INJURY BIOMECHANICS RESEARCH

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Development of a Biofidelic Dummy for Representation of Complex Injuries During Vehicle Crash

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Overview

Introduction

- Biofidelic dummy
- Responsible institutions

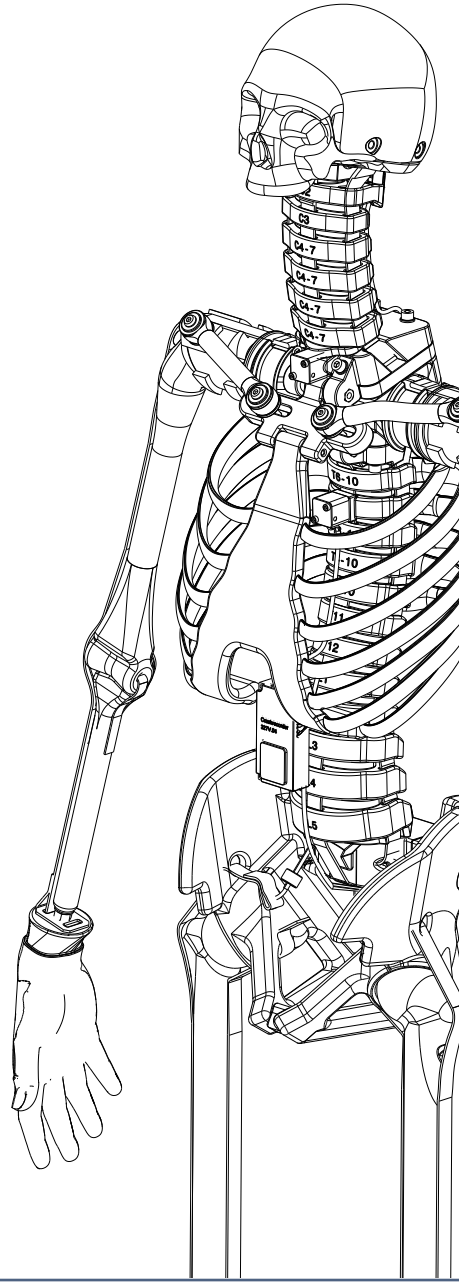
Concept and development of a new dummy model

- Model core function
- Development process

Validation of the biofidelic dummy

- Sled tests
- Full-scale crash tests

Summary and outlook



Introduction - Biofidelic-Dummy (PRIMUS breakable)

- Bone components
- Ligaments and tendons
- Soft tissue
- Anthropomorphic geometry
- Real range of motion
- Age, weight, height and mass distribution 50-percentile
- Inertial measuring unit in head, pelvis and thorax
- Correlation between **dummy damage** and **human injury**

Source: Crashtest-Service

Institutions responsible for the dummy project

HTWD

Research, development, testing

CTS
crashtest-service.com

Manufacturing, testing, sales

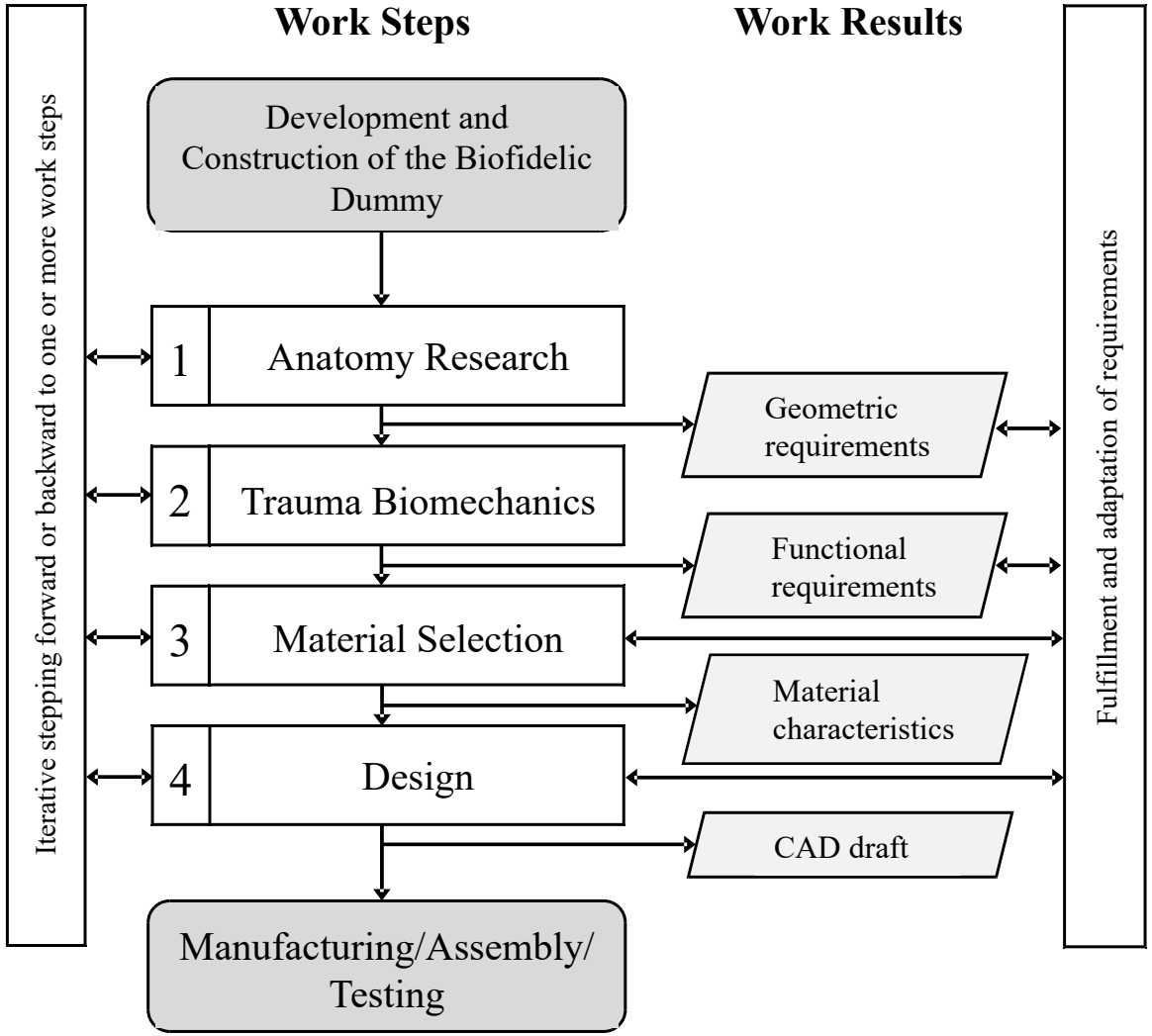
Model core function

Correlation between human injury and material damage to the dummy

Development

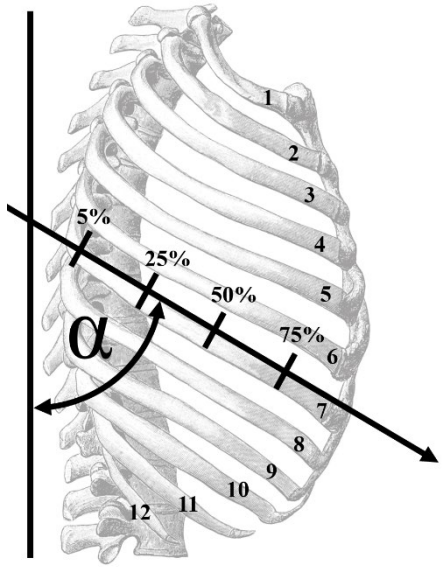
4-phase process according to VDI guideline 2221

VDI – Verein Deutscher Ingenieure
(The Association of German Engineers)



Development - example thorax

1 Anatomy research

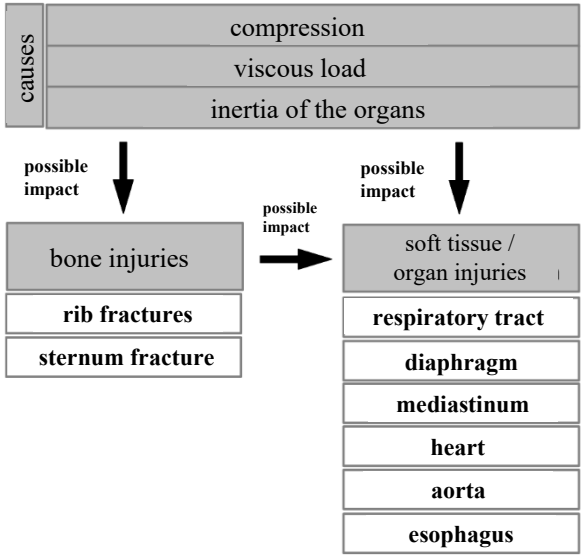


5% 25% 50% 75%

Dorsal Ventral

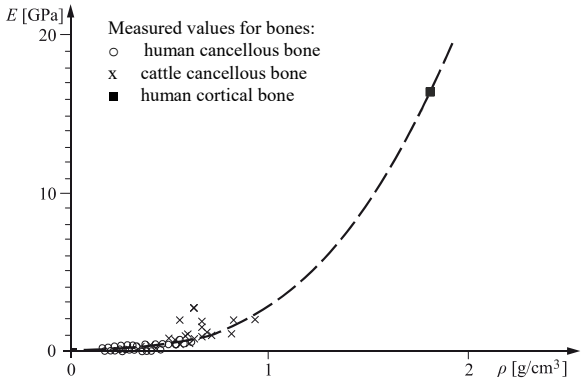
Rib geometry [10]

2 Trauma-Biomechanics



Thoracic stresses [11]

3 Material selection

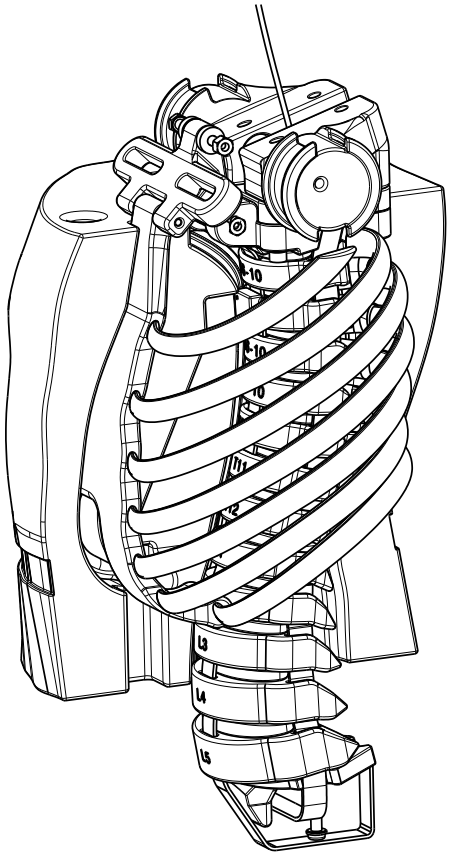


Characteristics of the biological tissue [12]

Material data [13]

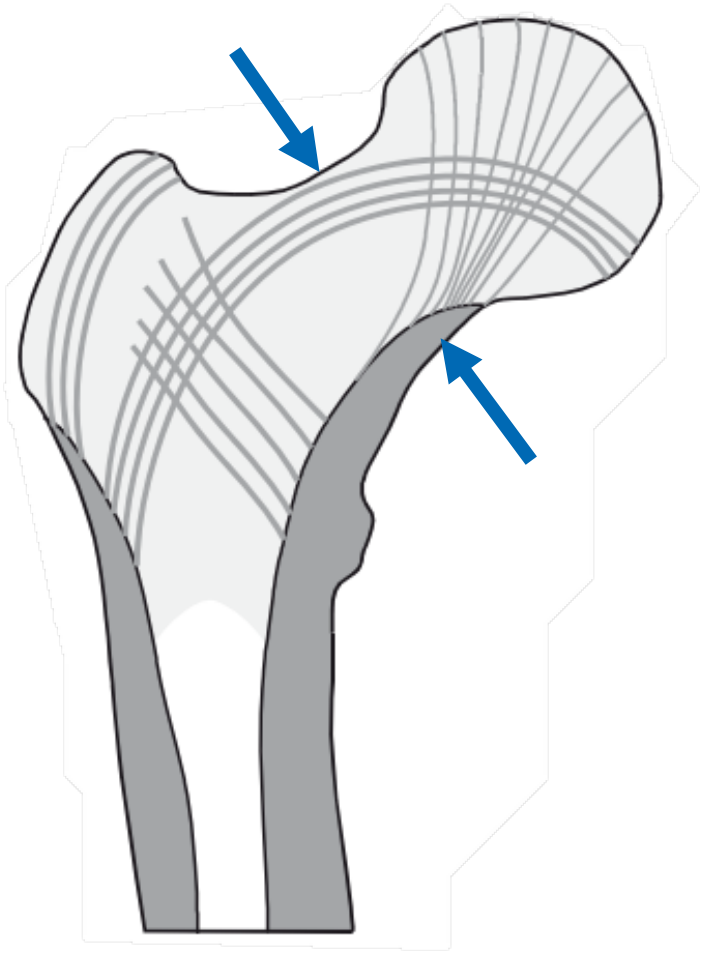
	bones	bone replacement
density [g/cm³]	1,7-2,3	1,39
bending strength [N/mm²]	157-209	87
tensile strength [N/mm²]	51- 164	47
Young´s modulus in general [N/mm²]	9600-27400	3400
Young´s modulus bone joint [N/mm²]	420-750	
max. strain under tension [%]	1,4-3,2	1,6

4 Construction

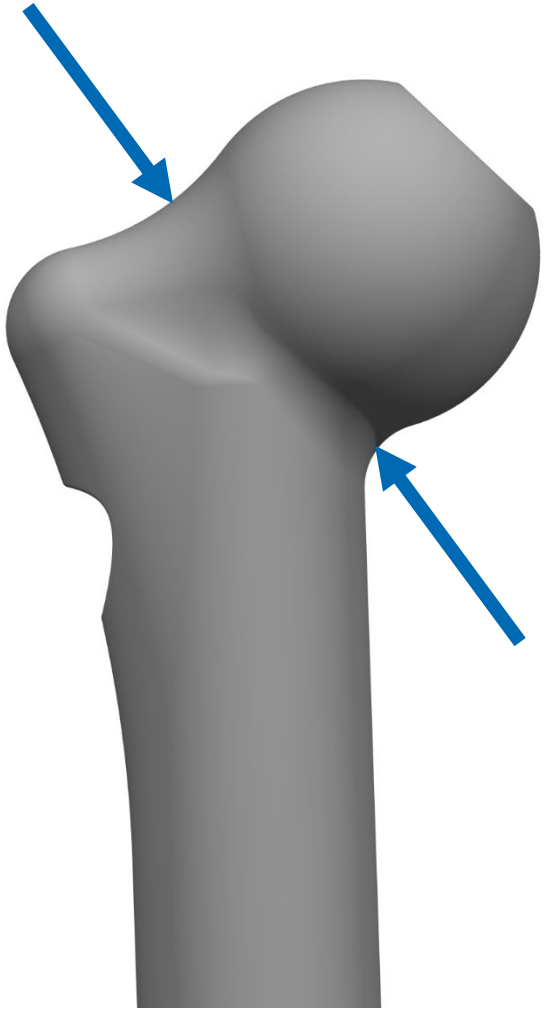


Chest reconstruction

Construction – example of femur dimensioning

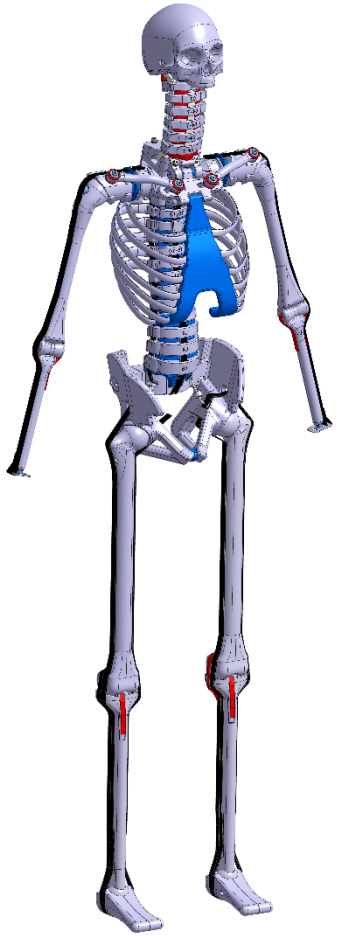


Sectional view of the femoral head [14]



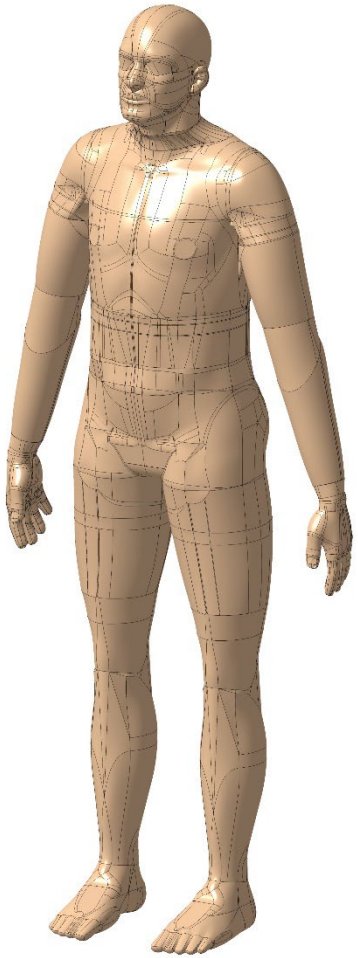
Dummy construction of the femoral head

Development and design results



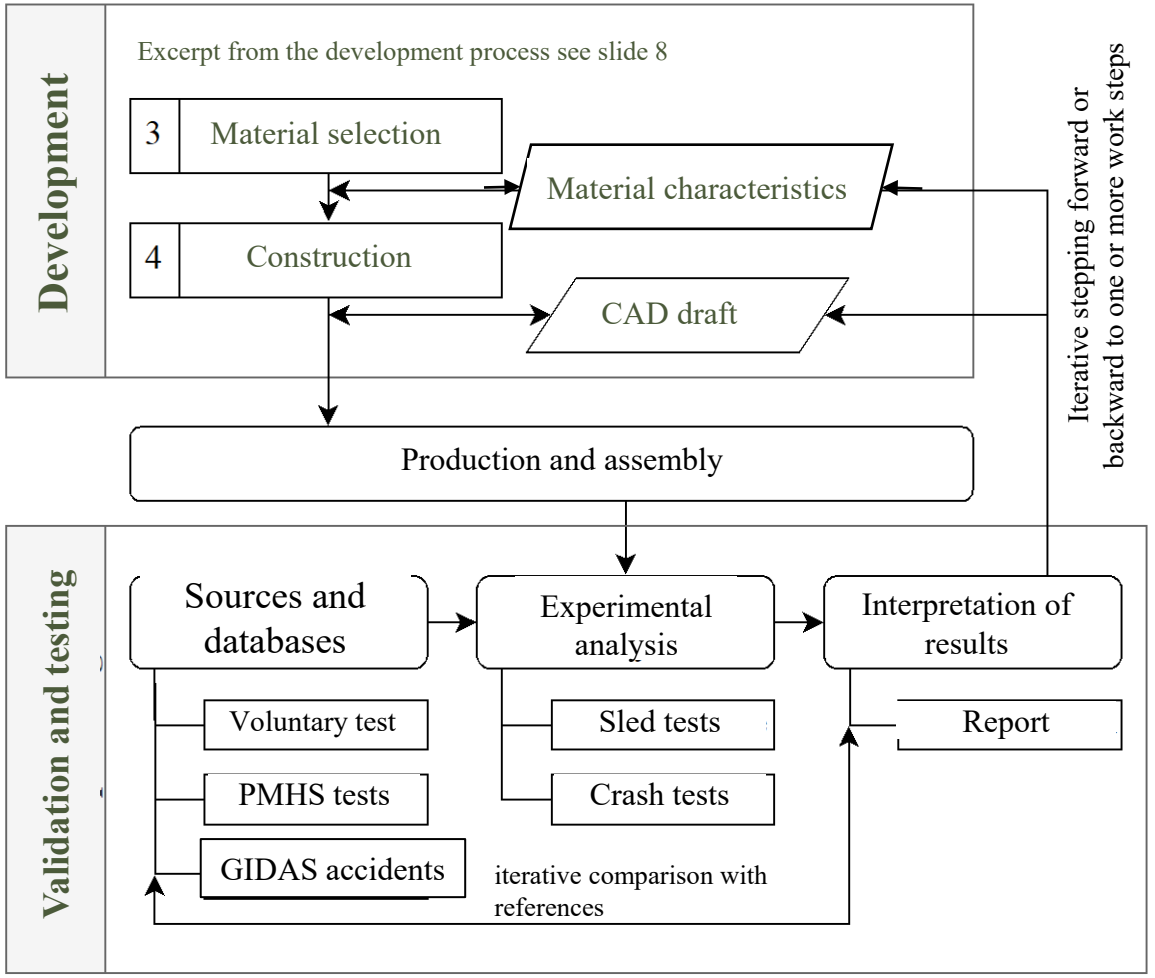
Dummy skeleton

Dummy size:	1,75 m
Dummy weight:	79 kg
Assemblies:	9
Parts:	238
Number of different materials:	7



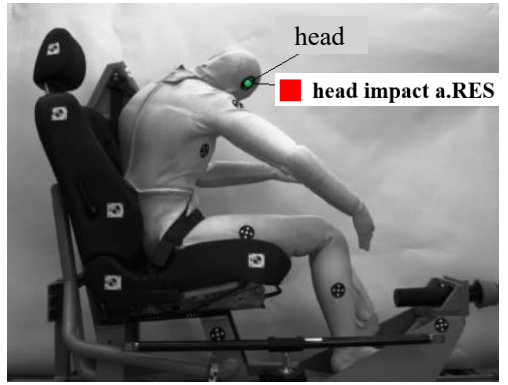
Dummy with soft tissue replacement

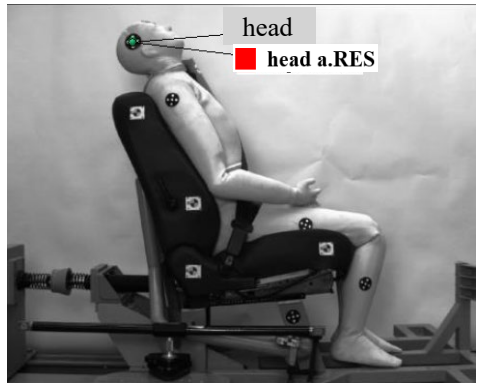
Validation and testing

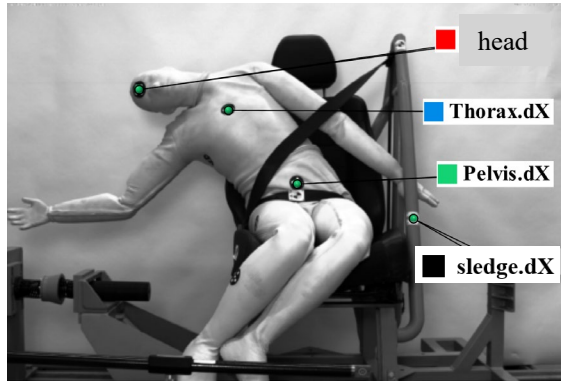


Sled tests

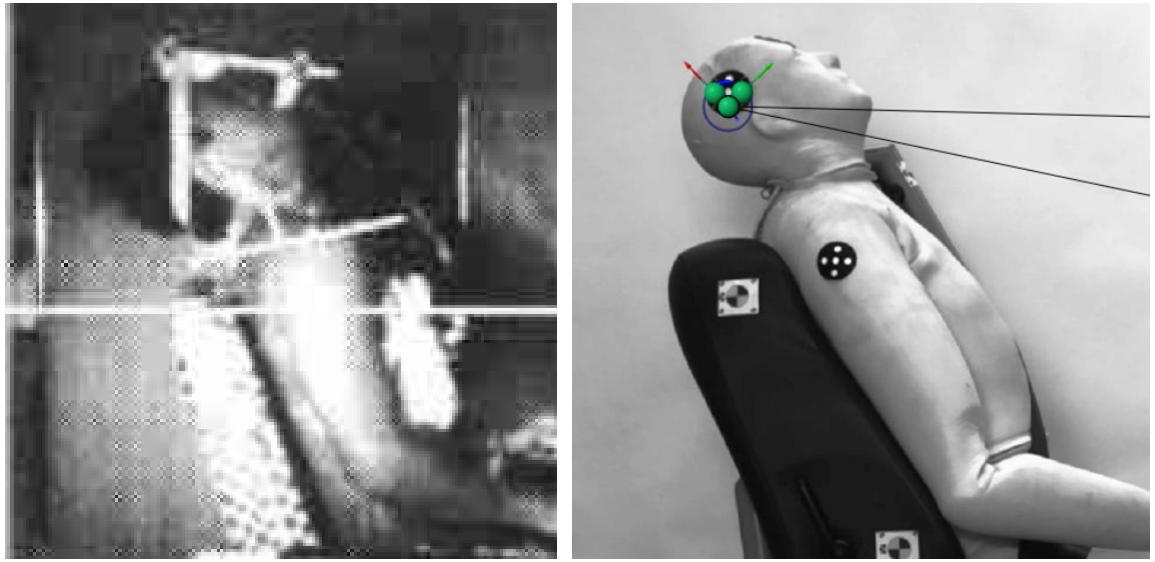
- Sources and databases
  - Voluntary tests
    - Frontal impact
    - Rear impact
  - PMHS tests
    - Side impact





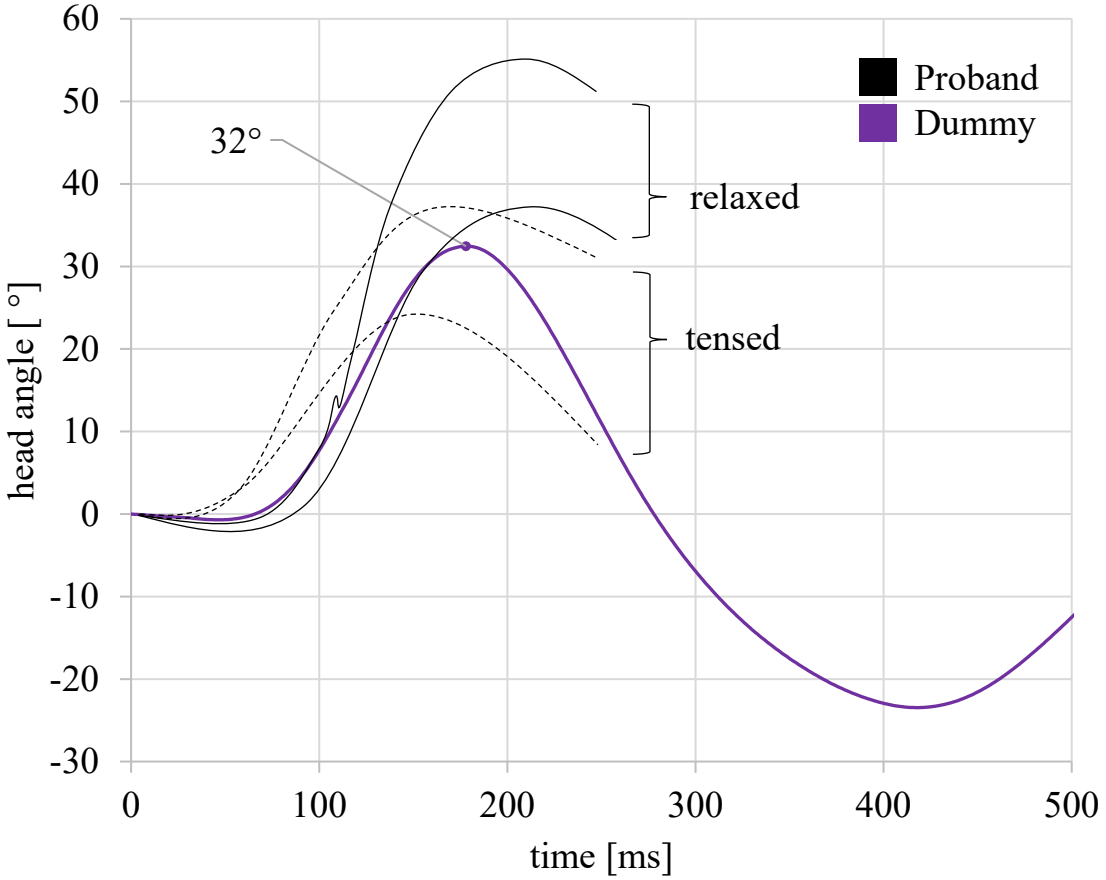


Sled tests: rear impact according to Ono et. al.



Test subject and crash test dummy compared at maximum head deflection [15]

Rear impact 8 km/h



Head angle Ψ-t-diagram

Full-scale crash tests

car-pedestrian 35 km/h

car-car 75 km/h

car-tree 52 km/h

car-bicycle 45

car-car 30 km/h

car-tree 65 km/h

figure 35: Overview of full-scale crash tests

Full-scale crash tests: car-tree 65 km/h

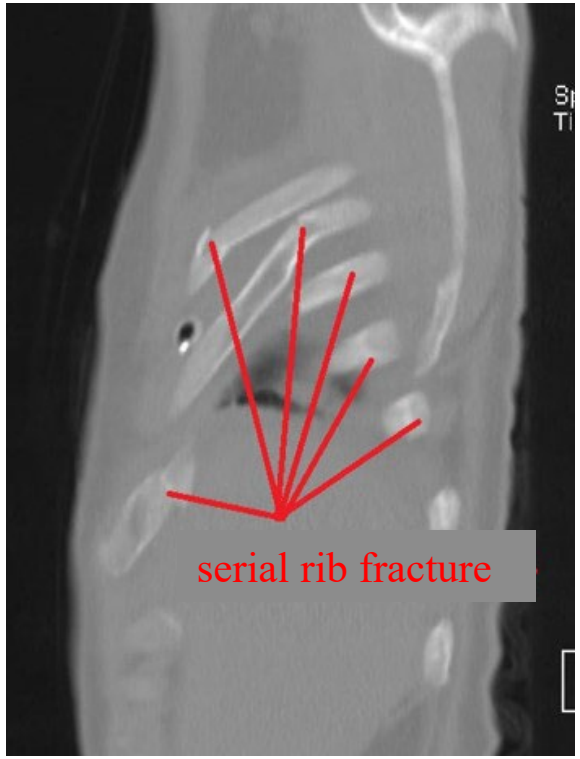
Accident tree collision [16]

Crash test tree impact

Injury comparison: car-tree 65 km/h

Human:

serial rib fracture 2-7 r.



X-ray of serial rib fracture 2-7 r. [16]

Dummy:

serial rib fracture 3-7 .

Technical autopsy serial rib fracture 3-7 r.

Injury comparison: car-tree 65 km/h

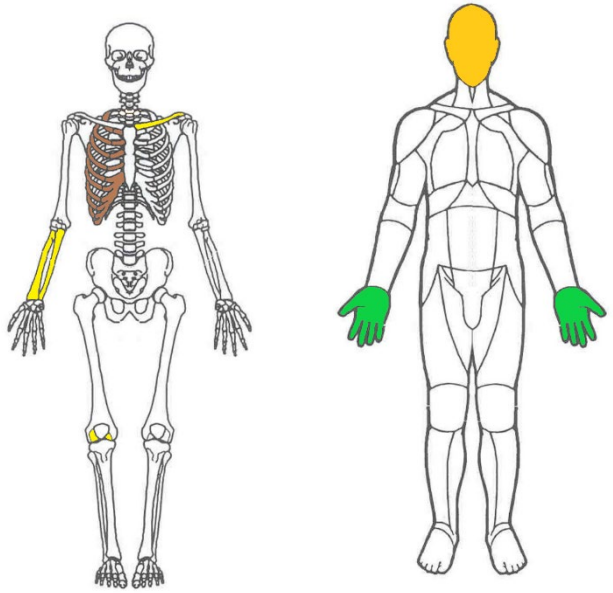
Injuries real accident 1180018		**Damage dummy crash test 2**			
description	AISG05	min. correlating description	AISG05 min.	max. correlating description	AISG05 max.
temporal contusion hemorrhage	140606.3	mild traumatic brain injury	161000.1	severe traumatic brain injury	161006.3
diffuse subarachnoid hemorrhage	140694.2				
abrasion over right eye lat.	210202.1	no correlating damage			
hematoma under left clavicle	410402.1	clavicle fracture l.	750500.2	medial clavicle fracture (proximal) l.	750511.2
pulmonary contusion	441410.3	no correlating damage			
hematothorax r.	442200.3				
serial rib fracture 2-7 re.	450213.4	serial rib fracture 3-7 r.	450213.4	serial rib fracture 3-7 r.	450213.4
no injury		fracture of thoracic vertebrae	650416.2	large thoracic vertebra fracture	650434.3
abrasion right hand lat.	710202.1	soft tissue injury hands lat.	710099.1	abrasion hands lat.	710202.1
no injury		simple forearm fracture r.	752253.2	simple forearm fracture r.	752253.2
		knee r. outer/internal ligament	840405.2	knee r. outer/internal ligament partial tear	840406.2
MAIS = 4		min. MAIS = 4		max. MAIS = 4	
ISS = 26 (Polytrauma)		ISS_{min} = 24 (Polytrauma)		ISS_{max} = 34 (Polytrauma)	

Evaluation

Database-dependent survival probability [17]

AIS-code	color	AIS injury severity	NTDB [%]	GIDAS AIS [%]	GIDAS MAIS [%]
0		uninjured	100	100	100
1		minor	99,3	99,8	99,9
2		moderate	99,2	99,4	99,6
3		serious	96,5	98,3	95,8
4		severe	85,4	74,6	74,9
5		critical	60,4	61,5	42
6		maximum	21	0	0
9		not further specified			

NTDB National Trauma Database, GIDAS German In Depth Accident Study,
AIS Abbreviated Injury Scale, MAIS max. AIS value



Visualization of local injuries

Summary

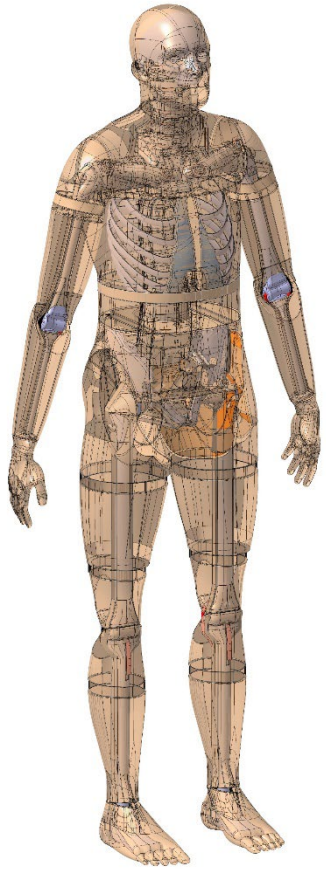
Dummies for standardized tests

not all relevant injuries can be visualized

human injury mechanisms are very complex

no omnidirectional use possible

Dummy development with a biofidelic approach



Validation

seat sledge test:

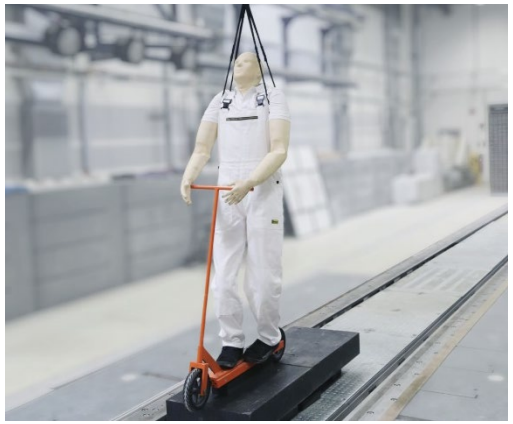
realistic response behavior in the application of the vehicle crash

crash tests:

5 out of 6 tests are within the range of real injury severity (MAIS-related)

Application and outlook

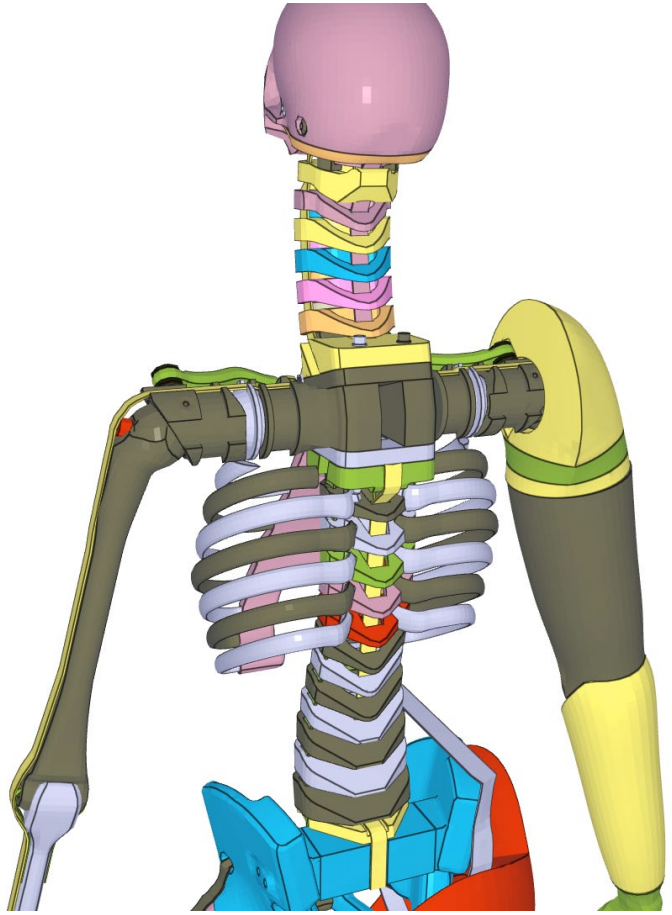
Application



E-scooter crash test setup [18]

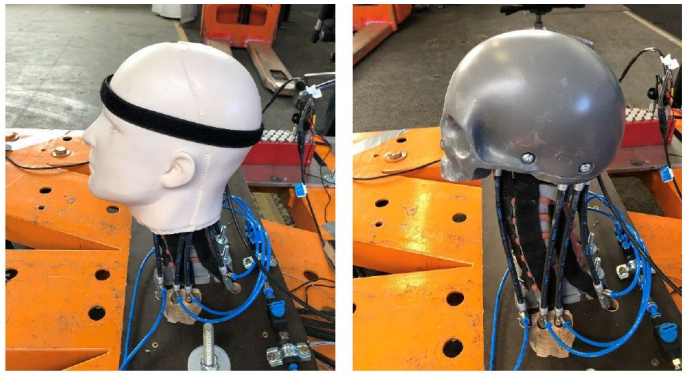
Seated application in special protection [19]

FEM simulation model

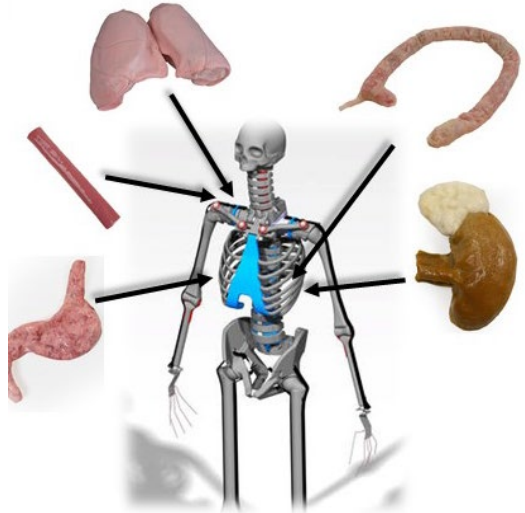


Rib series fracture in the FEM simulation

Research subjects



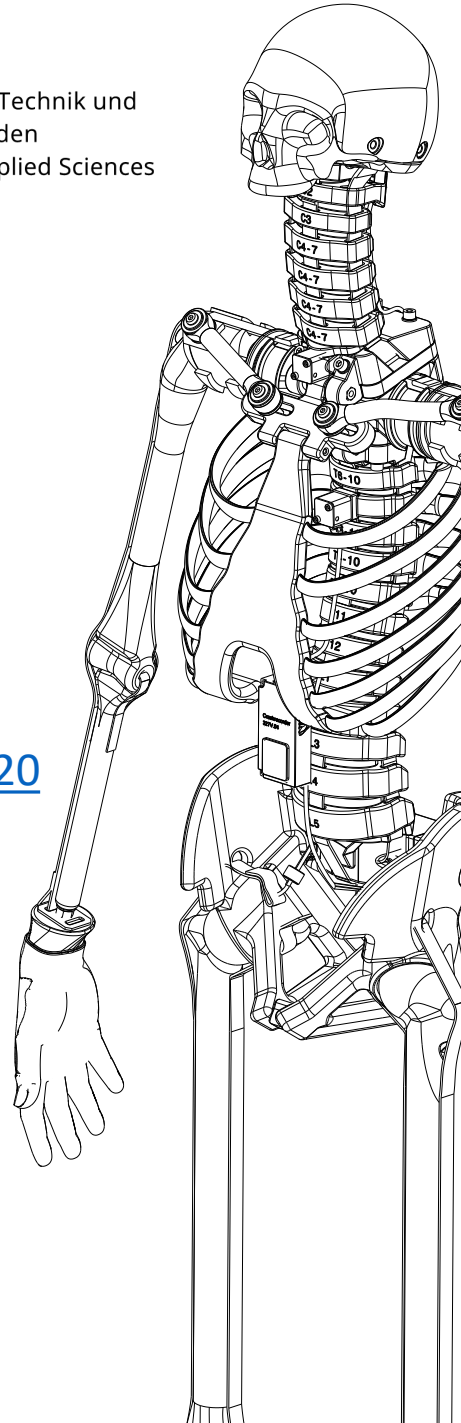
Cervical spine with pneumatic replacement muscles



Enhancement using hollow and full organs in the thorax area

HTW D Hochschule für Technik und Wirtschaft Dresden University of Applied Sciences

Thank you for your attention!



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CTS crashtest-service

www.crashtest-service.com/en

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