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Modeling of Living Systems and Simulation in Biomechanics
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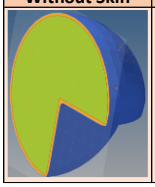
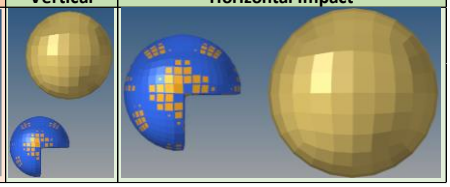
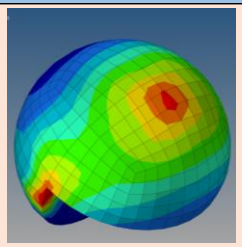
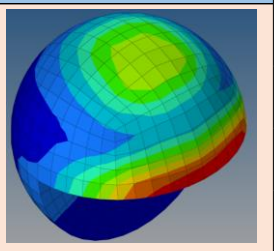
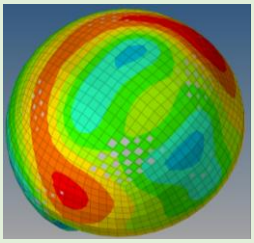
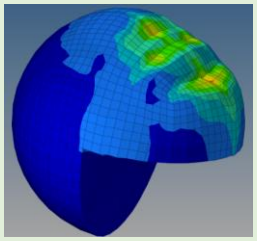
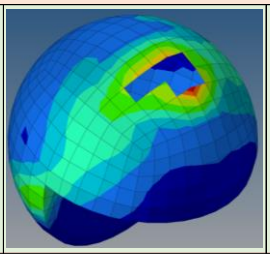
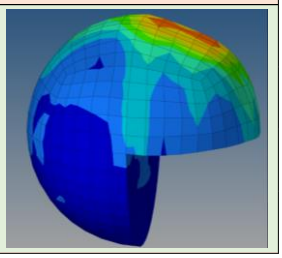
Human Head Modeling and Simulation

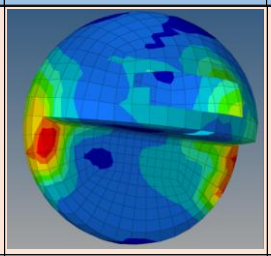
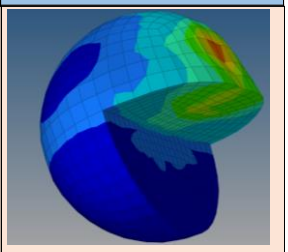
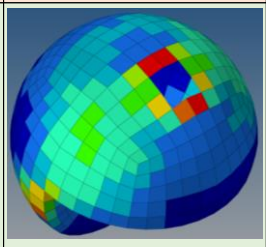
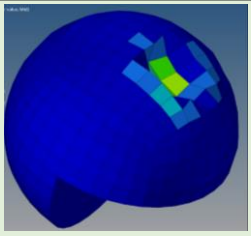
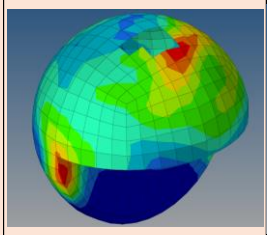
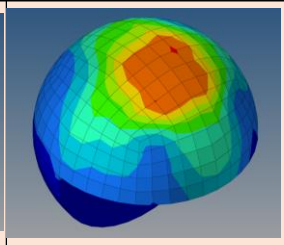
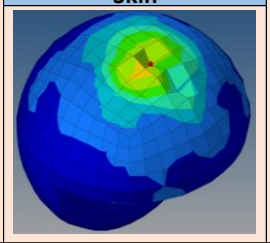
This report shows the results and a brief analysis of the simulation with different human head models, using HyperWorks21. For this propose, two main types of impact were considered, one vertical and another horizontal (Figure beside). For both configurations, the head was fixed from the bottom side, representing the presence of the neck. Furthermore, two main models were used, the first one contains the Brain, Pia, CSF and Skull. The second one contains all these four parts plus the Skin (Figure beside). Each part has the following characteristics:

Main layers of simulated models		Types of impact	
Without Skin	With Skin	Vertical	Horizontal Impact
			

- The Brain was modeled using 3D elements and two different models: Boltzman Humain (foam 34) and Mooney-Rivlin (hyperelastic 42).
- The Pia was modeled using 2D elements.
- The CSF was modeled using 3D elements.
- The Skull was modeled using 2D elements and was divided in 3 parts representing the cortical and spongious materials.
- The Skin was modeled using 3D elements.

The table below shows, with detail, the results of simulation due to parameter change.

File Name (X_0000.rad and X_0001.rad)	Simulation Conditions		Analysis	Von Misses Strees Map	
				Skull	Brain
Head Base Model	Type of Mesh	Rough Mesh	- No skull fracture, relative low stress in the brain. - The maximum stress in skull reach 23.37 MPa. - The maximum stress in the brain reach 2.49 kPa.		
	Ball Speed	3.0 m/s			
	Ball Direction	Vertical (on the top of the head)			
	Brain Model	Boltzman Humain			
Head Refined	Type of Mesh	Refined	- No skull fracture, the stress in the brain and skull are much higher than the Base Model with a rough mesh. - The maximum stress in skull reach 45.83 MPa. - The maximum stress in the brain reach 48.95 kPa.		
	Ball Speed	3.0 m/s			
	Ball Direction	Vertical (on the top of the head)			
	Brain Model	Boltzman Humain			
Head Mooney Refined	Type of Mesh	Refined	- Failed: "The volum of the mesh reach a number less than or equal zero". - The increase in mesh elements and the change in the type of brain material probably caused large deformations, resulting in non-convergence of the solver.		
	Ball Speed	3.0 m/s			
	Ball Direction	Vertical (on the top of the head)			
	Brain Model	Mooney Rivlin			
Head High Speed Fracture	Type of Mesh	Rough Mesh	- Skull fracture in 6 elements. - High stress in the skull: maximum stress 44.22 MPa. - High stress in the brain, it means high risk of damage in the frontal lobe. Maximum stress 19.58 kPa.		
	Ball Speed	5.0 m/s			
	Ball Direction	Vertical (on the top of the head)			
	Brain Model	Boltzman Humain			

File Name (X_0000.rad and X_0001.rad)	Simulation Conditions		Analysis	Von Misses Strees Map	
				Skull	Brain
Head High Speed Face Impact	Type of Mesh	Rough Mesh	- Skull fracture in 13 elements. - High stress in the skull: maximum stress 26.80 MPa. - High stress in the brain, it means high risk of damage in the frontal lobe. Maximum stress 27.37 kPa.		
	Ball Speed	5.0 m/s			
	Ball Direction	Horizontal (on the forehead)			
	Brain Model	Boltzman Humain			
Head High Speed Mooney	Type of Mesh	Rough Mesh	- Skull fracture in 4 elements. - High stress in the skull: maximum stress 37.37 MPa. - Low stress when compared with the previous models, however, it shows a higher deformation in the area of impact. Maximum stress 4.34 kPa.		
	Ball Speed	5.0 m/s			
	Ball Direction	Vertical (on the top of the head)			
	Brain Model	Mooney Rivlin			
Head High Speed With Skin	Type of Mesh	Rough Mesh	- The skin was added in the head model. - Skull fracture. The stress in the brain is lower due the new layer added. - Max Stress skull: 18.76 MPa. - Max Stress brain: 4.26 kPa. - Max Stress skin: 5.96 MPa.	Skull 	Brain 
	Ball Speed	5.0 m/s		Skin 	
	Ball Direction	Vertical (on the top of the head)			
	Brain Model	Boltzman Humain			

It is possible to see graphically the comparison of the stress in the skull and the brain for each model simulated.