Engineering Biomechanics of Human Impact Injury with the Use of Human Tissue Biosimulant Artifacts

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Outline

- **List of Recent Collaborators**
- **Objectives**
- **The NIST Dynamic Impact Testing and Calibration Instrument**
- **Impact Testing with Various Geometry Tools**
- **Impact Testing with Various Thickness of a Fat Bio-simulant**
- **FEM Simulation of Bio-simulant Artifacts Impact Testing**
- **Conclusions**

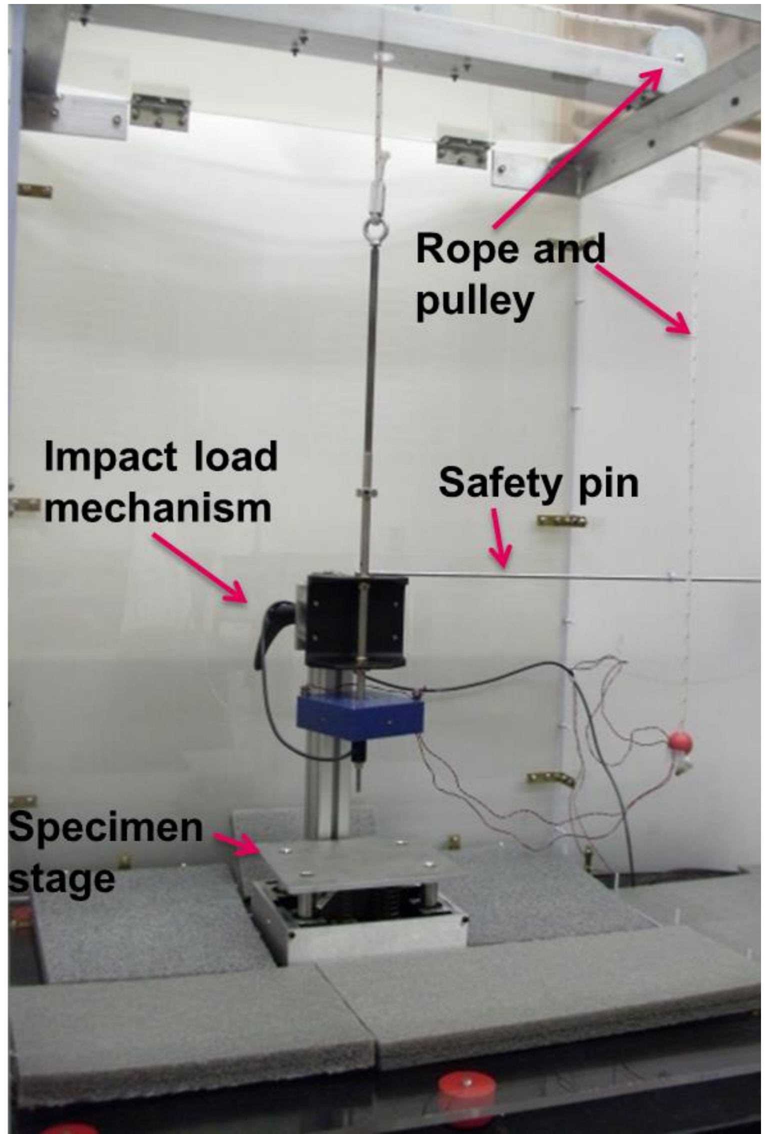
List of Recent Collaborators

- **Dr. Yong Sik Kim** (Research Associate)
- **Dr. Tae Ho Yang** (Research Associate)
- **Nicholas Civetti** (Former Student Trainee)
- **Dr. Hyun Kyoon Lim** (Korea Research Institute of Standards and Science, Department of Medical Physics/University of Science and Technology)
- **Vincent Salpietro** (SURF Student)

Objectives

- **Develop specialized instruments for experimental mechanics testing of human bio-simulant artifacts.**
- **Measure the severity and extend of human-robot impact injury with human biosimulant artifacts.**
- **Develop computer simulations of human-robot impact events with the use of human biosimulant artifacts.**

NIST Dynamic Impact Testing and Calibration Instrument (DITCI) for the Disposable Robot Safety Artifacts Based on a Modified GM Kapuskasing Style Drop Impact Tester



Impact Tools

BG/BGIA risk assessment recommendations according to machinery directive IFA

ISO/PDTS 15066

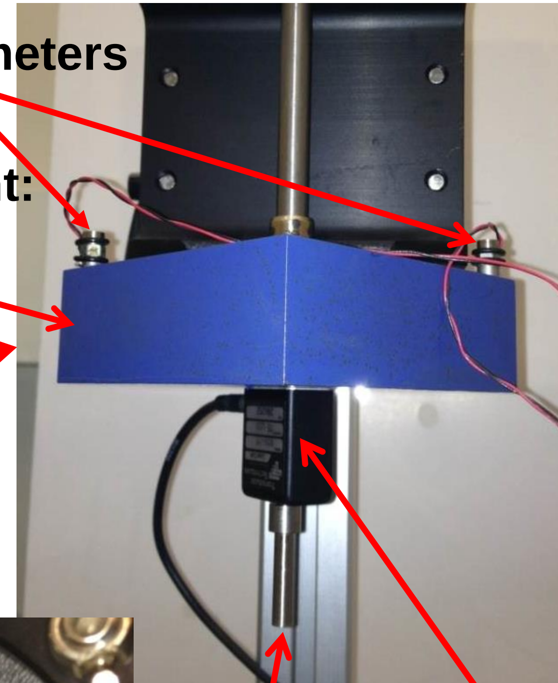
Technical Specification

Conical tip probe tools

Screw Driver tip tools

Impact Tools, Sensors and Sample Holder

Magnified

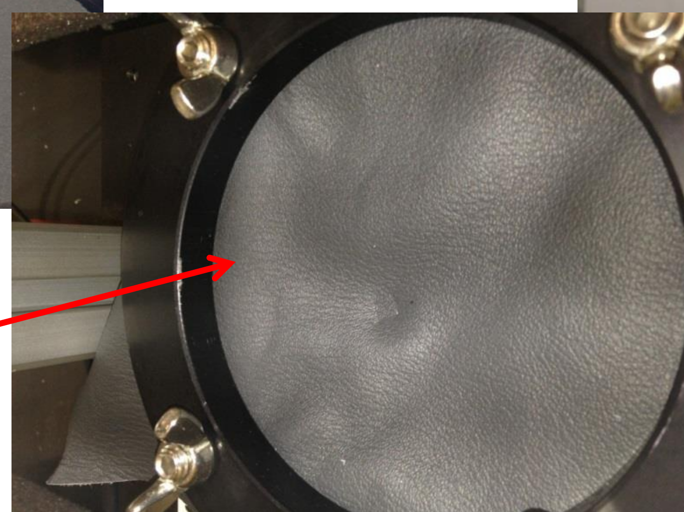


Accelerometers

Total Drop Weight: 30.4 N (6.8 lbf)

Load Cell Capacity: 333.6 N (75 lbf)

Rectangular cross section tool (5 mm x 6 mm)

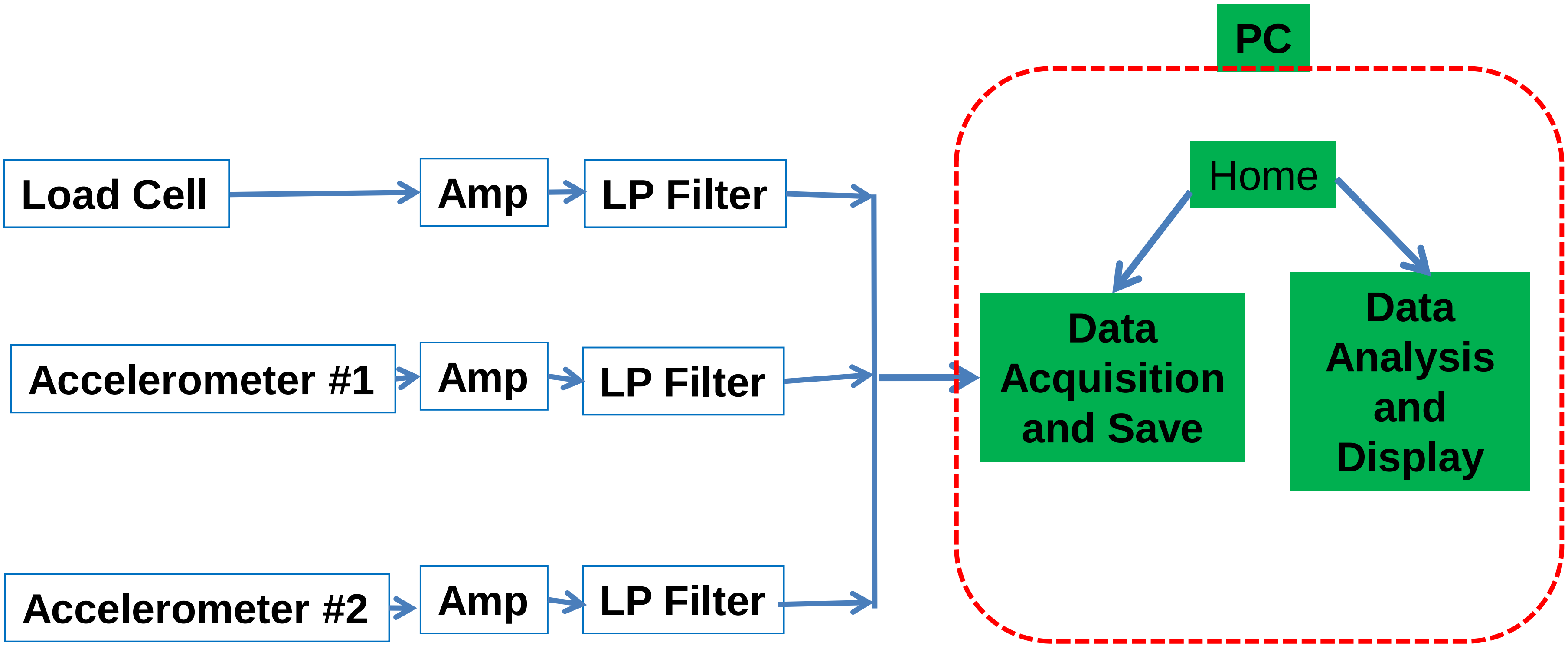


Skin Biosimulant “Full Cowhide Side, Upholstery or Garment Leather”, thickness about 1.1mm, Chromium Tanned

Spring Supported Stage for Mounting the Test Artifacts Simulates Human Body Parts Stiffness

Spring supported stage for mounting the test artifacts in the Dynamic Impact Testing and Calibration Instrument (DITCI). The rectangular frame encloses several steel coil springs all of the same length (3.5" in our case). Because the height of the frame is lower than the height of the springs (2" in our case) the top plate remains suspended above the frame resting on the top of the springs at a distance equal to the difference of the two heights (1.5" in our case).

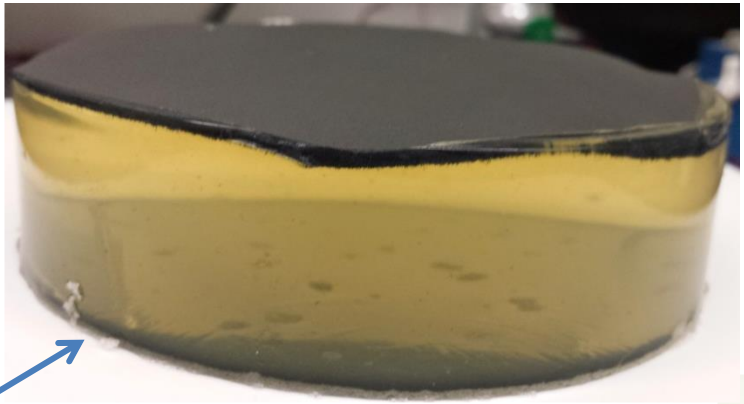
Data Collection and Analysis



Skin Biosimulant After Impact Testing

Soft Tissue Bio-Simulant Artifacts Before and After Dynamic Impact Testing

Photo of the top (skin) side of a 10 cm (4”) diameter cylindrical shape soft tissue bio-simulant artifact



Side view photo of a soft tissue artifact

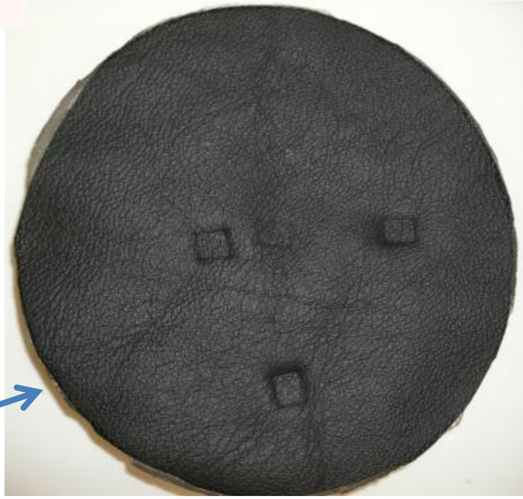
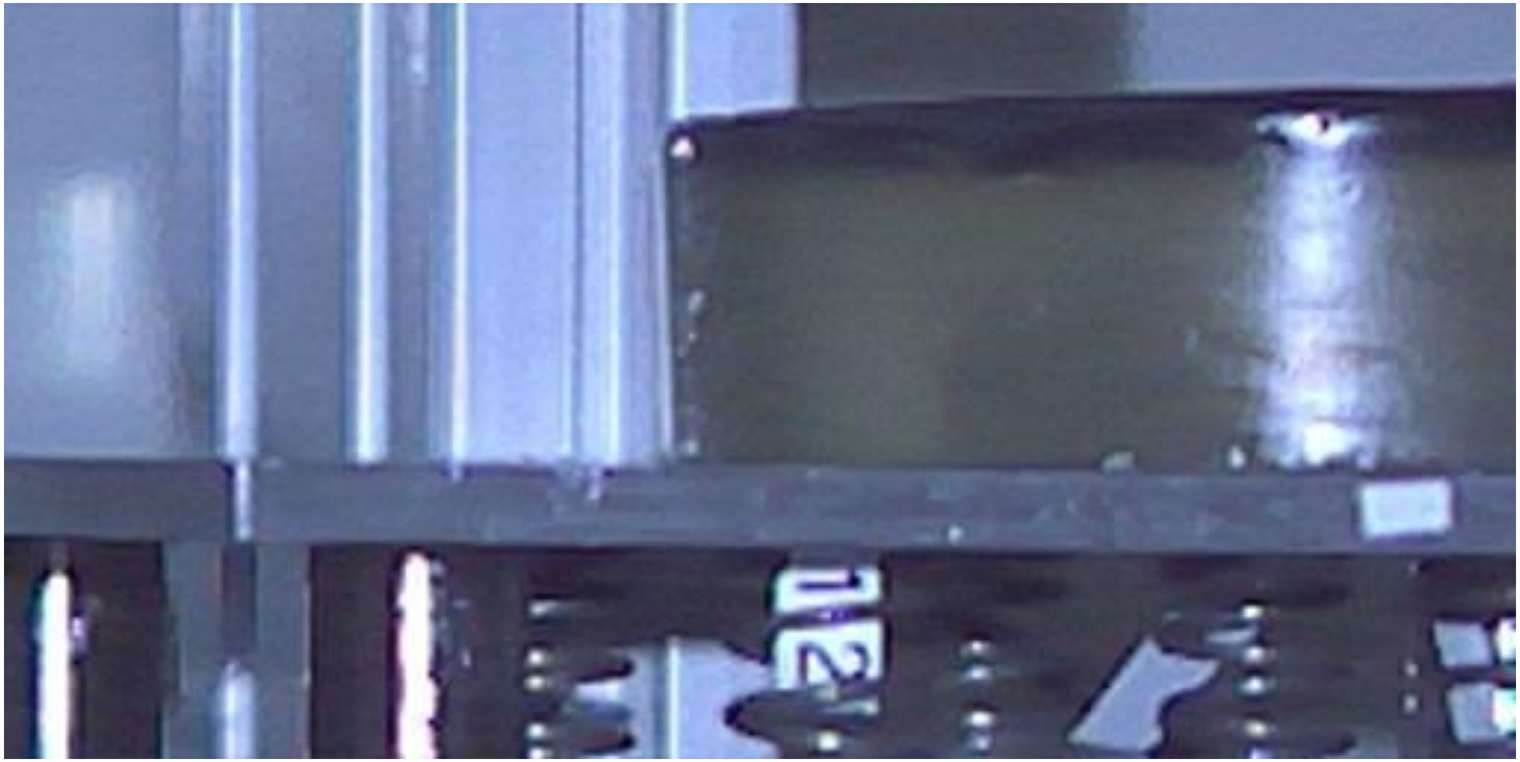


Photo of the top (skin) side of a soft tissue artifact after impact testing with a 5 mm x 6 mm rectangular cross section impact tool

Dynamic Impact Testing Video for Soft Tissue Bio-Simulant Artifact

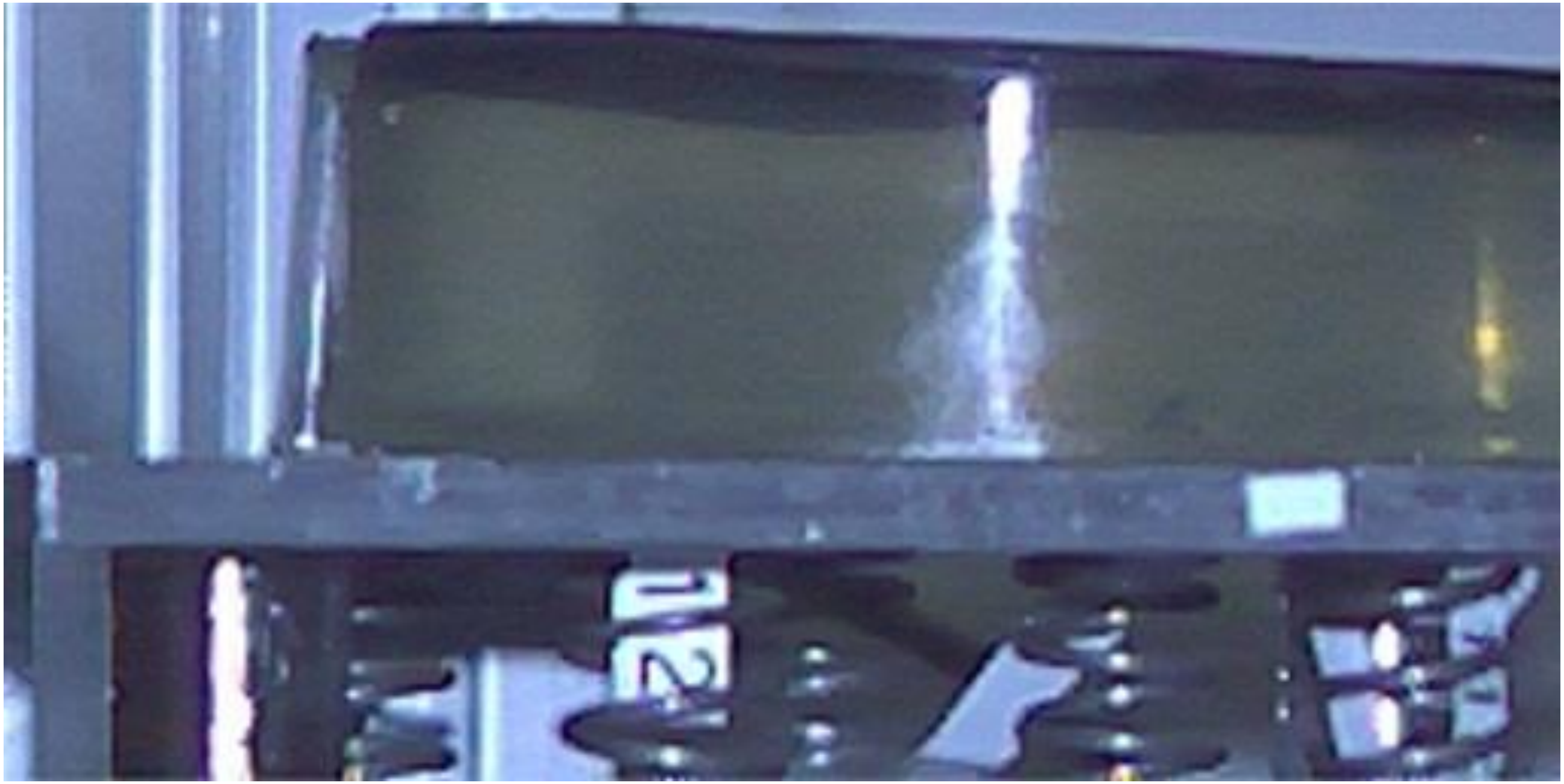
Video "DITCI 77H12D30T 160F19x24Tool 2000FPS 062314 B," was produced under the following impact testing conditions:
Impact load drop height = 77 mm, Biosimulant sample size (skin + soft tissue) = 120 mm diameter x 30 mm thickness, Maximum impact force (approximately) = 160 N (35.9 lbf)
Impact tool size = Rectangular cross section 19 mm x 24 mm [this tool cross section generates an average pressure of 35 N/cm2 (50.7 psi), for a maximum impact force of 160 N (35.9 lbf)
Video time scale = 2000 frames per second, Artifact+Spring supported stage stiffness = 10.7 N/mm [stiffness recommended by ISO/PDTS 15066 for belly tissue 10 N/mm (57.1 lbf/in)]
NOTE = If you look carefully at the left side of the sample you will see the impact shock wave propagating through the sample



Rectangular cross section impact tool of 19 mm x 24 mm

Dynamic Impact Testing Video for Soft Tissue Bio-Simulant Artifact

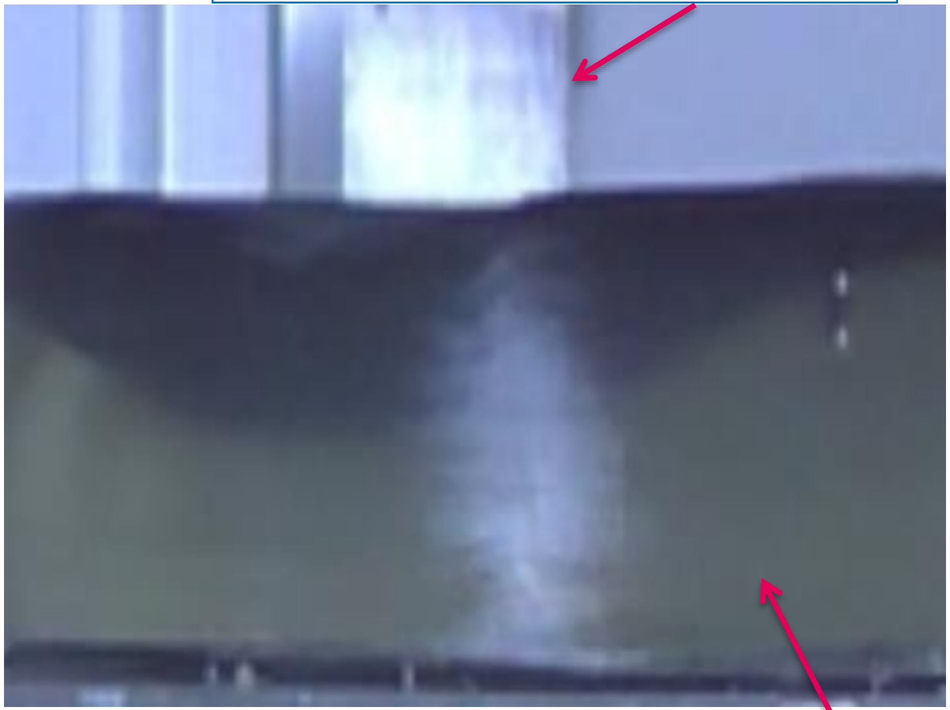
Video "DITCI 73H12D30T 140F1x6Tool 2000FPS 062314 - Screw-driver impact tool," was produced under the following impact testing conditions:
Impact load drop height = 73 mm, Biosimulant sample size (skin + soft tissue) = 120 mm diameter x 30 mm thickness, Maximum impact force (approximately) = 140 N (31.4 lbf)
Impact tool size = Screw-driver cross section 1 mm x 6 mm [this tool cross section generates an average pressure of 2,333 N/cm2 (3,384 psi), for a maximum impact force of 140 N (31.4 lbf)
Video time scale = 2000 frames per second, Spring supported stage stiffness = 10.7 N/mm [stiffness recommended by ISO/PDTS 15066 for belly tissue 10 N/mm (57.1 lbf/in)]



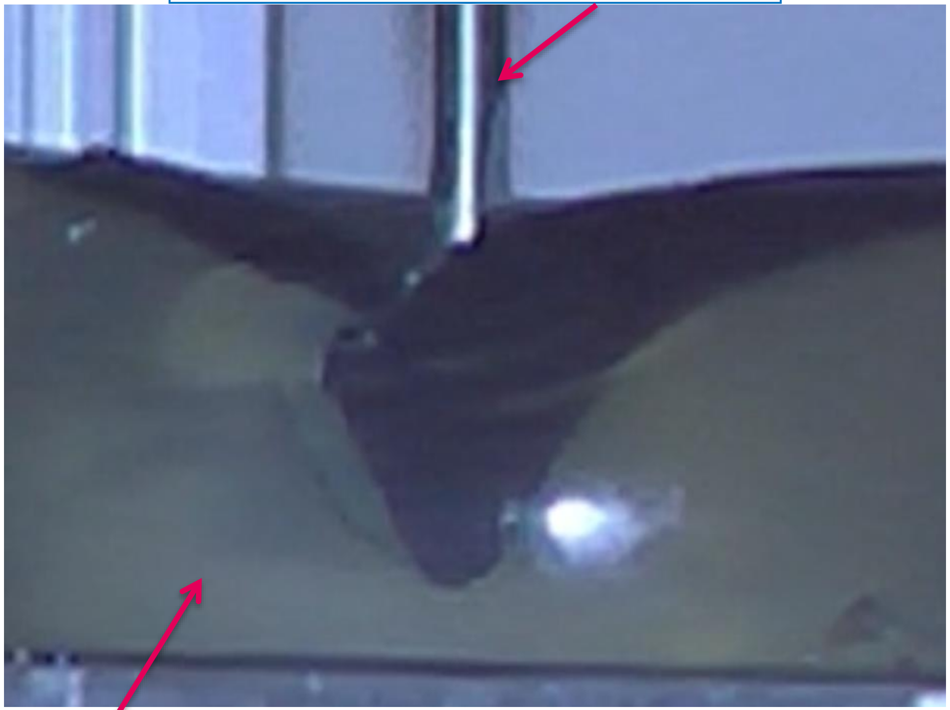
Comparison of Test Results

For 140 N (31.4 lbf) Maximum impact force the 1 mm x 6 mm cross section impact tool generates 227% deeper penetration than the19 mm x 24 mm cross section impact tool at 160 N (35.9 lbf) Maximum impact force

19 mm x 24 mm impact tool

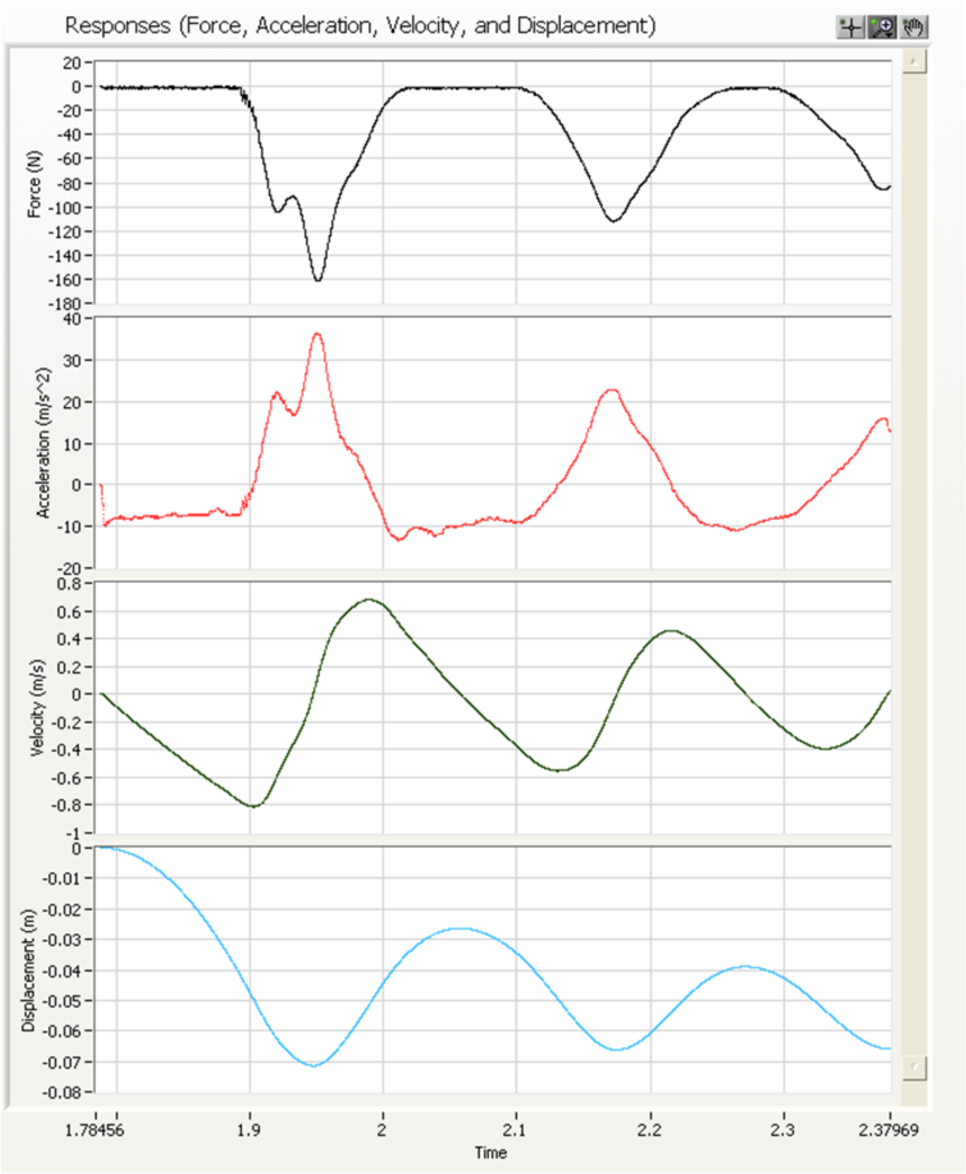


1 mm x 6 mm impact tool



Human biosimulant soft tissue artifact

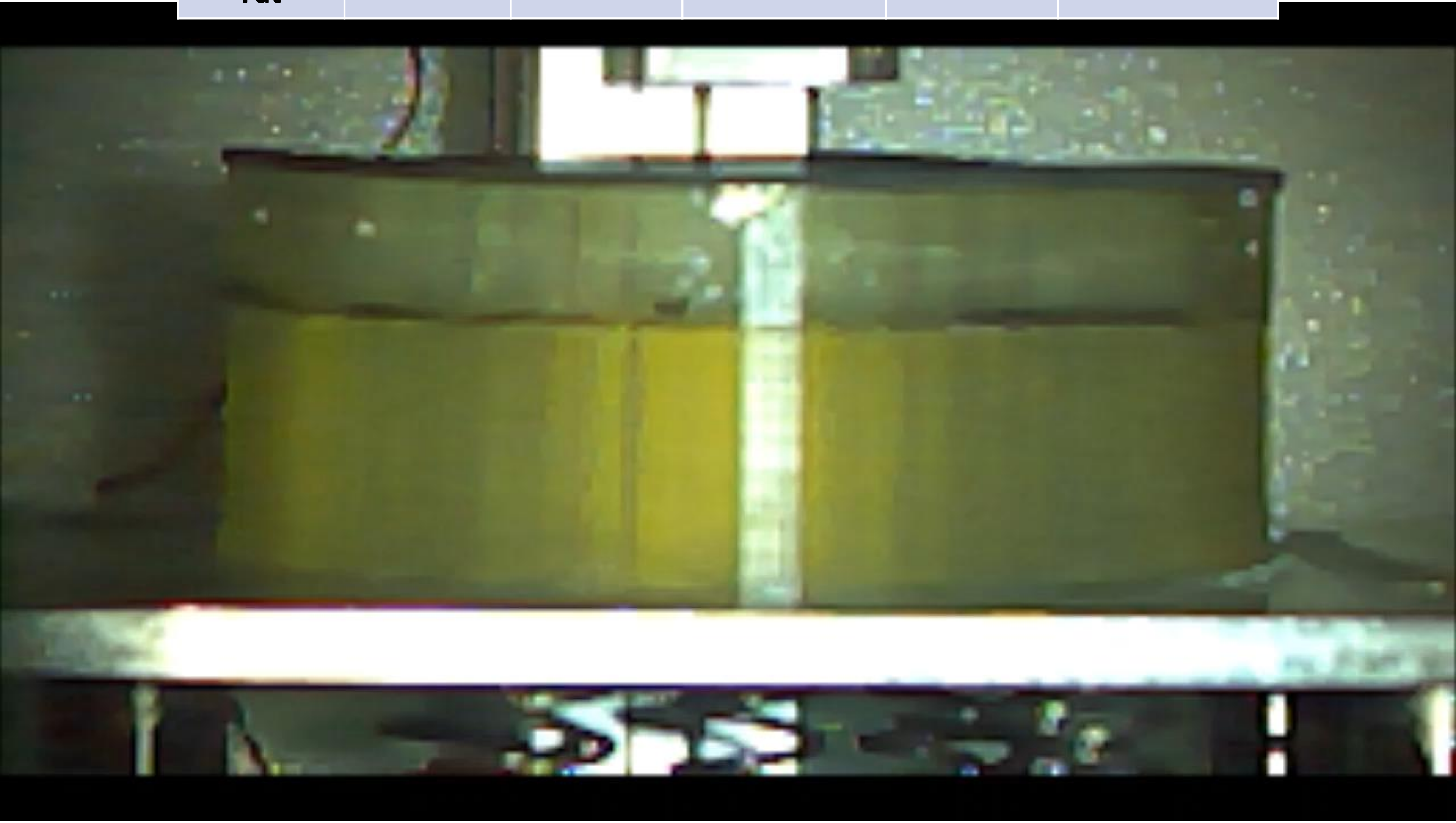
Dynamic Impact Testing and Calibration Instrument (DITCI) Testing of Soft Tissue Bio-Simulant Artifacts



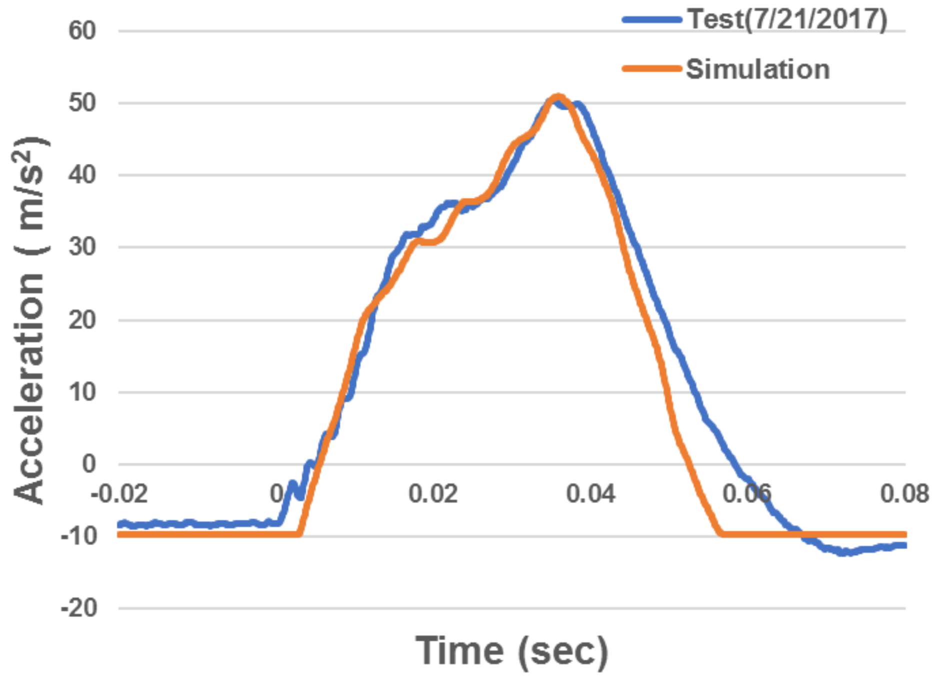
Display of the analysis of DITCI data for approximately 160 N maximum impact force

DITCI Impact Test	Specimen name	Impact Velocity	Maximum acceleration	Maximum force	Maximum displacement
NO Fat	GS1	-0.7133 m/s	39.07 m/s^2	-147.89 N	-0.0176 m

DITCI Impact Test	Specimen name	Impact Velocity	Maximum acceleration	Maximum force	Maximum displacement
15 mm Fat	GS4	-0.8055 m/s	39.85 m/s^2	-69.39 N	-0.0211 m



Comparison of a human soft tissue artifact impact DITCI test experimental acceleration data, with a FEM simulation of the same test



	Maximum Acceleration (m/s^2)	Time duration (sec)
Test	50.41	0.0530
Simulation	50.81	0.0475
Difference (%)	+0.8	-10.4

Conclusions

- **With the use of simple and inexpensive test instruments and human bio-simulant artifacts we are able to study the Biomechanics of Human Impact Injury.**
- **Very interesting knowledge of the Human Impact Injury has been acquired, which could be used for the reduction of human injuries.**