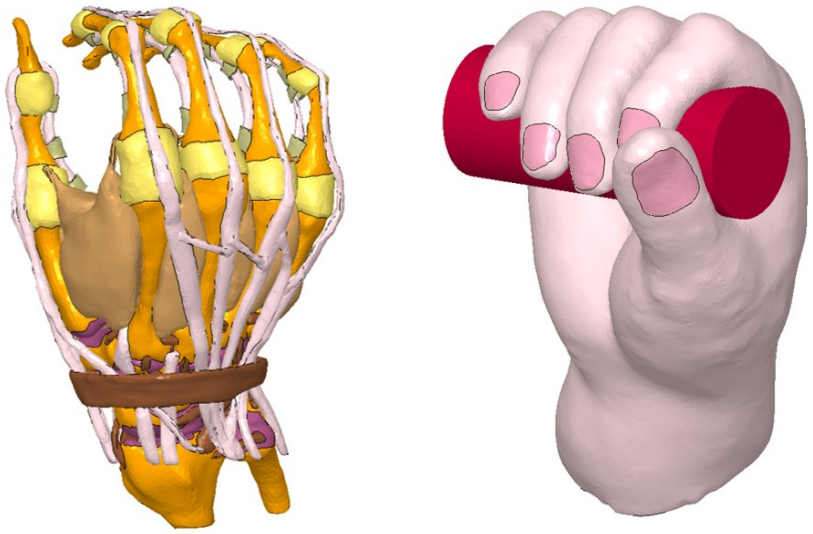
Detailed Finite Element Modeling of the Mechanism of Power Grip



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Summary

- Context and problematic
- Geometry acquisition
- Model setting
- Results
- Discussion
- Perspectives

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Context and problematic

- Grasping is a common task in daily life
- Power grip is one of the most frequent grasping task
- Force and repetition of this task contributes to trauma (Shiri et al. 2006), pain (Thomsen et al., 2007) and fatigue (Kramer and Knudson 1992).

➔ Investigating forces and constraints during power grip is crucial.

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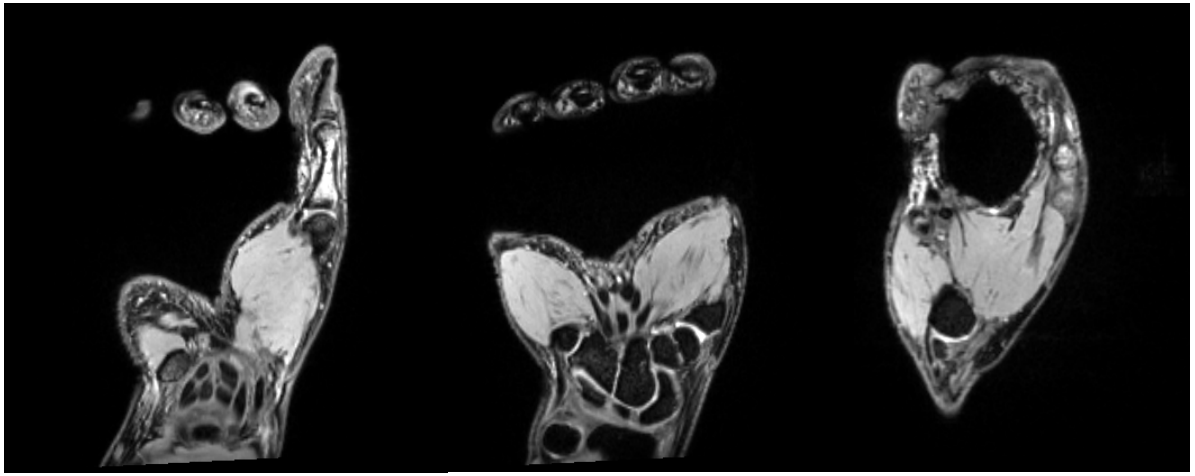
Geometry Acquisition

- The geometry acquisition was based on an MRI of the right hand of a male subject closed to the 50th percentile (1m78, 78kg).

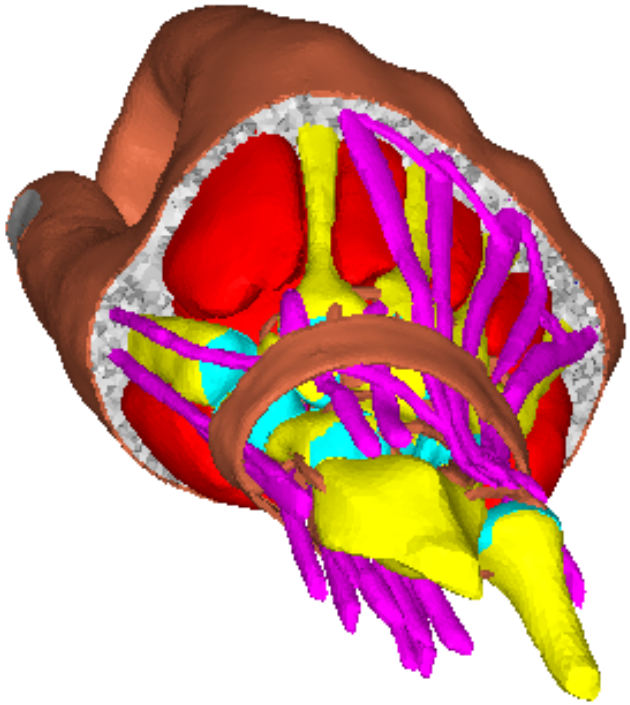
Soft Handle
No pressure applied



MRI siemens 3T Skyra (Erlangen, germany)

Geometry Acquisition

- Segmentation was performed with 3D Slicer
- When components were not visible, reconstruction was made manually based on anatomical data.



Components:

- Bones
- Cartilage
- Muscles
- Tendons
- Ligaments
- Soft tissues
- Skin
- Nails

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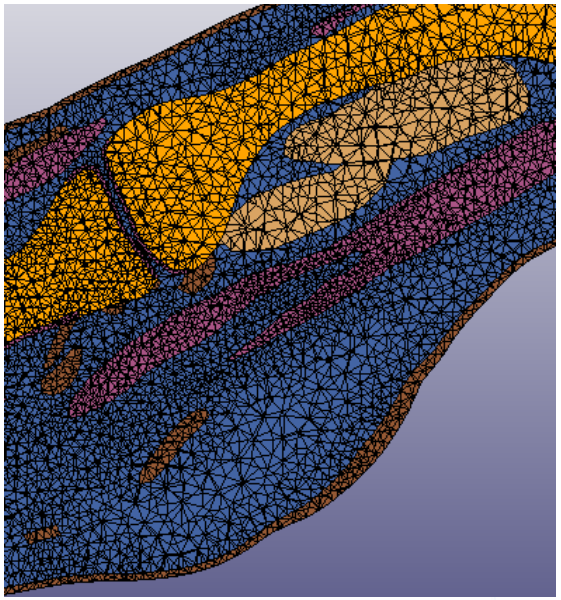
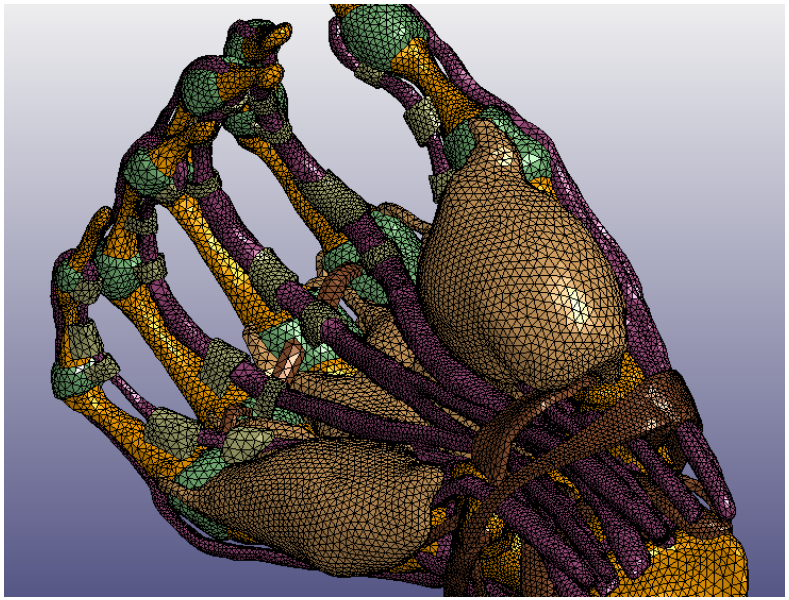
Model Setting

- Mesh was continuous between all components except between tendon and other components.
- Tetrahedron mesh
- Mesh size : approximatively 1mm (1304903 elements, 339325 nodes)





Model Setting

Materials:

Part	Density (kg/m3)	Young Modulus (Mpa)	Poisson ratio	Bulk Modulus (Mpa)	Short time Shear modulus (Mpa)	Longtime Shear modulus (Mpa)
Bones	1000	20000	0.3	-	-	-
Cartilage	1000	100	0.3	-	-	-
Muscles	1000	-	-	0.25	0.1154	0.086
Tendon	1000	1200	0.49	-	-	-
Ligaments	1000	1200	0.3	-	-	-
Soft tissues	1000	100	0.3	-	-	-
Skin	1000	100	0.3	-	-	-
Nails	1000	20000	0.3	-	-	-

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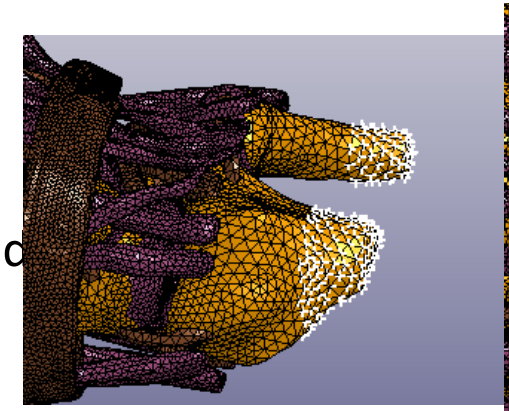
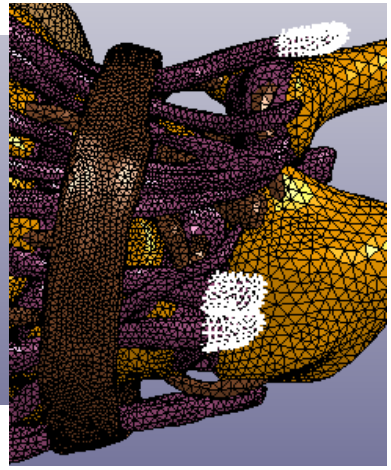
Model Setting

- Boundary Conditions:
  - Radius and Ulna extremities fixed
  - Extremities of the tendons responsible of wrist extension fixed
  - Handle fixed



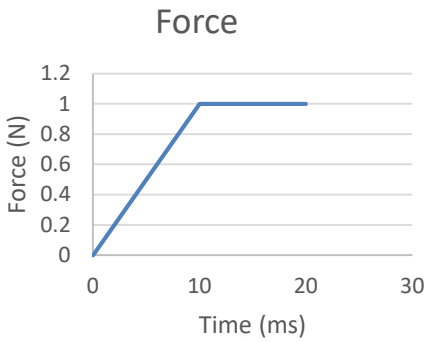


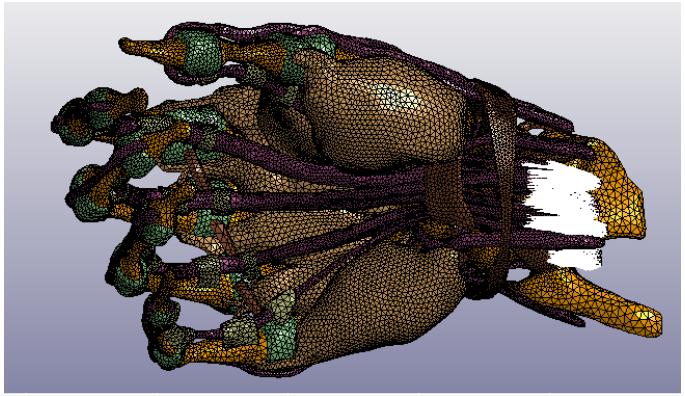
- Load :

  3 cases (approximatively 300N, 150N and 75N of grip force)

  Ramp force applied on the flexor tendons of the 5 fingers.

  Repartition of forces in fingers according to Lee and Rim (1991)





Finger	Thumb	Index	Medial	Ring	Little
Force (%)	27%	21%	24%	16%	12%

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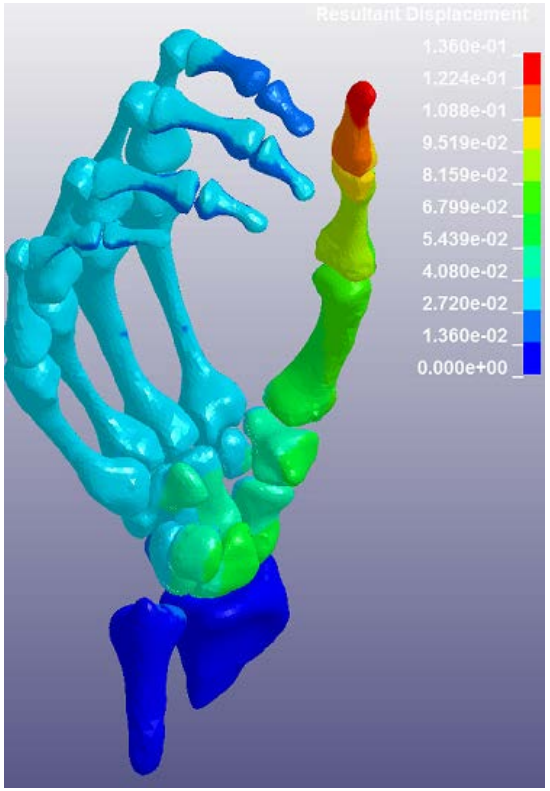
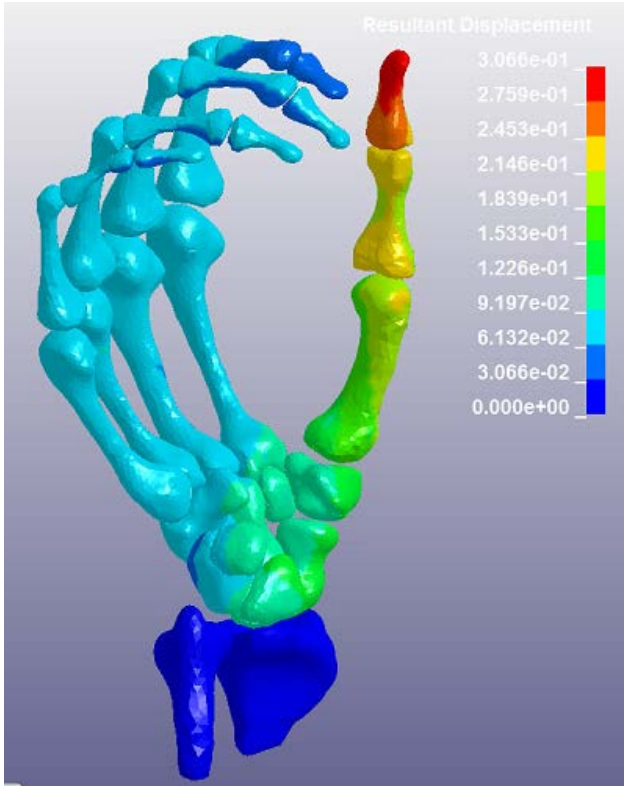
Results

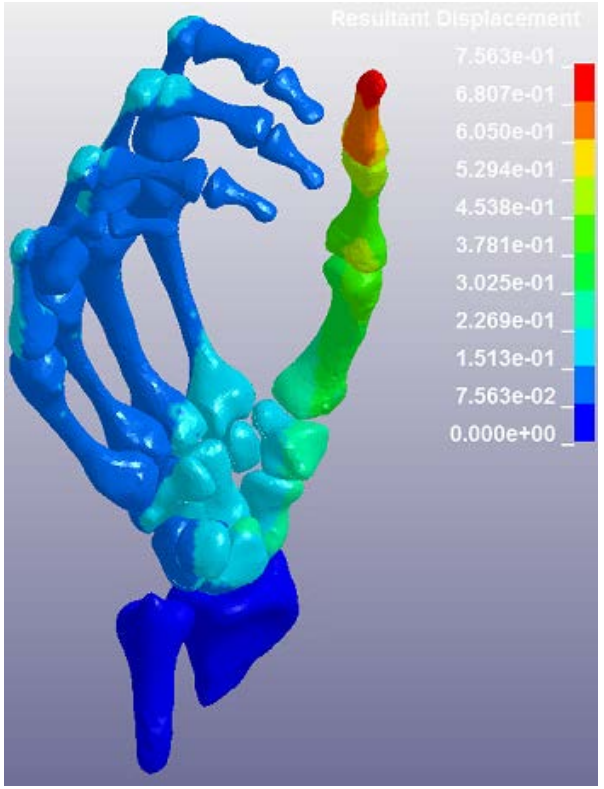
- Displacement



75N



150N



300N

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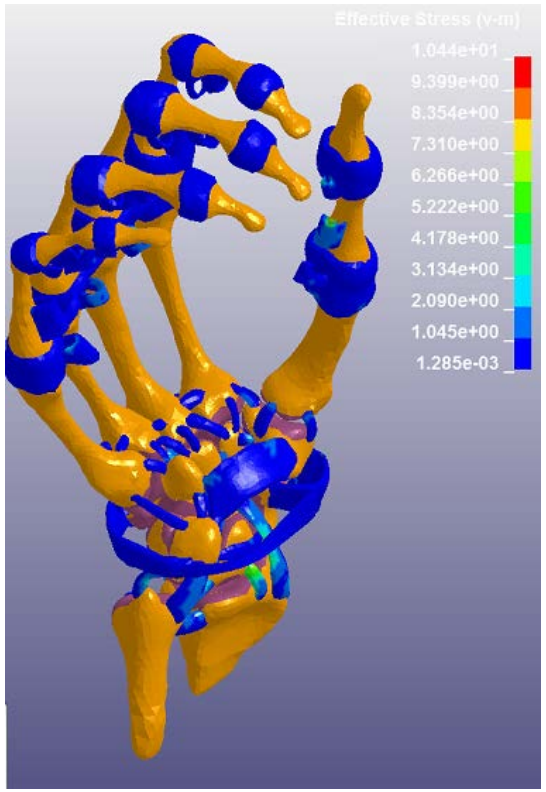
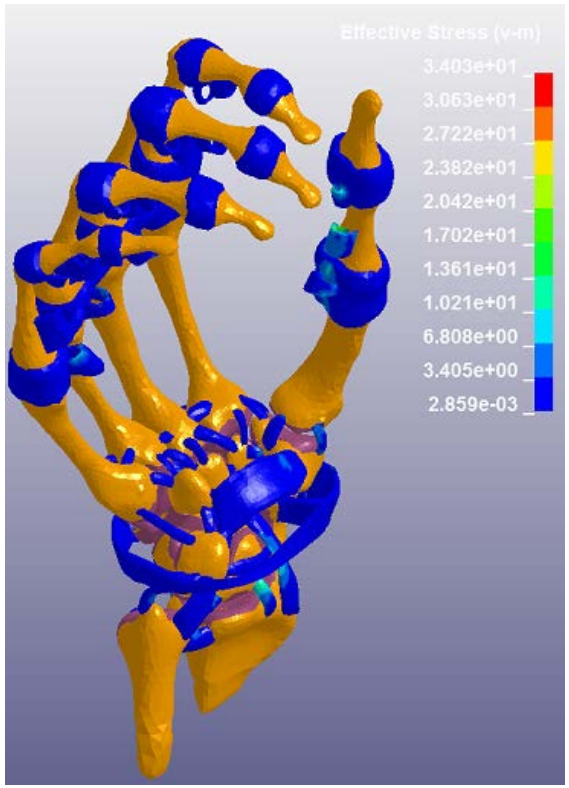
Results

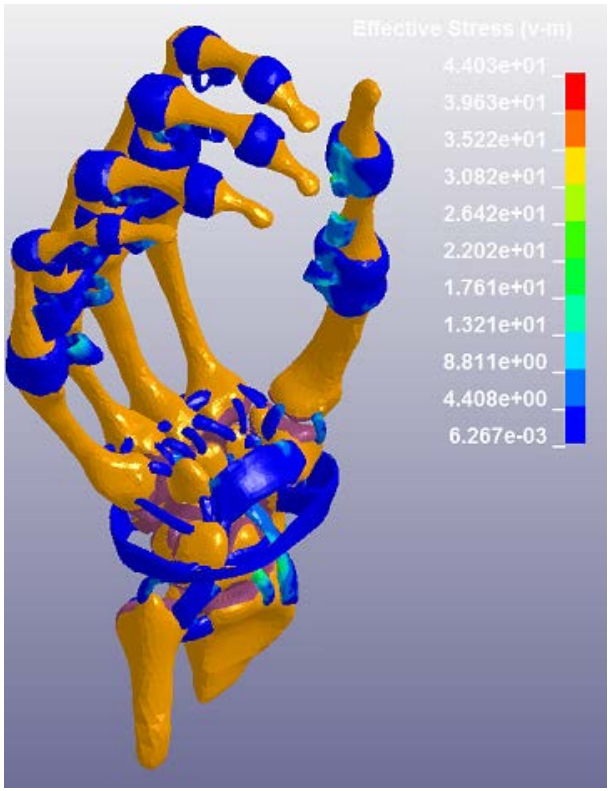
- Ligaments Stress (Von-Mises)



75N



150N



300N

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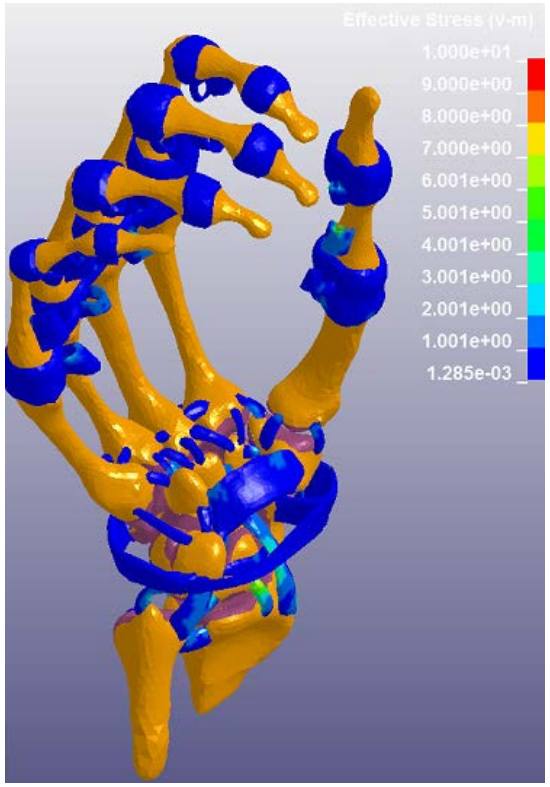
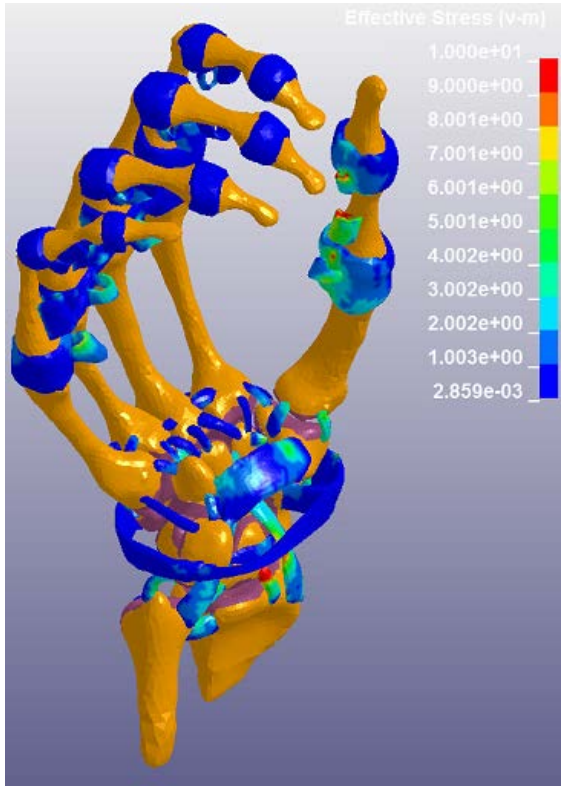
Results

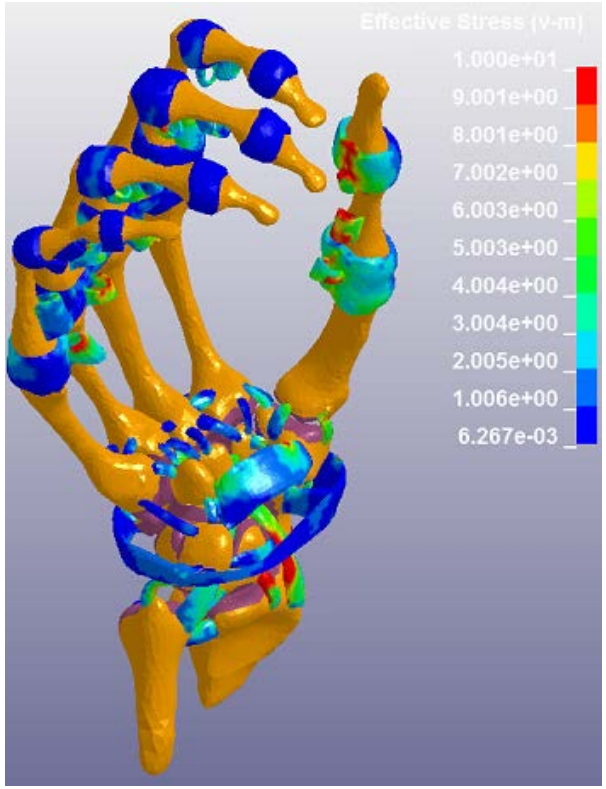
- Ligaments Stress (Von-Mises)



75N



150N



300N

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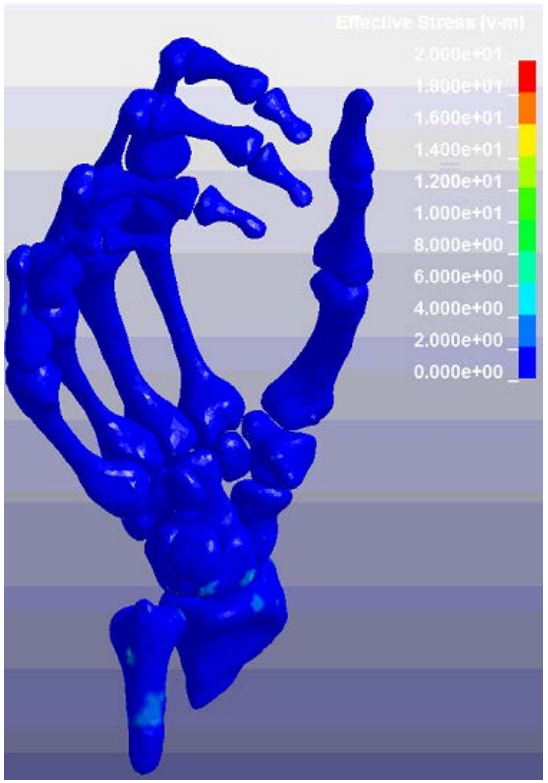
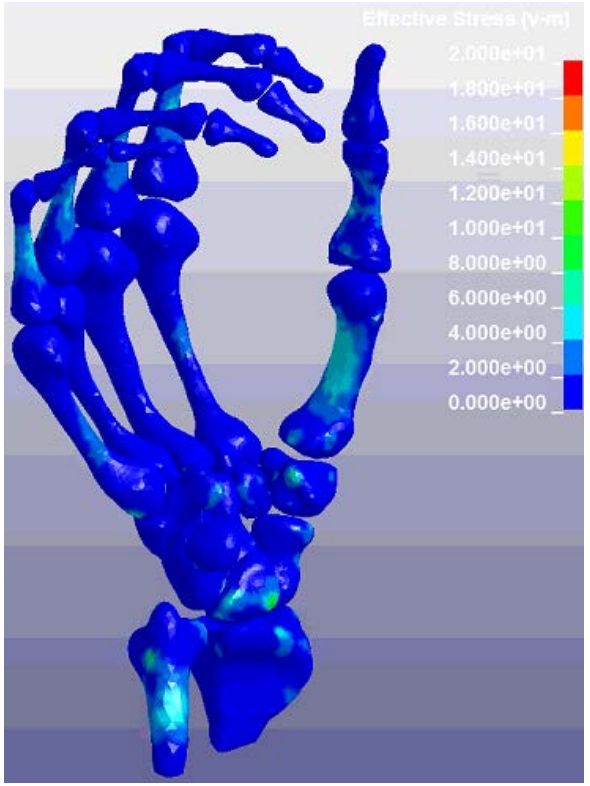
Results

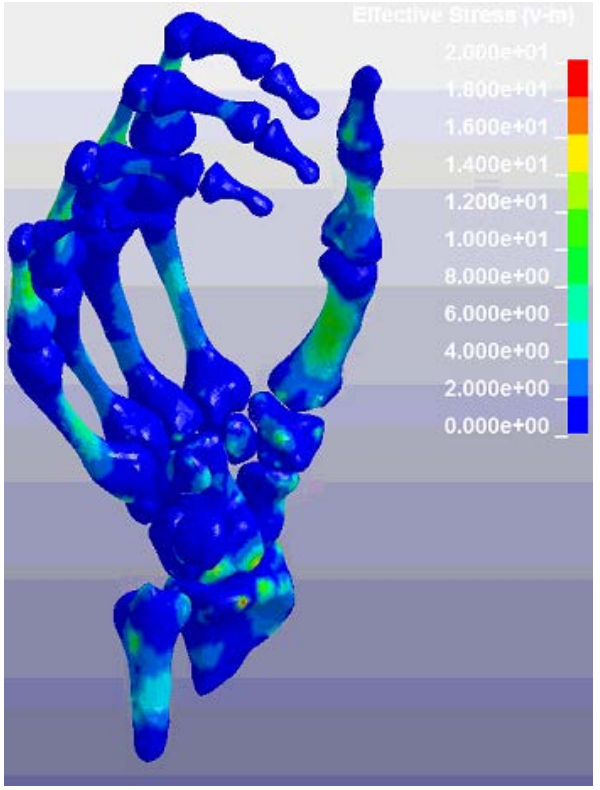
- Bones and cartilage Stress (Von-Mises)



75N (max: 19MPa)



150N (max: 55Mpa)



300N (max: 77MPa)

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Results

Force repartition

Various areas of skin in order to measure pressure repartition

Area	Case 1 (300N)	Case 2 (150N)	Case 3 (75N)	Rossi et al. (2012)
Palm	22% (60N)	27% (40N)	30% (20N)	50%
P1-P2	65% (175N)	61% (90N)	61% (40N)	20%
P3	4% (10N)	2% (3N)	1% (1N)	20%
Thumb	9% (25N)	10% (15N)	8% (5N)	10%

X : Too low X : Good X : Too high

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Discussion

- A detailed finite element model of the human hand was developed. It allows better understanding of the mechanism of power grip.
- The mesh was continuous which limits the number of contacts.
- The model can generate significant grip forces (300N) compared to maximal grip forces (600N to 900N in literature)
- Grip force is mostly contained at P1-P2 level at the cost of P3 and palm compared to Rossi et al. (2012). A few aspects of the model can be responsible of this difference:
  - The handle is fixed and rigid vs deformable
  - Ulna and radius are fixed vs mobile
  - Finger joints are maybe too stiff in the model
  - Force repartition of Lee and Kim (1991) is maybe different of force repartition in tendons

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Perspectives

- Study the effects of boundary conditions and joint capsules in grip force repartition.
- Study the pressure exerted by fingers independently.
- Improve grip force repartition of the model.
- Add external loadings on the handle (vibration, impact…) and study their effects.
- Add reflexes and motor control.
- Use Model reduction in order to reduce computational cost.

➔ **Improve ergonomics of tools in daily life**

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Questions ?

I would like to thank all participants to this research for their precious support:

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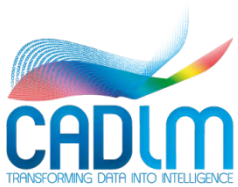
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