Development of Flex-GTR Master Leg FE Model and Evaluation of Validity of the Current Threshold Values against Flex-GTR Master leg

June 27, 2013

Japan Automobile Standards Internationalization Center (JASIC)

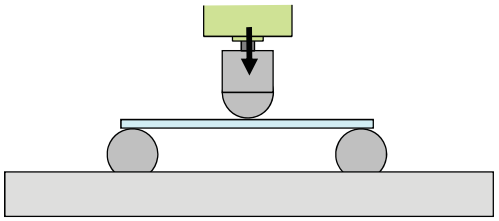
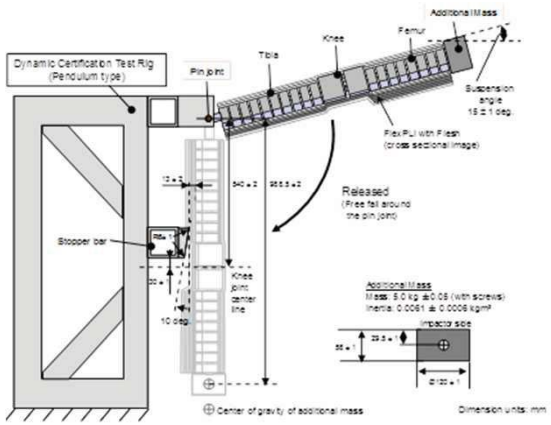
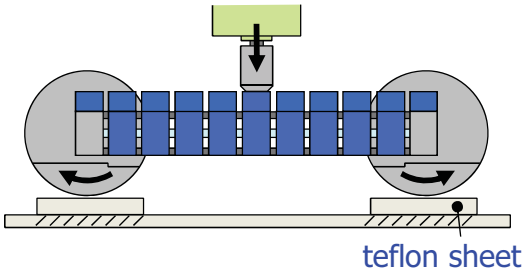
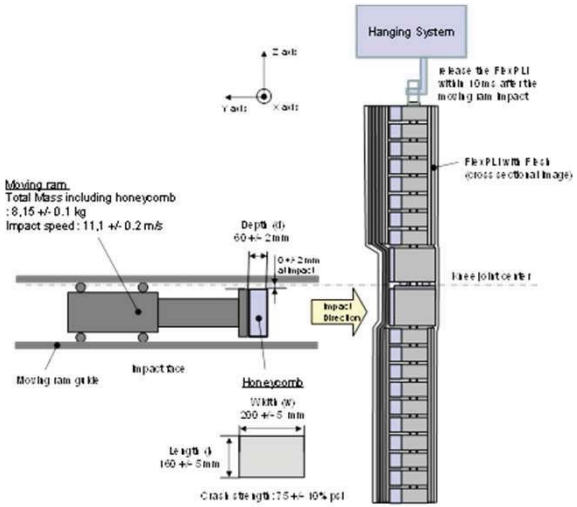
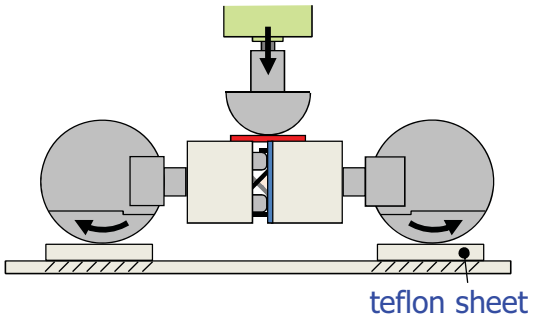
Background

- The current threshold values for Flex-GTR were obtained by converting the human threshold values to those of the Flex-GTR using correlation functions between human FE model and Flex-GTR FE model. (JASIC method)
- However, the Flex-GTR FE model was developed against the Flex-GTR-prototype, therefore, it is unclear that the current threshold values are still valid for the latest Flex-GTR version called "Flex-GTR Mater leg".
- Therefore, we decided to develop a "Flex-GTR Master leg FE model" by validating the model against the Master leg, and to evaluate the validity of the current threshold values against Flex-GTR Master leg using the model.

Part 1: Development of Flex-GTR Master leg FE model

Methodology

- "Flex-GTR Master leg FE model" was developed and validated against the following requirement corridors determined from Flex-GTR Master legs:

(1) Tibia/Femur bonecore 3 point bending certification test		(4) Pendulum certification test	
(2) Tibia/Femur assembly 3 point bending certification test		(5) Inverse certification test	
(3) Knee assembly 3 point bending certification test			

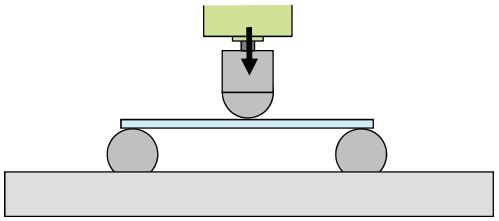
Validation Result (1)

Tibia/Femur bonecore 3 point bending certification test

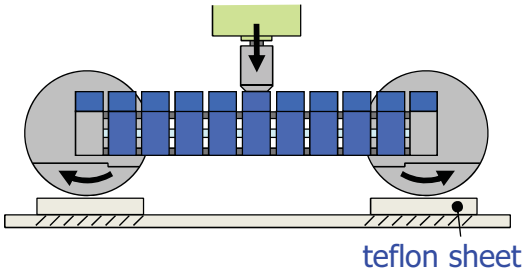
Validation Result (1)

Tibia/Femur bonecore 3 point bending certification test

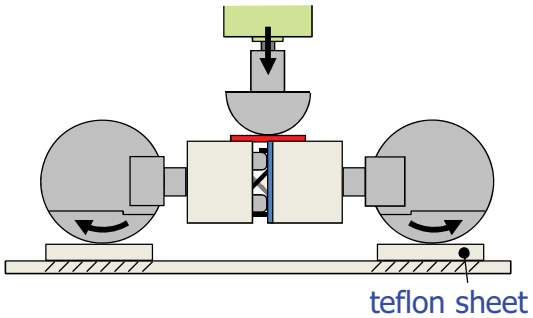
(1)
Tibia/Femur bonecore
3 point bending certification test



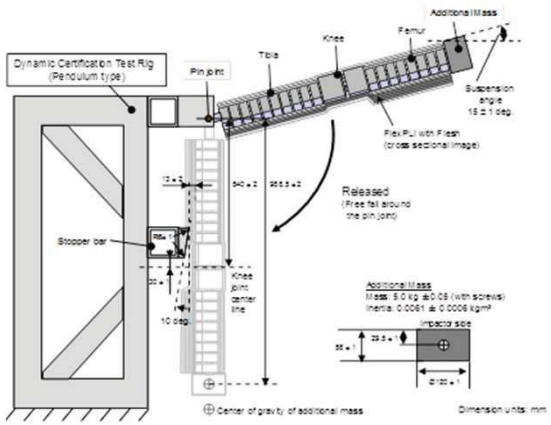
(2)
Tibia/Femur assembly
3 point bending certification test



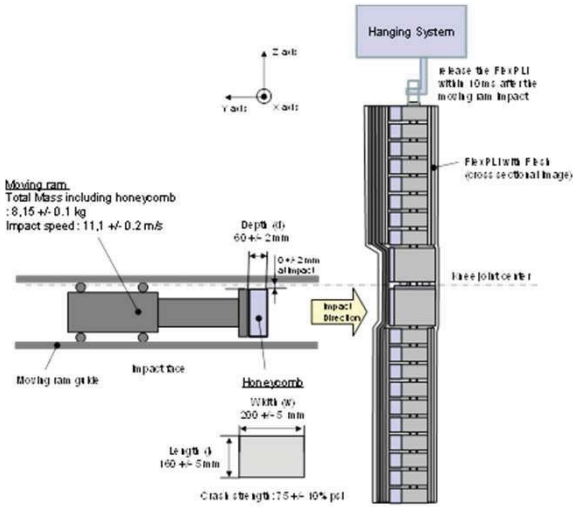
(3)
Knee assembly
3 point bending certification test



(4)
Pendulum certification test



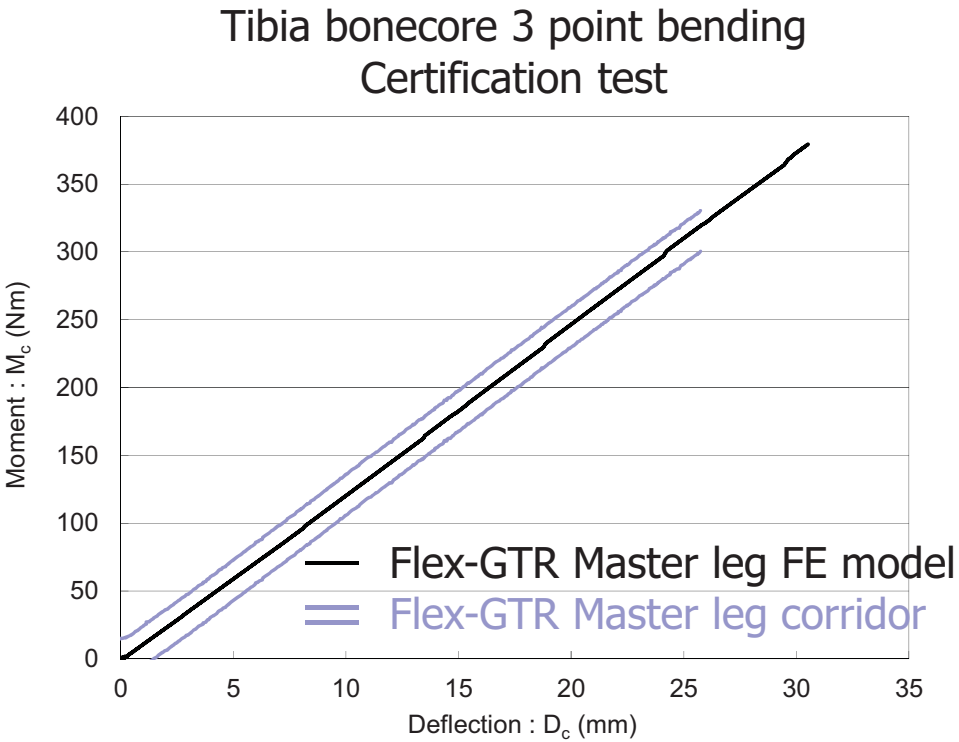
(5)
Inverse certification test

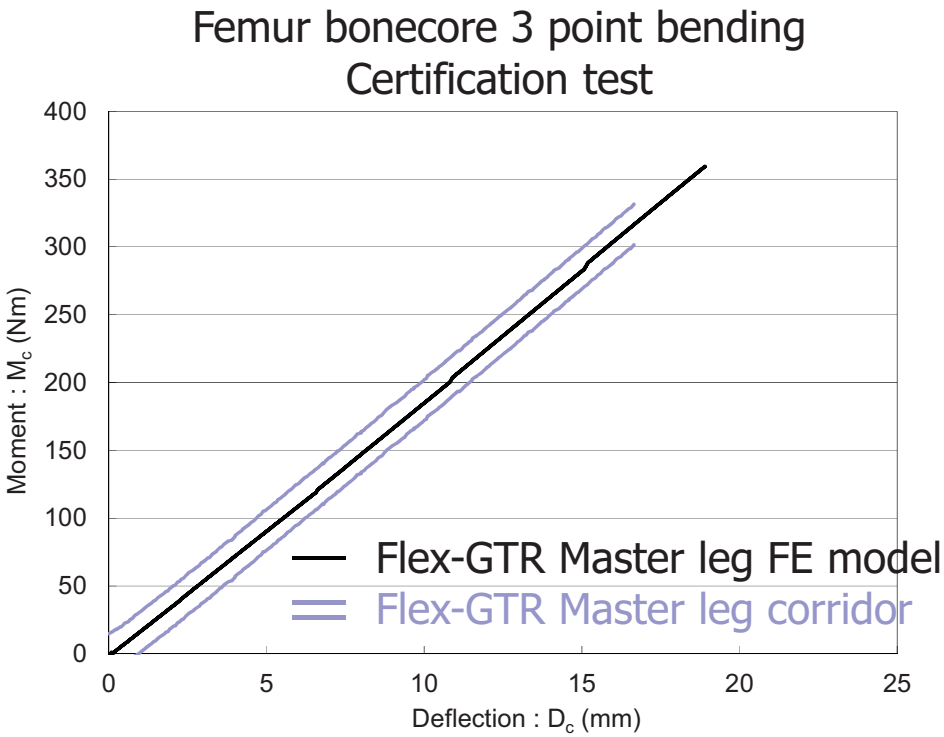


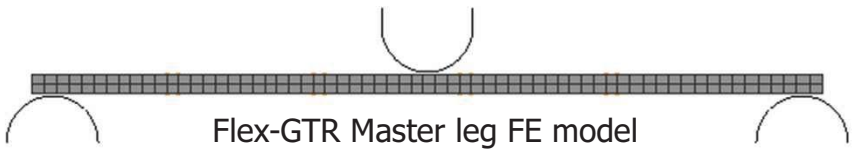
Validation Result (1)

Tibia/Femur bonecore 3 point bending certification test

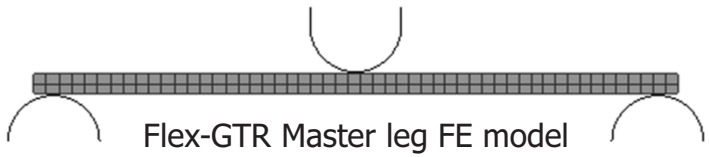
- Flex-GTR Master leg FE model represents the mean of the Flex-GTR Master leg tibia/femur bonecore corridors.







Flex-GTR Master leg FE model
Tibia bonecore



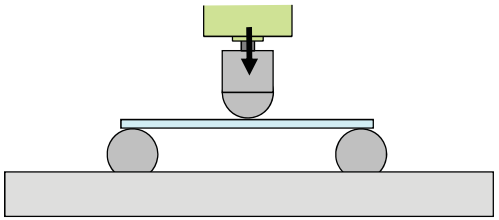
Flex-GTR Master leg FE model
Femur bonecore

Validation Result (2)
Tibia/Femur assembly 3 point bending certification test

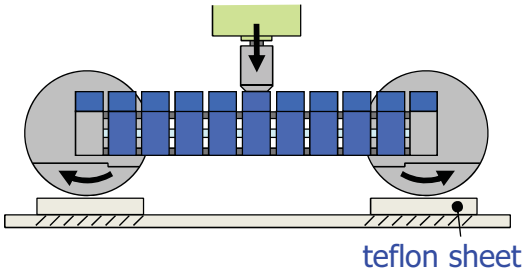
Validation Result (2)

Tibia/Femur assembly 3 point bending certification test

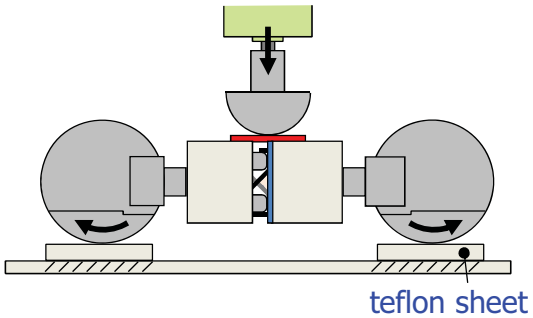
(1)
Tibia/Femur bonecore
3 point bending certification test



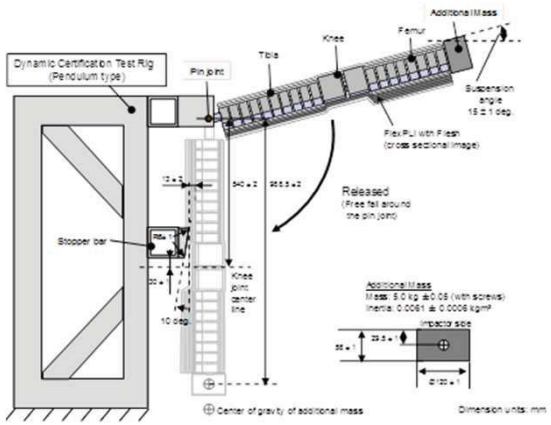
(2)
Tibia/Femur assembly
3 point bending certification test



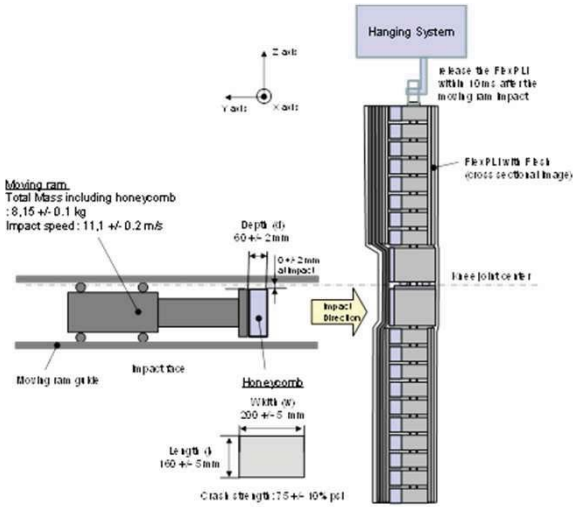
(3)
Knee assembly
3 point bending certification test



(4)
Pendulum certification test



(5)
Inverse certification test

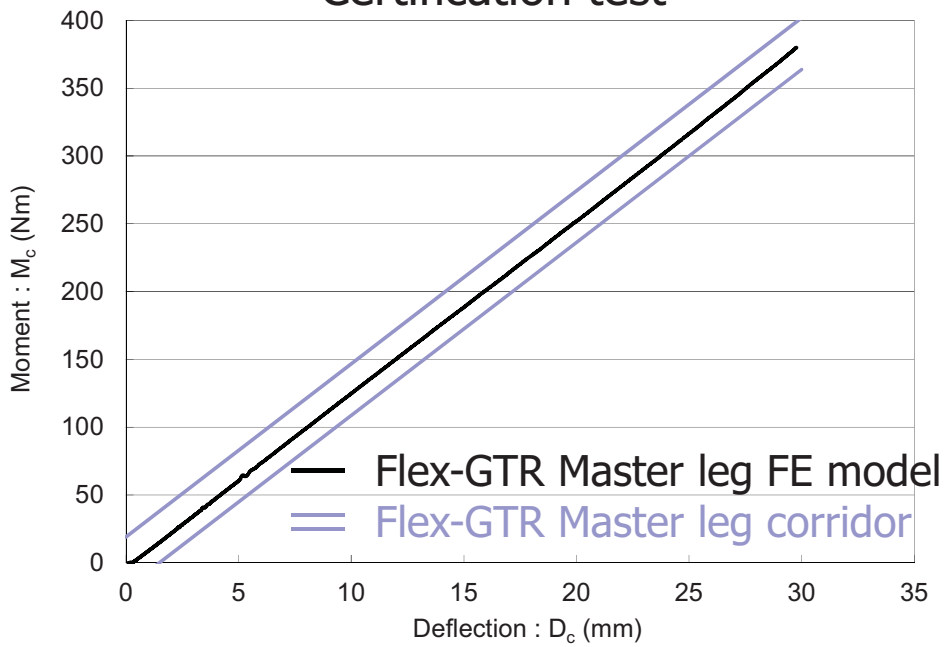


Validation Result (2)

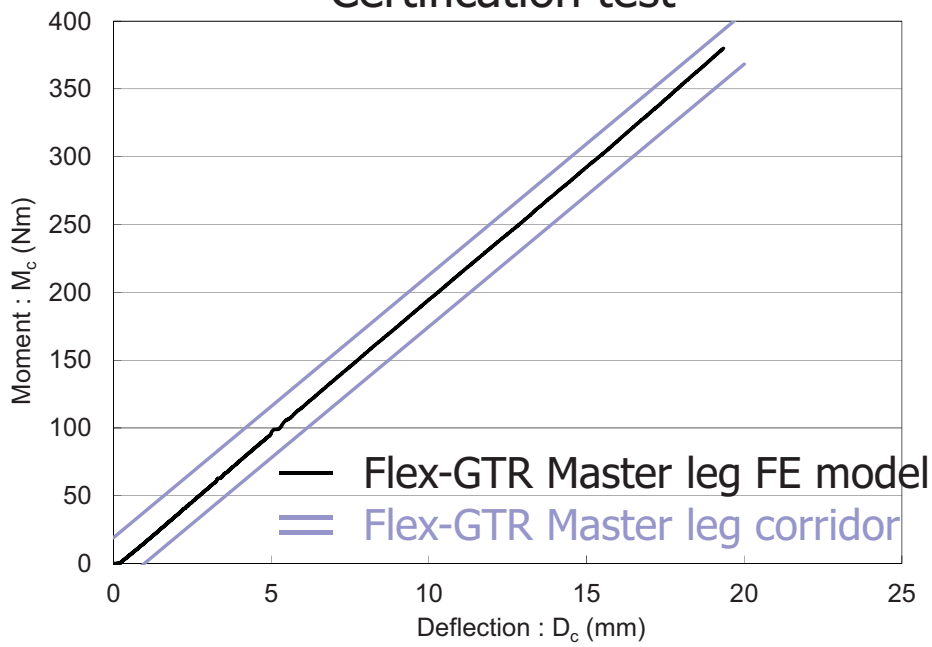
Tibia/Femur assembly 3 point bending certification test

- Flex-GTR Master leg FE model represents the mean of the Flex-GTR Master leg tibia/femur assembly corridors.

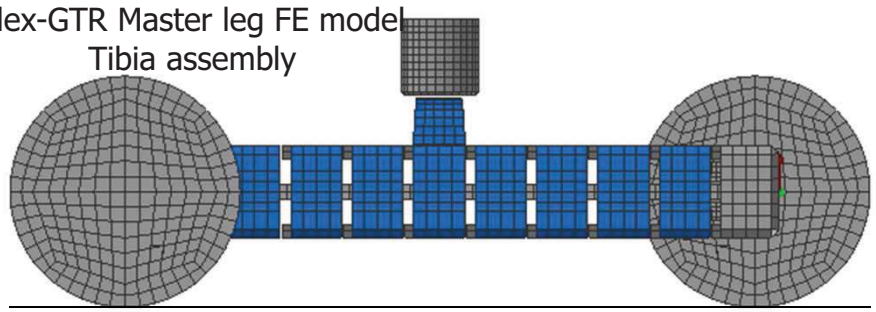
Tibia assembly 3 point bending Certification test



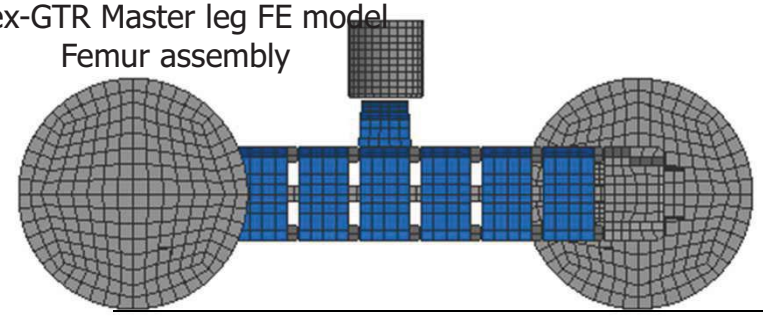
Femur assembly 3 point bending Certification test



Flex-GTR Master leg FE model
Tibia assembly



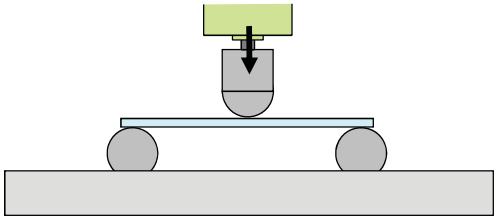
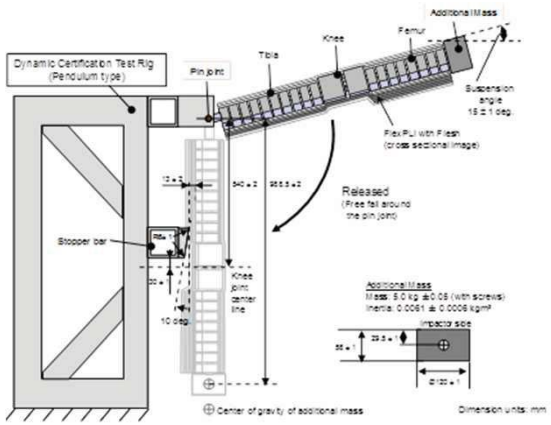
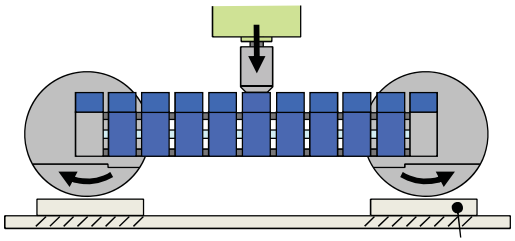
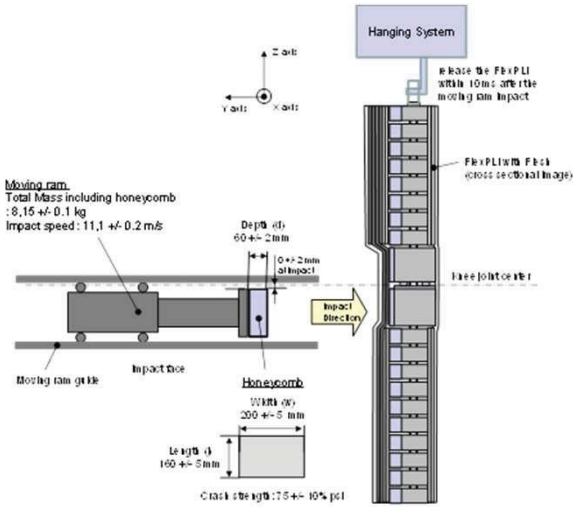
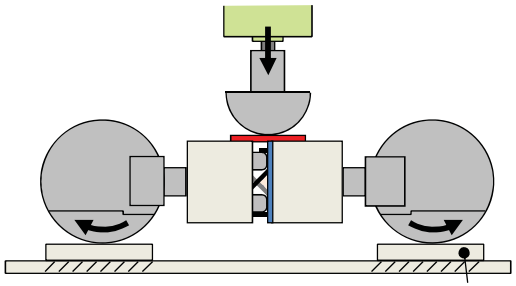
Flex-GTR Master leg FE model
Femur assembly



Validation Result (3)
Knee assembly 3 point bending certification test

Validation Result (3)

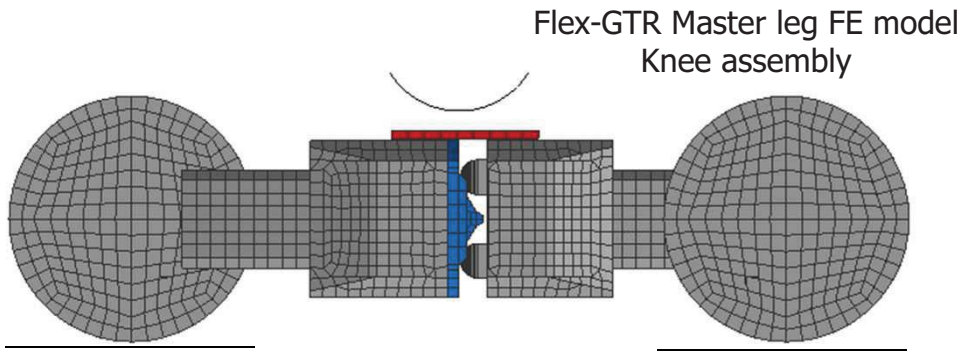
Knee assembly 3 point bending certification test

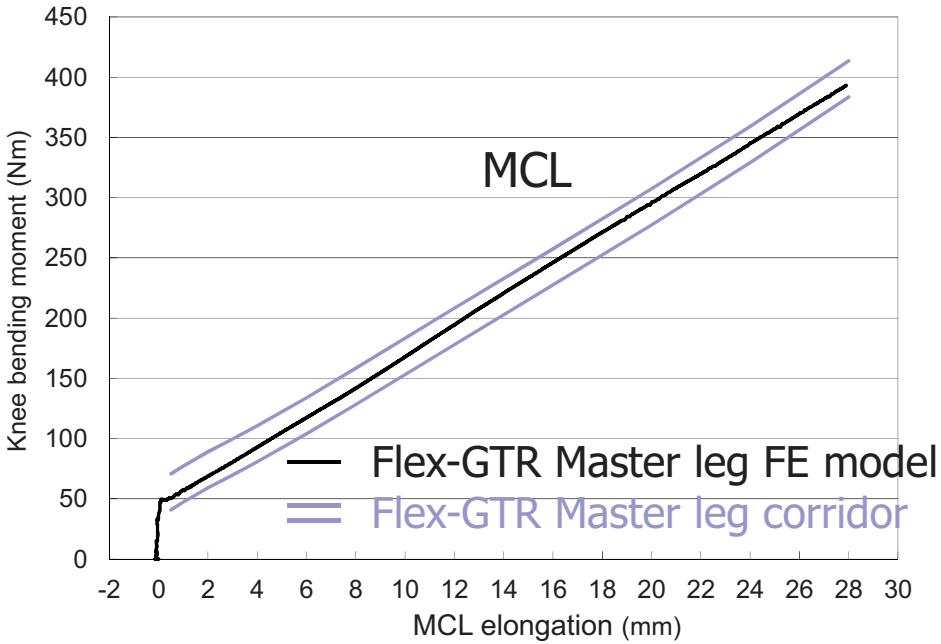
(1) Tibia/Femur bonecore 3 point bending certification test		(4) Pendulum certification test	
(2) Tibia/Femur assembly 3 point bending certification test		(5) Inverse certification test	
(3) Knee assembly 3 point bending certification test			

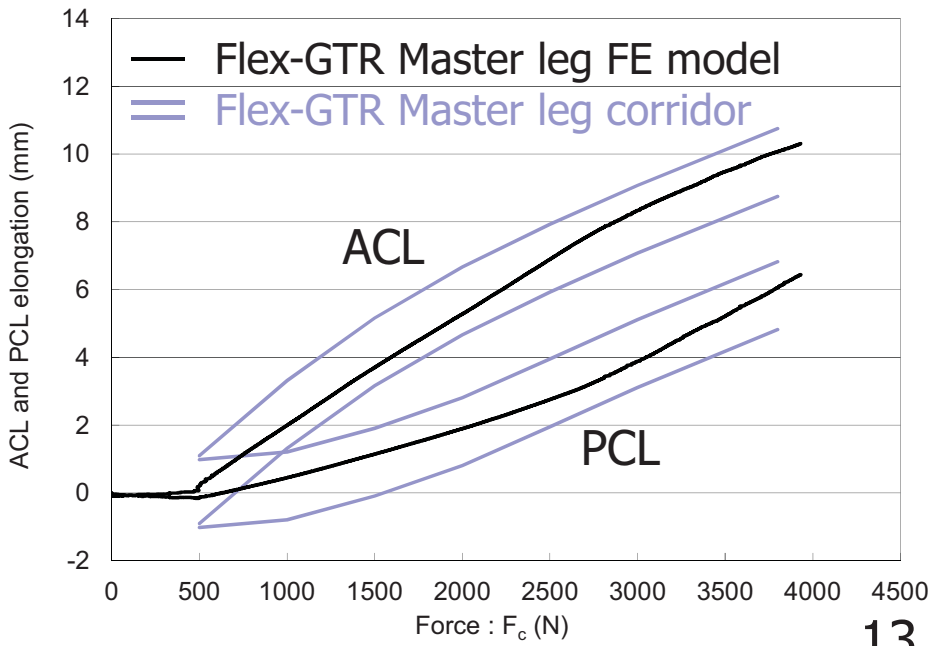
Validation Result (3)

Knee assembly 3 point bending certification test

- Flex-GTR Master leg FE model represents the mean of the Flex-GTR Master leg knee assembly corridors.

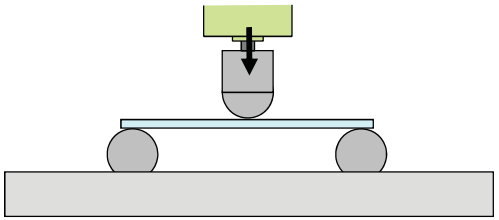
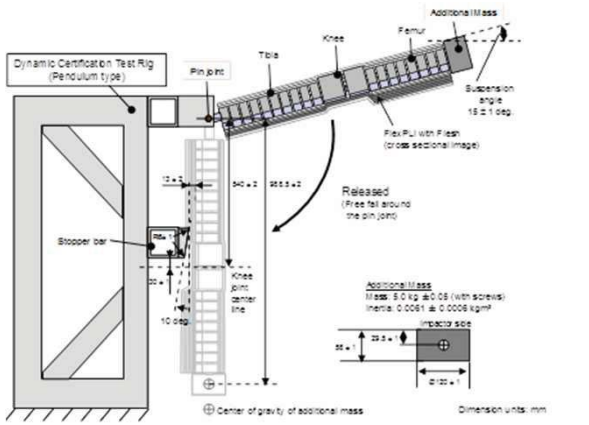
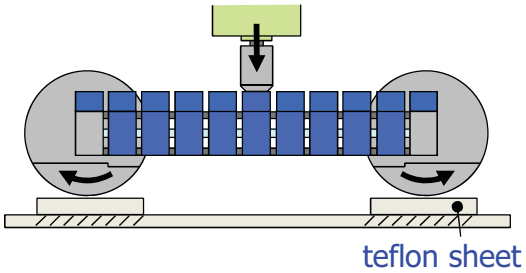
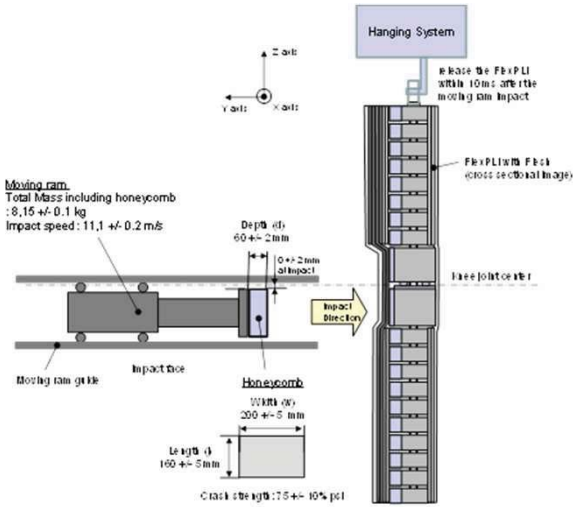
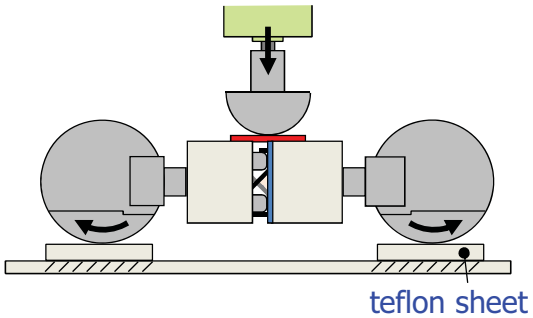






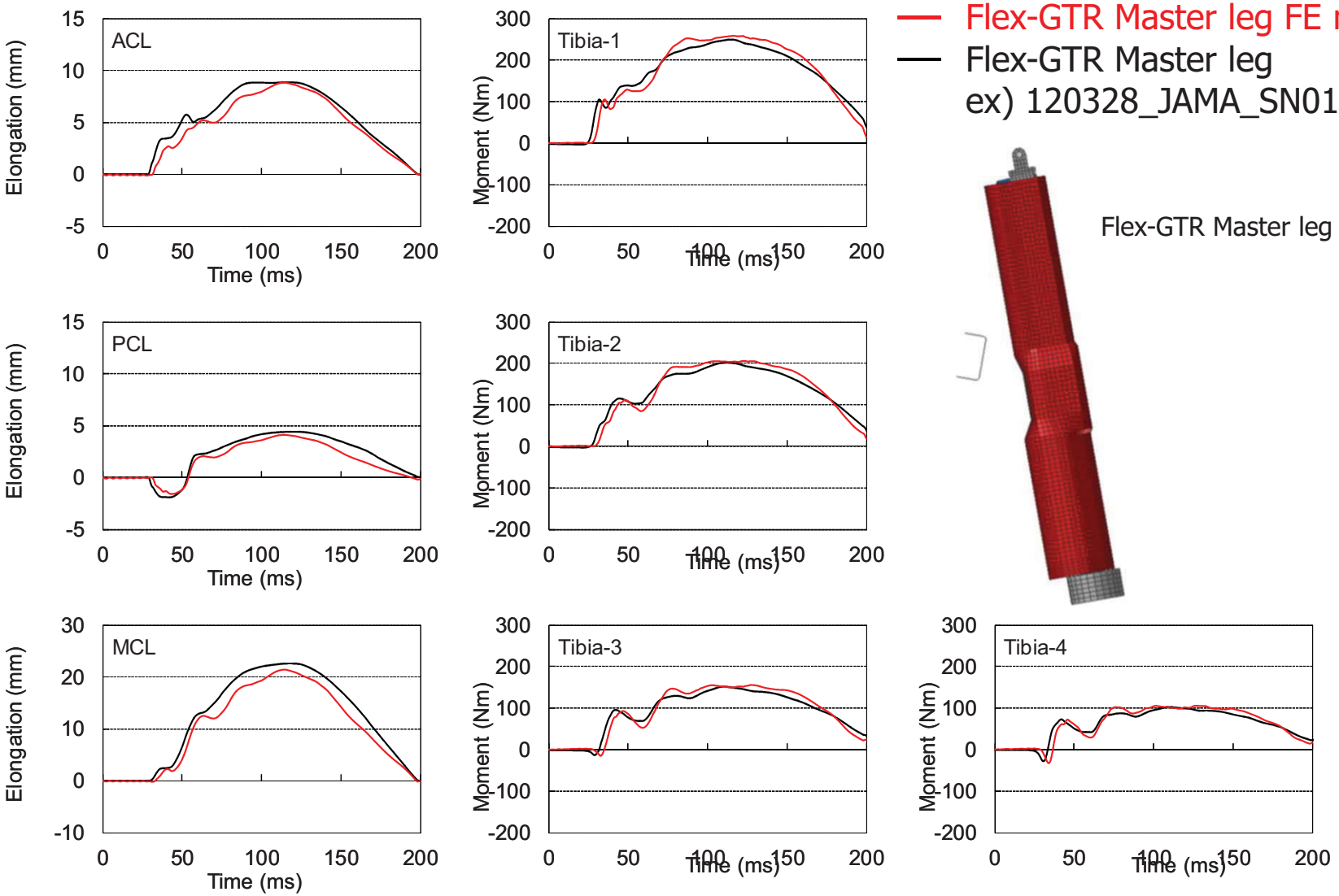
Validation Result (4)
Pendulum certification test

Validation Result (4)
Pendulum Certification Test

(1) Tibia/Femur bonecore 3 point bending certification test		(4) Pendulum certification test	
(2) Tibia/Femur assembly 3 point bending certification test	 teflon sheet	(5) Inverse certification test	
(3) Knee assembly 3 point bending certification test	 teflon sheet		

Validation Result (4): Pendulum Certification Test

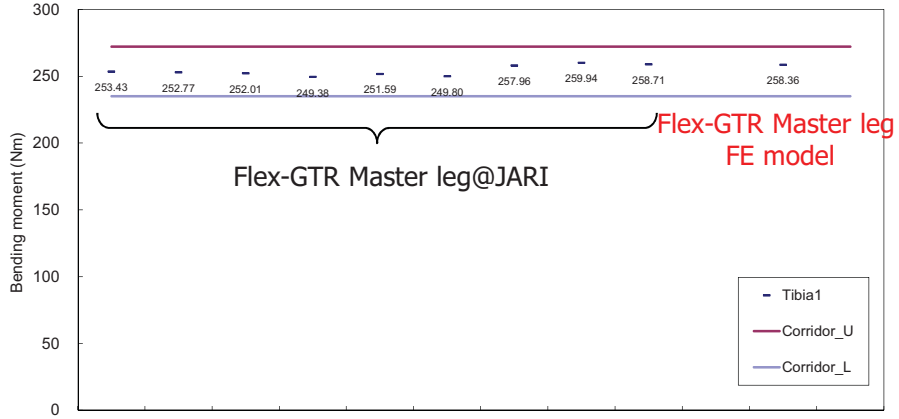
- Flex-GTR Master leg FE model wave forms are comparable with those of a Flex-GTR Master leg.



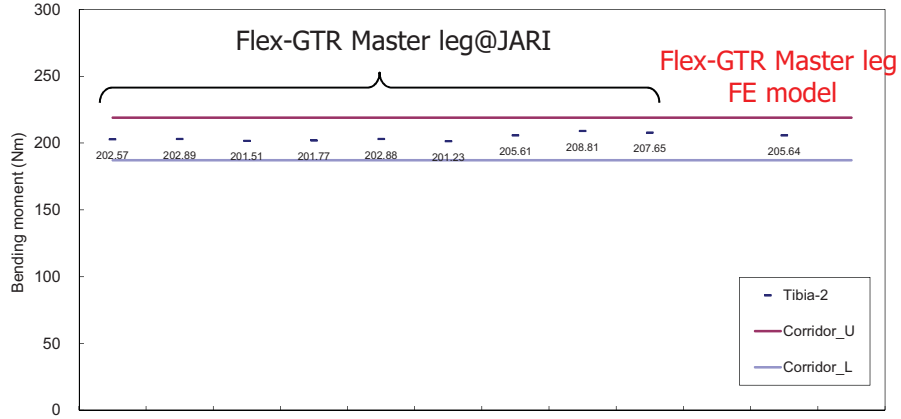
Validation Result (4): Pendulum Certification Test

- Flex-GTR Master leg FE model falls within the Flex-GTR Master leg pendulum certification test corridors.

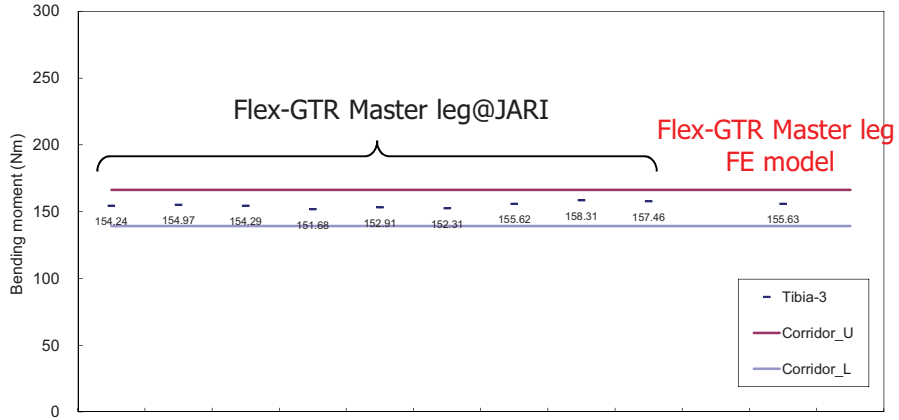
Tibia-1



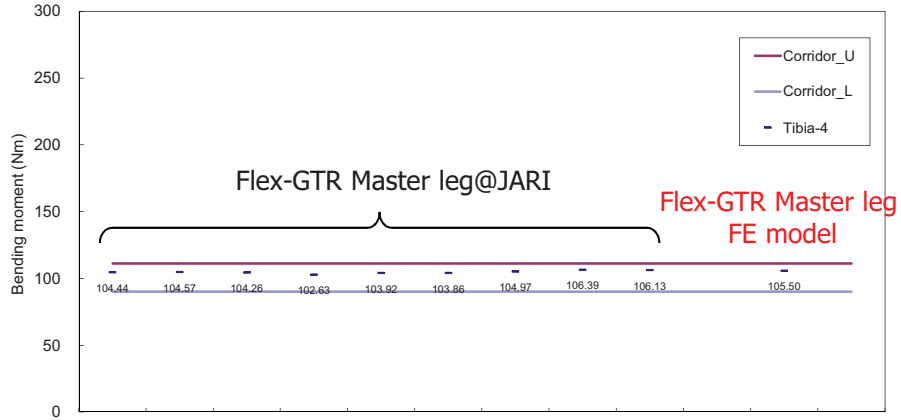
Tibia-2



Tibia-3



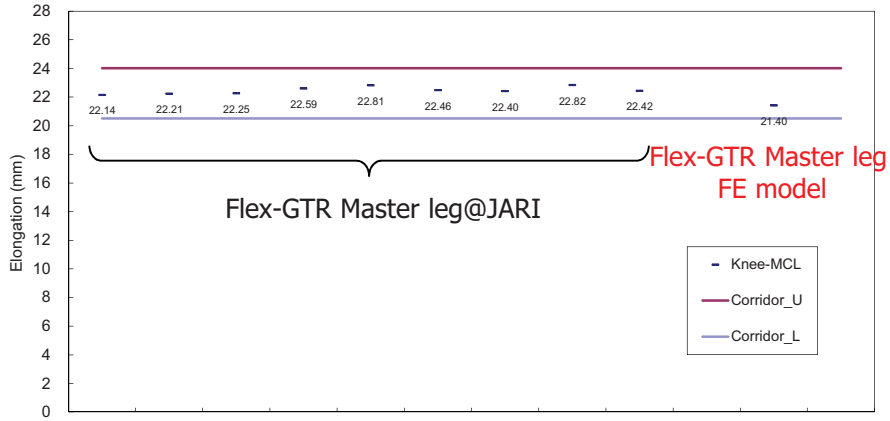
Tibia-4



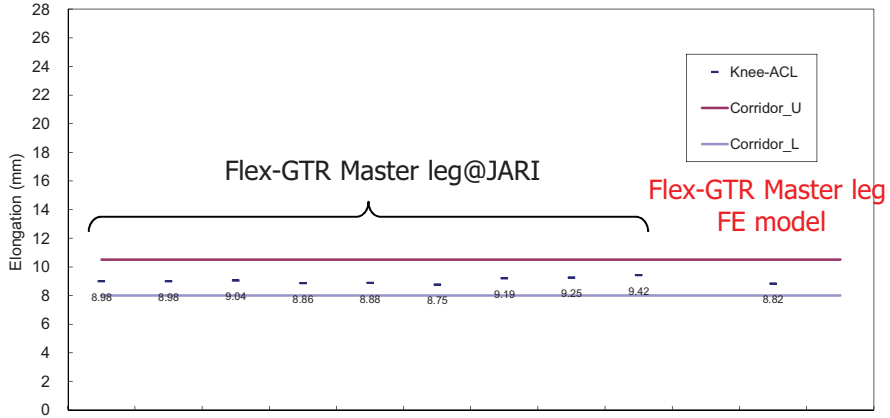
Validation Result (4): Pendulum Certification Test

- Flex-GTR Master leg FE model falls within the Flex-GTR Master leg pendulum certification test corridors.

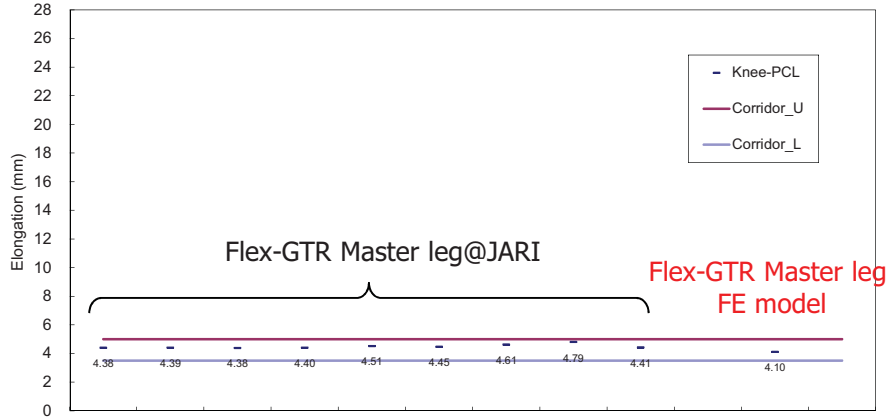
MCL



ACL

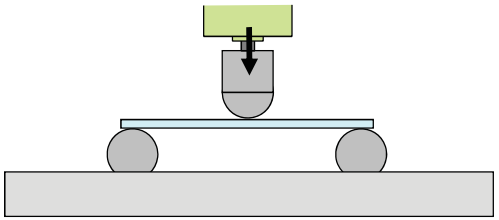
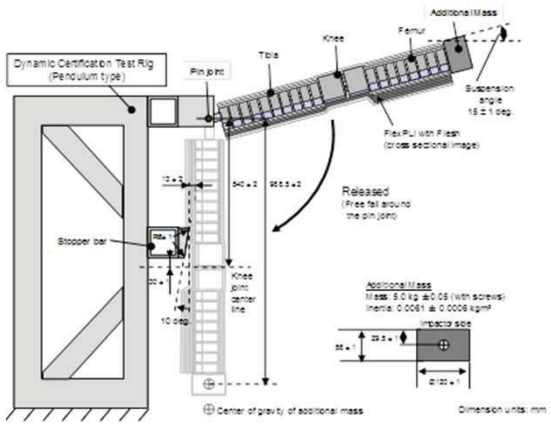
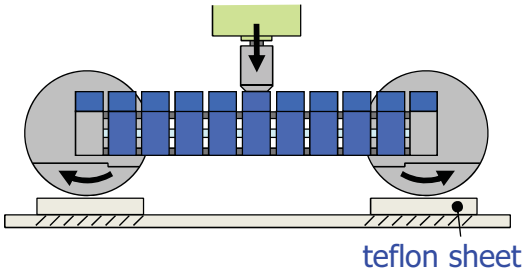
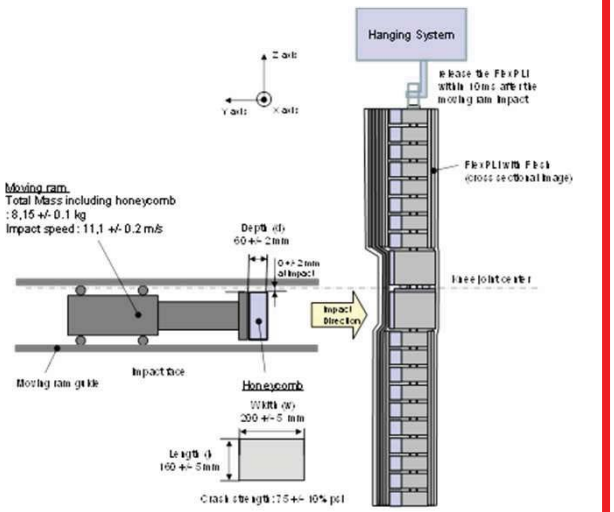
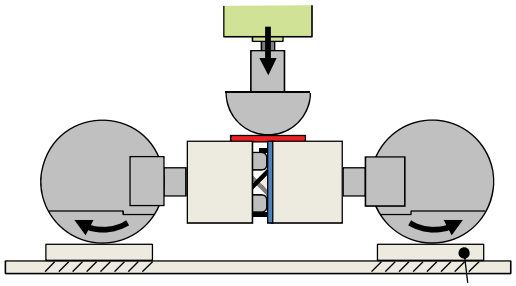


PCL



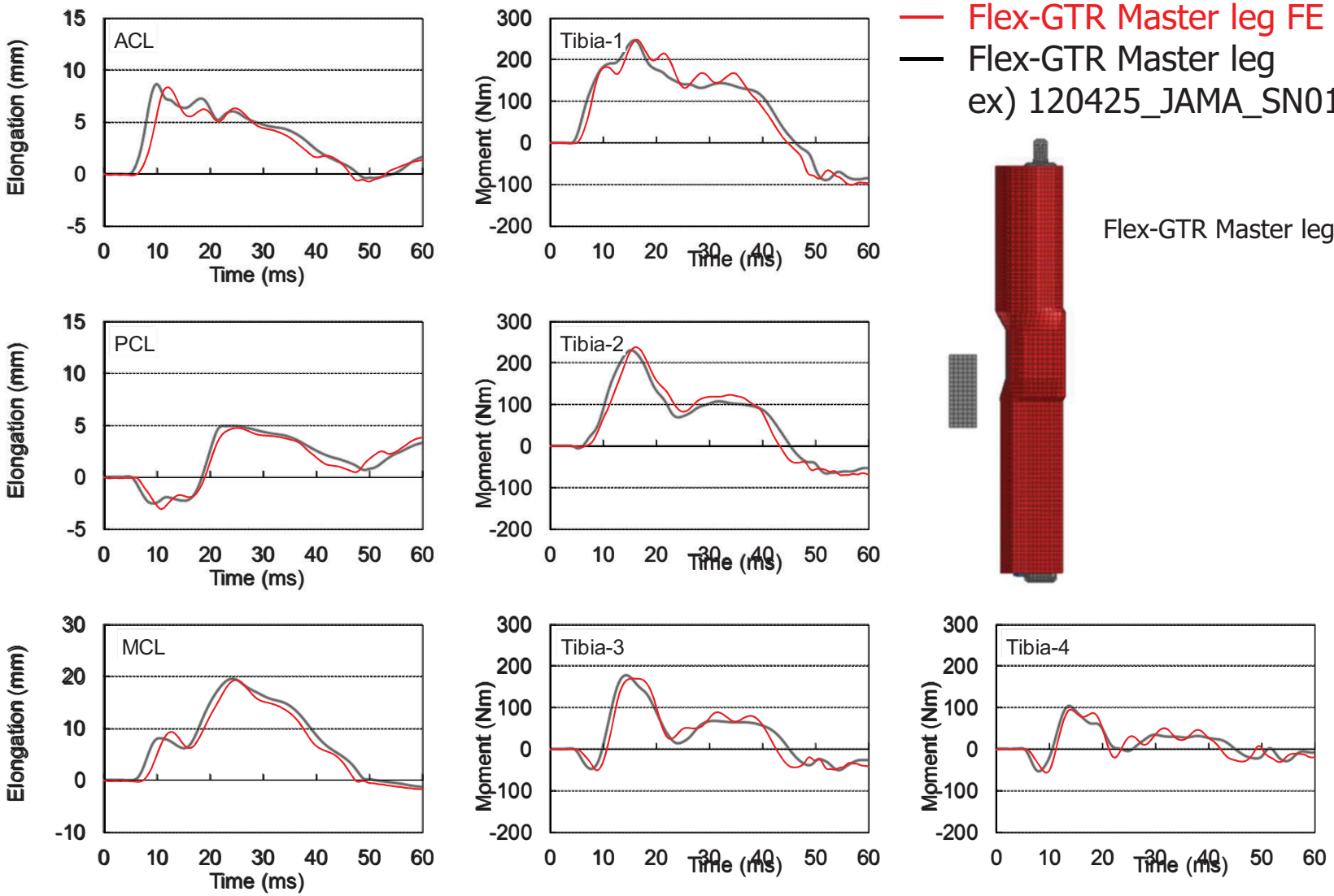
Validation Result (5)
Inverse Certification Test

Validation Result (5)
Inverse Certification Test

(1) Tibia/Femur bonecore 3 point bending certification test		(4) Pendulum certification test	
(2) Tibia/Femur assembly 3 point bending certification test		(5) Inverse certification test	
(3) Knee assembly 3 point bending certification test			

Validation Result (5): Inverse Certification Test

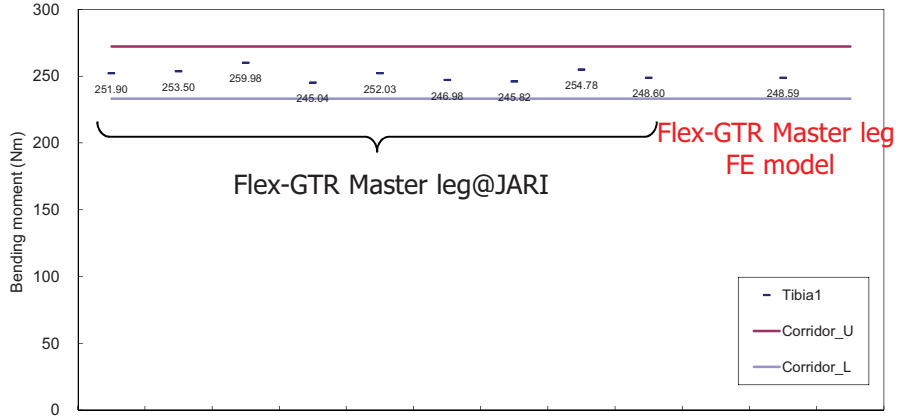
- Flex-GTR Master leg FE model wave forms are comparable with those of a Flex-GTR Master leg.



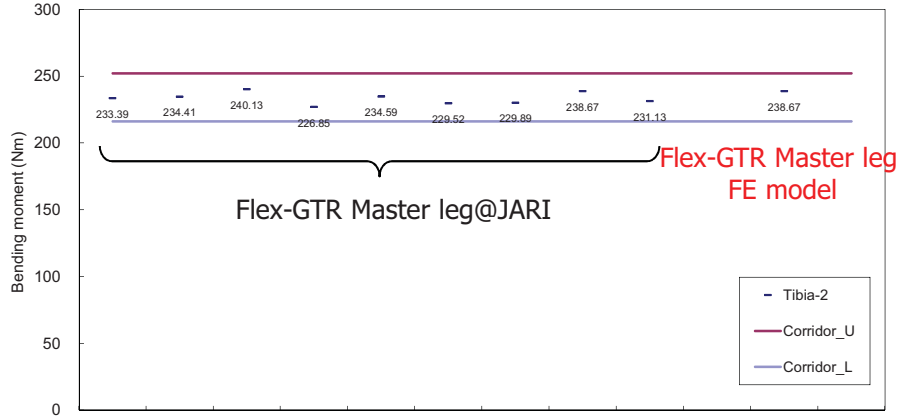
Validation Result (5): Inverse Certification Test

- Flex-GTR Master leg FE model falls within the Flex-GTR Master leg inverse certification test corridors.

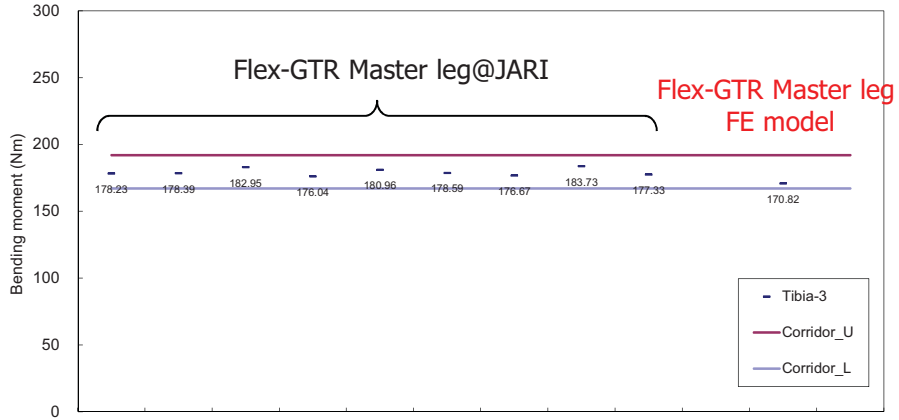
Tibia-1



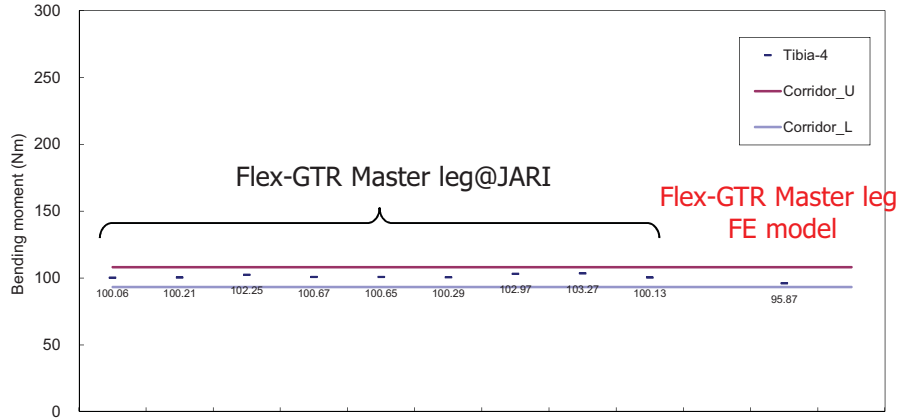
Tibia-2



Tibia-3



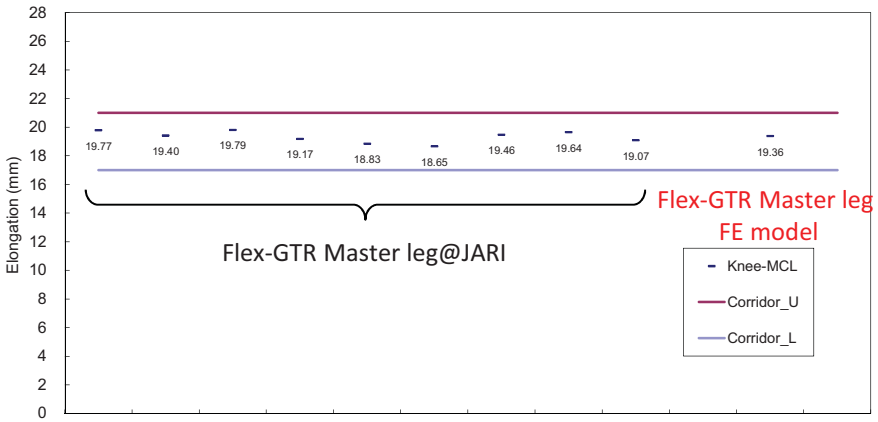
Tibia-4



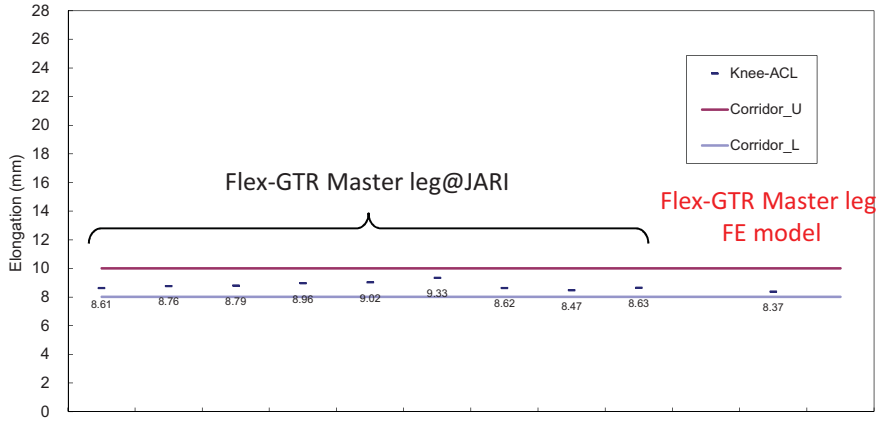
Validation Result (5): Inverse Certification Test

- Flex-GTR Master leg FE model falls within the Flex-GTR Master leg inverse certification test corridors.

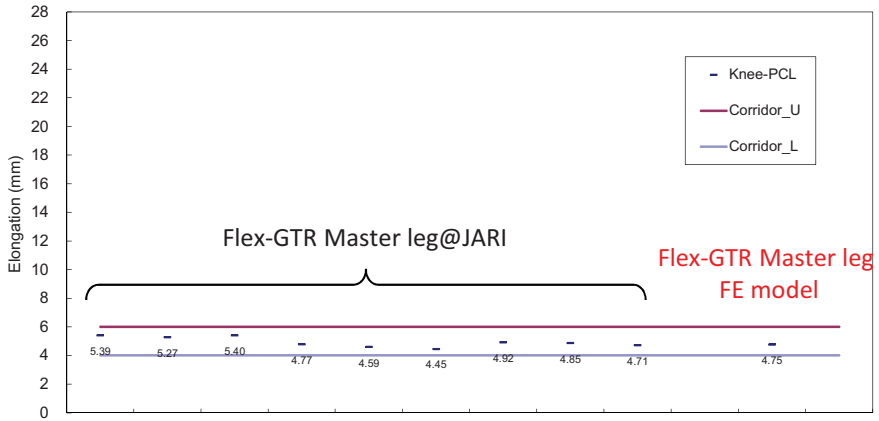
MCL



ACL



PCL



Summary

Part 1: Development of Flex-GTR Master leg FE model

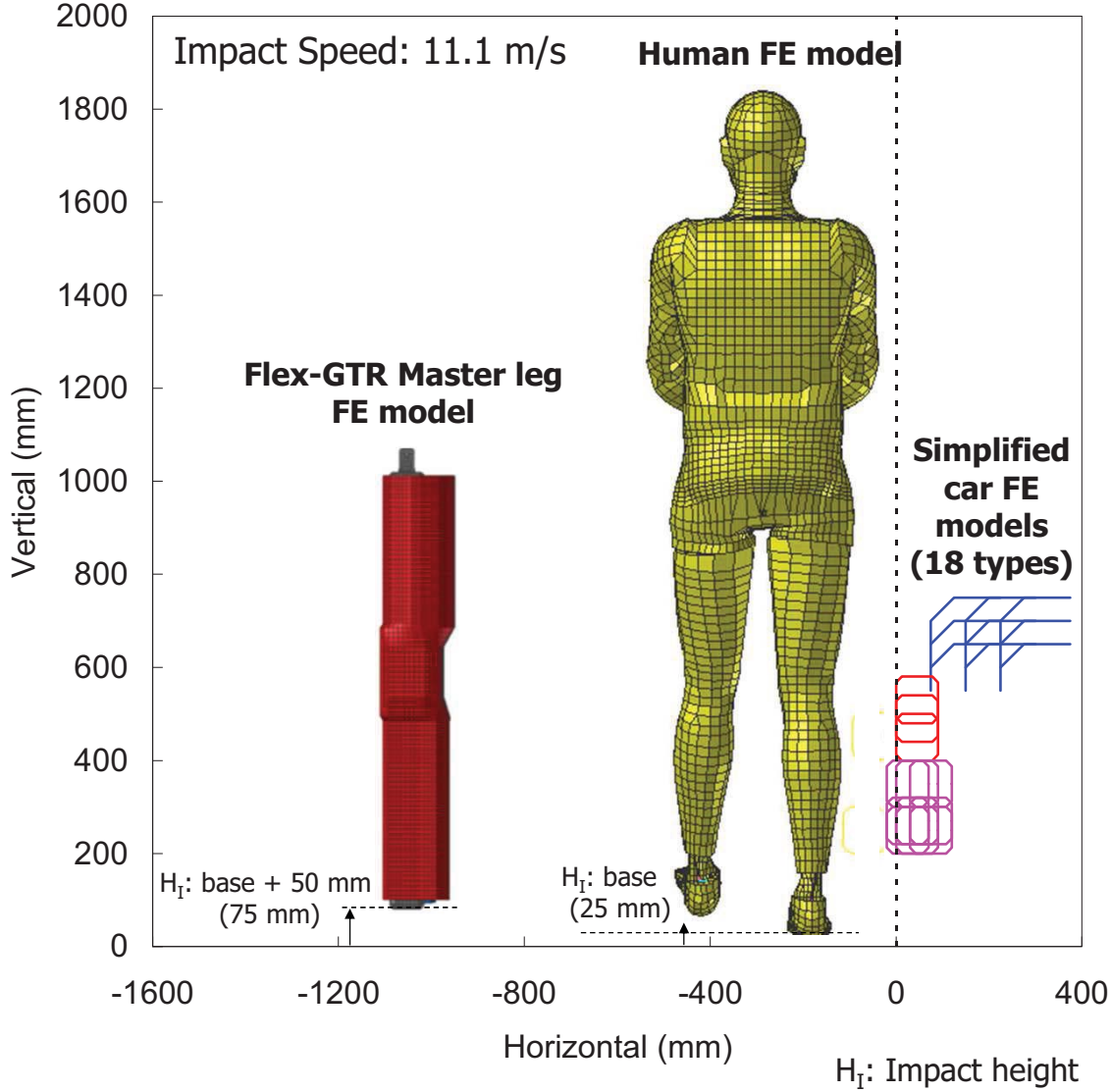
- In Part 1, "Flex-GTR Master leg FE model" was developed and validated against the corridors of the Flex-GTR Master leg certification tests.
- The "Flex-GTR Master leg FE model" well represented the corridors and time histories of the Flex-GTR Master leg certification tests, therefore, the validity of "Flex-GTR Master leg FE model" against an actual Flex-GTR Mater leg was confirmed.

- In Part 2, correlation study between Flex-GTR Master leg FE model and Human FE model were carried out and the validity of the current threshold values was evaluated against Flex-GTR Master leg.

Part 2: Correlation Study between Flex-GTR Master leg FE model and Human FE model and Evaluation of the Validity of the Current Threshold Values against Flex-GTR Mater leg

Correlation study between Flex-GTR Master leg FE model and Human FE model

Methodology

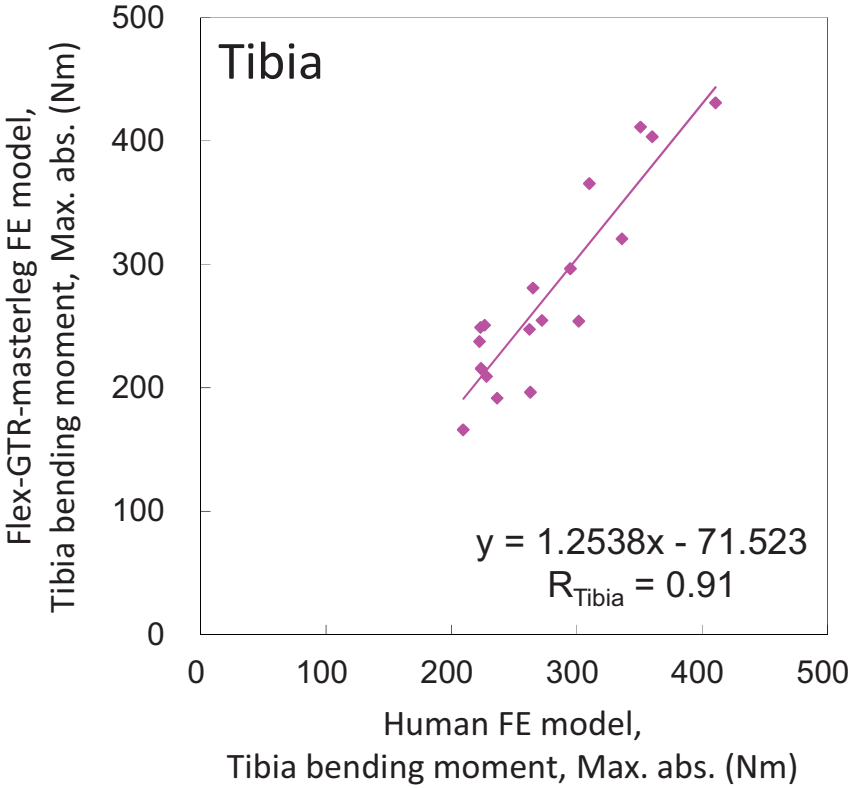


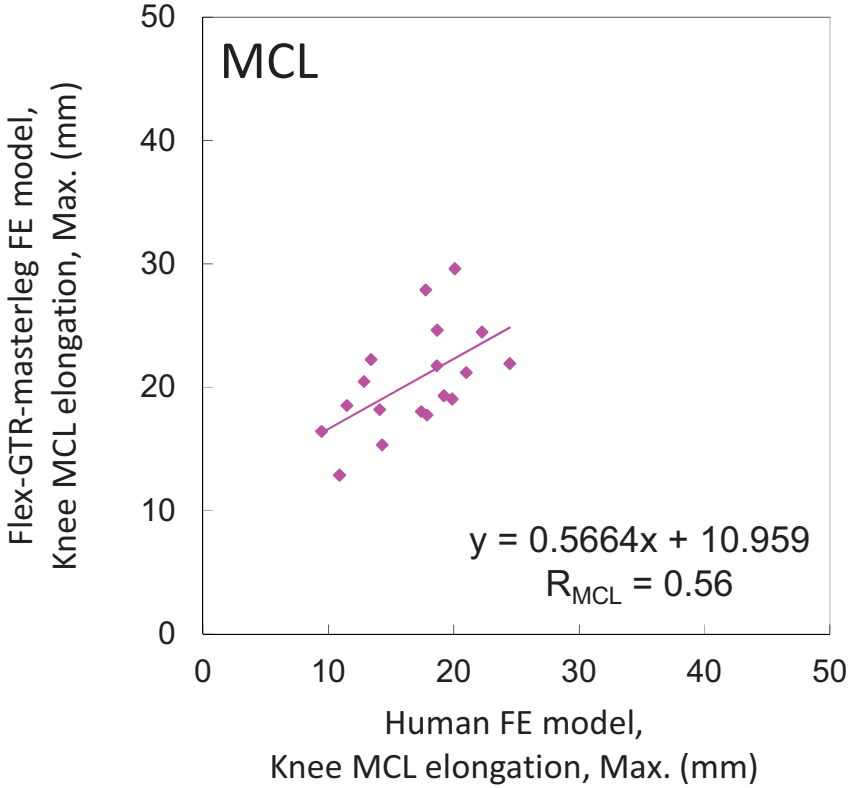
- Flex-GTR Master leg FE model and Human FE model were impacted to simplified car FE models (18 types), then a correlation study was conducted between Flex-GTR Master leg FE model and Human FE model.

Correlation study between Flex-GTR Master leg FE model and Human FE model

Results(Tibia, MCL)

- It was confirmed that Tibia and MCL outputs of Flex-GTR Master leg FE model well correlated with those of Human FE model.

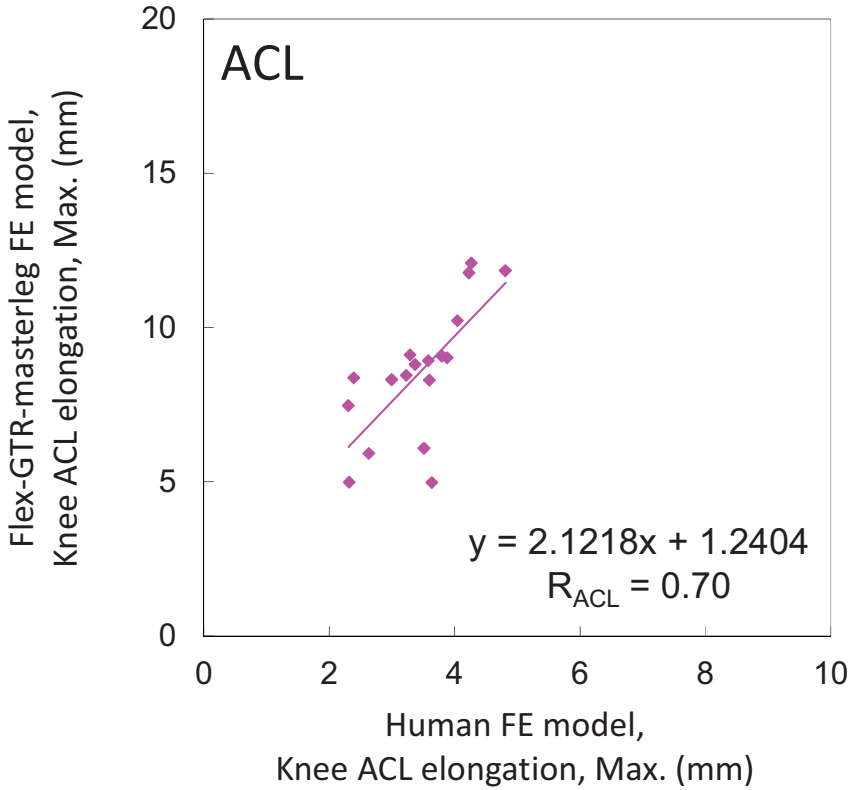




Correlation study between Flex-GTR Master leg FE model and Human FE model

Results(ACL)

- It was confirmed that ACL outputs of Flex-GTR Master leg FE model well correlated with those of Human FE model.



Evaluation of the validity of the current threshold values

- Reanalyzed threshold values for Tibia and MCL are comparable with the current threshold values.

Tibia

Current threshold value	Human FE model	Reanalyzed threshold value
340 Nm	328 Nm	340 Nm

Convert using correlation function between Previous Flex-GTR FE model and Human FE model
$y = 1.259x - 72.798$

Convert using correlation function between Flex-GTR Master leg FE model and Human FE model
$y = 1.2538x - 71.523$

MCL

Current threshold value	Current threshold value without effect of muscle tone	Human FE model	Reanalyzed threshold value without effect of muscle tone	Reanalyzed threshold value
22.0 mm	20.0 mm	17.3 mm	20.8 mm	22.8 mm

Exclude the effect of muscle tone
/ 1.1

Convert using correlation function between Previous Flex-GTR FE model and Human FE model
$y = 0.5584x + 10.335$

Convert using correlation function between Flex-GTR Master leg FE model and Human FE model
$y = 0.5664x + 10.959$

Include the effect of muscle tone
x 1.1

Evaluation of the validity of the current threshold values

- Reanalyzed threshold value for ACL is comparable with the current threshold value.

ACL

Current threshold value	Human FE model	Reanalyzed threshold value
13.0 mm	6.1 mm	14.2

Convert using correlation function between Previous Flex-GTR FE model and Human FE model
$y = 1.803x + 1.996$

Convert using correlation function between Flex-GTR Master leg FE model and Human FE model
$y = 2.1218x + 1.2404$

Summary

Part 2: Correlation Study between Flex-GTR Master leg FE model and Human FE model and Confirmation of the Validity of the Current Threshold Values

- In part 2, correlation study between Flex-GTR Master leg FE model and Human FE model was carried out and the validity of the current threshold values was evaluated against Flex-GTR Master leg.
- As a result, we confirmed that the current threshold values are valid for Flex-GTR Master leg as well.

Conclusions

- Using the JASIC method to derive threshold values, it was found that there is no need to modify the current threshold values for the latest production model of the FlexPLI.