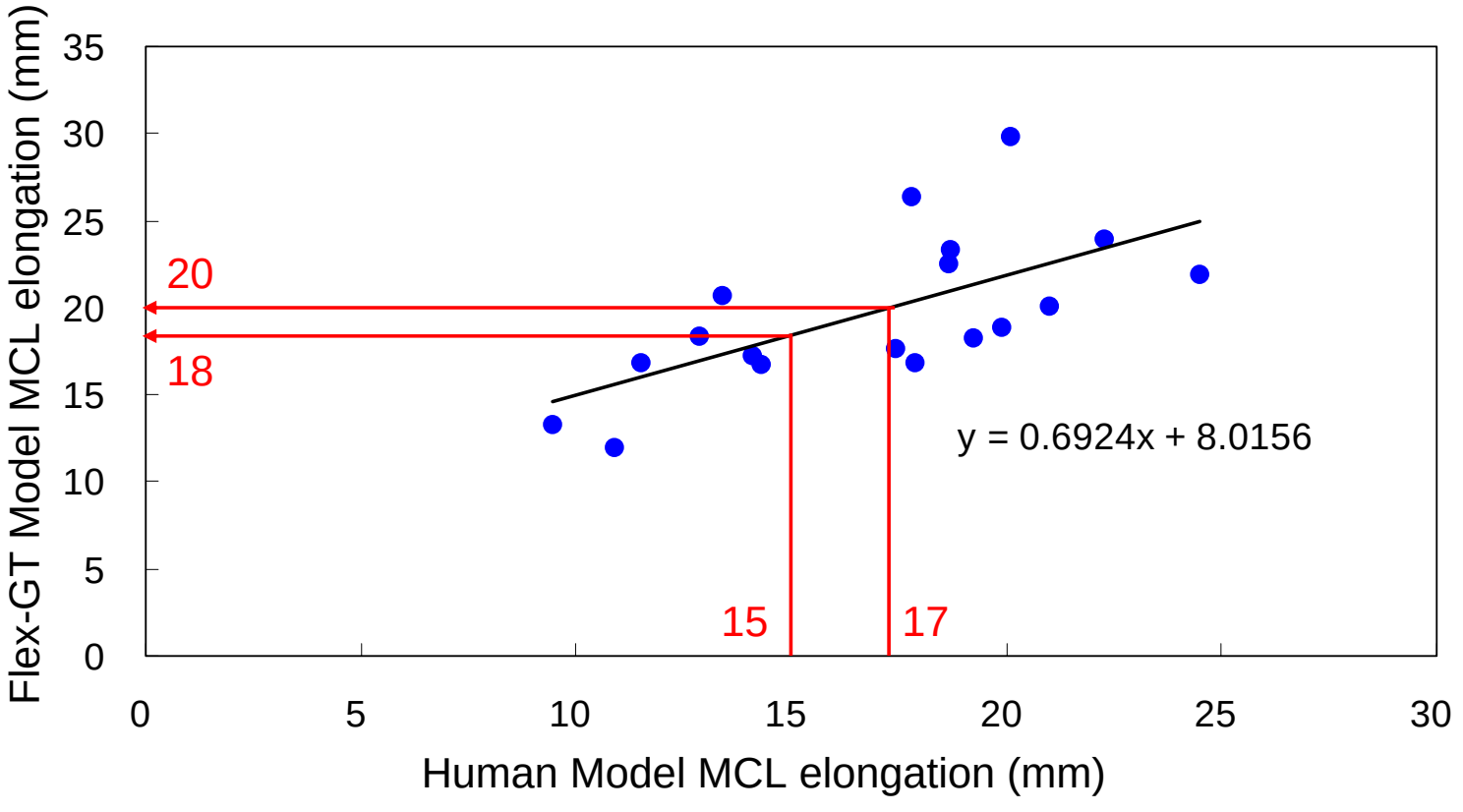


H_I: Impact Height
Type1 = base = 25mm (Human, Flex)
Type2 = base + 50 mm (Flex)
Type3 = base + 100 mm (Flex)

Parameter study was carried out using simplified car models.

Estimation of MCL Failure Threshold

Flex vs. Human model (not including high-bumper vehicles)



Flex-GT MCL elongation thresholds (18-20 mm) were deduced from the correlation obtained using the FE simulation results with simplified vehicle models **not including those representing high-bumper vehicles**

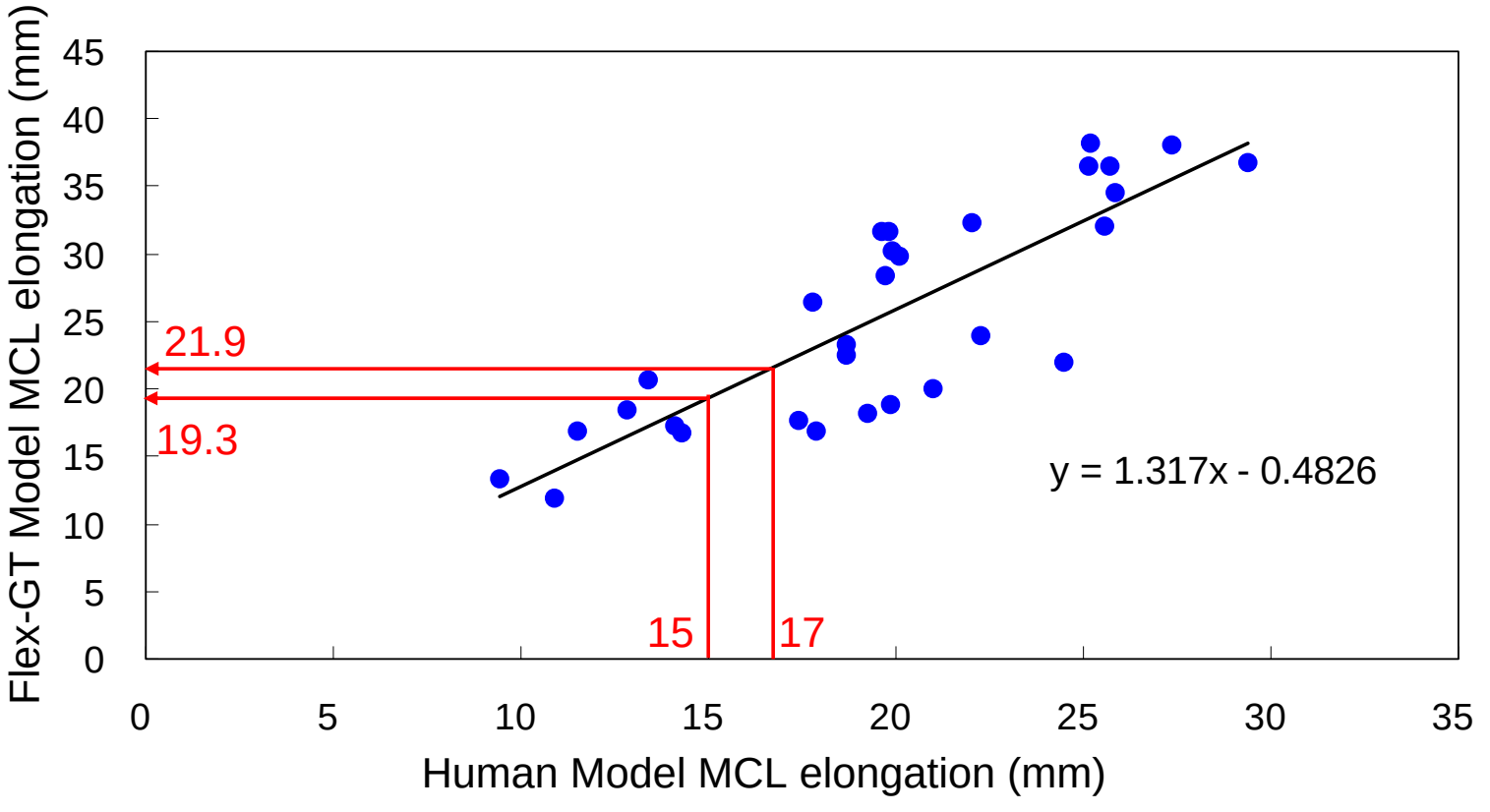
Issues with Current MCL Threshold

1. Flex-GT MCL elongation thresholds (18-20 mm) were deduced from the correlation obtained using the FE simulation results with simplified vehicle models not including those representing high-bumper vehicles

2. The effect of muscle tone on the knee joint tolerance taken into account in the current gtr has not been reflected in determining the MCL elongation thresholds

Estimation of MCL Failure Threshold

Flex vs. Human model (INCLUDING high-bumper vehicles)



Flex-GT MCL elongation thresholds will be 19-22 mm when the correlation obtained using the FE simulation results with simplified vehicle models INCLUDING those representing high-bumper vehicles is used

Effect of Muscle Tone

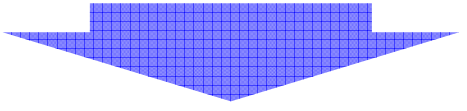
- Lloyd and Buchanan (1996) – Muscles are activated to support about 15% of static varus-valgus loads. Muscular contribution increased with increasing magnitude of VV moments
- Lloyd and Buchanan (2001) – For volunteers, average contribution to varus is 17 ± 9.7% and to valgus is 10 ± 6.3% of externally applied moment

David G. Lloyd, Thomas S. Buchanan
Strategies of muscular support of varus and valgus isometric loads at the human knee
J. of Biomechanics 34 (2001) 1257-1267

The effect of muscle tone has been addressed in Lloyd and Buchanan (1996, 2001) from the Journal of Biomechanics

Effect of Muscle Tone

- Flex-GT MCL elongation thresholds : 19.3-21.9 mm based on the correlation obtained using the FE simulation results with simplified vehicle models INCLUDING those representing high-bumper vehicles
- Effect of muscle tone : 10% in valgus bending
- Flex-GT MCL elongation thresholds taking into account the effect of muscle tone : 21.2-24.1 mm (average : 22.7 mm)



Proposed Flex-PLI MCL elongation threshold : 23 mm