Estimation Of Young's Modulus Of Ulna For Patient-specific Simulation

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Background

Artificial elbow joint：**Application to Rheumatoid Arthritis**

Problems after surgical operation

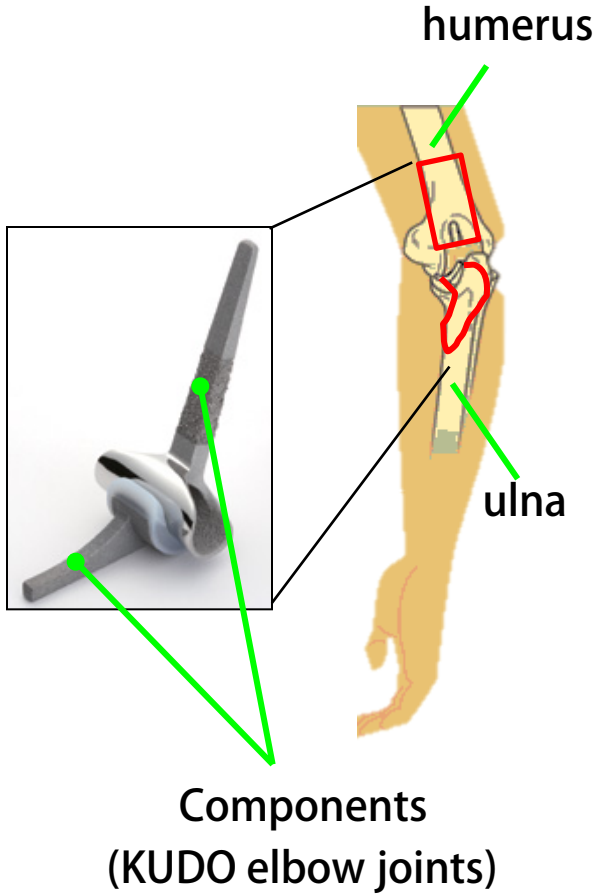
loosening around stem part of component
dislocation of elbow joint

→ **insufficient studies from biomechanical viewpoint**

Examination of stressed states in bone By FEM(Finite Element Method)

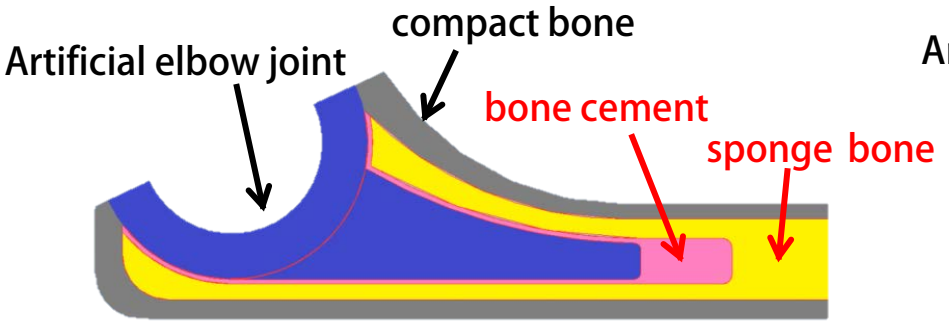
- Optimal insertion angle of component
- Stressed states in ADL(Activities of Daily Living)

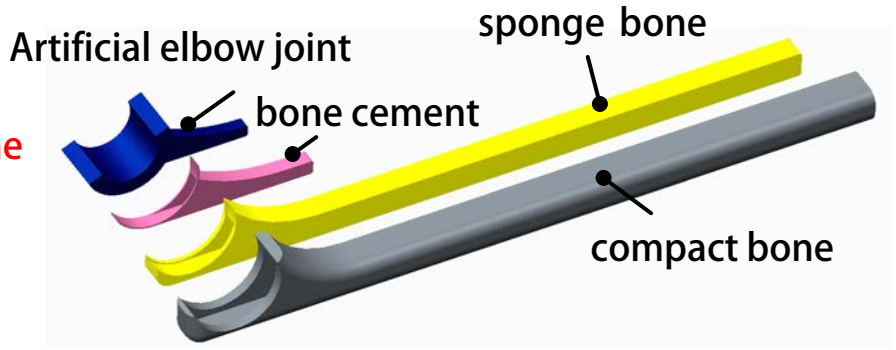
Proposal of guidelines for long-term use



Finite element model

Our former analytical model





This study: Precise model for each patient

Patient specific modeling based on CT

Patient-specific Simulation

1. CT scanning of object
2. Image processing (extract of bone part)
3. Finite element modeling
4. Estimation of Young's modulus
5. Finite element analysis

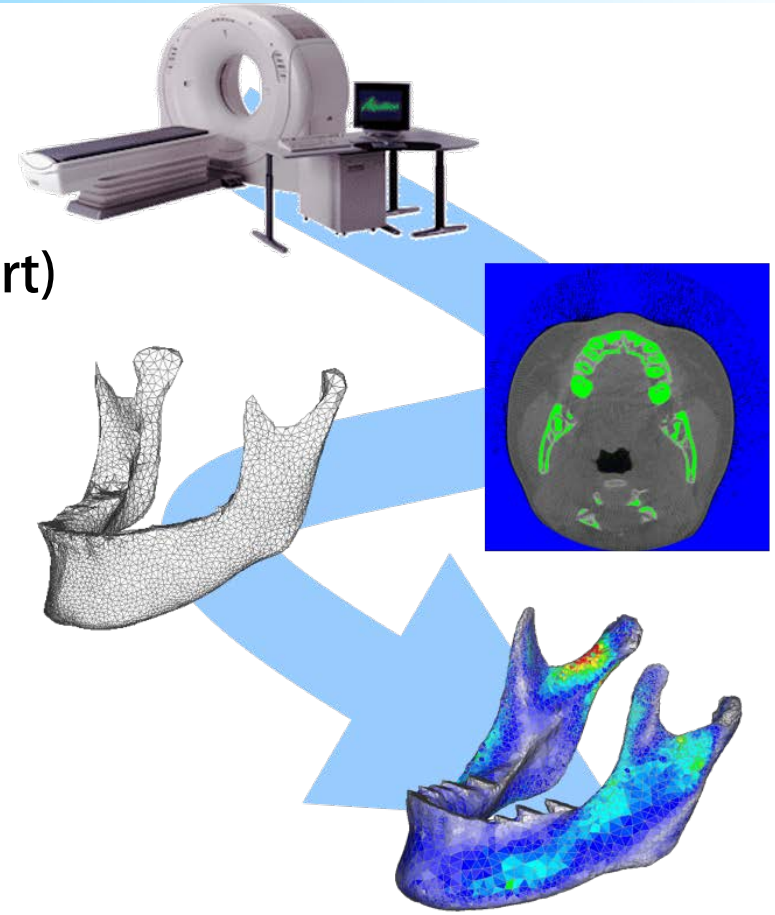
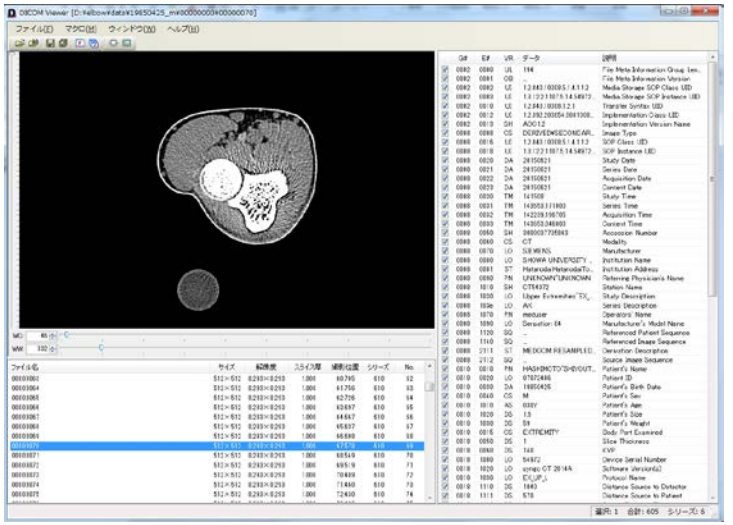
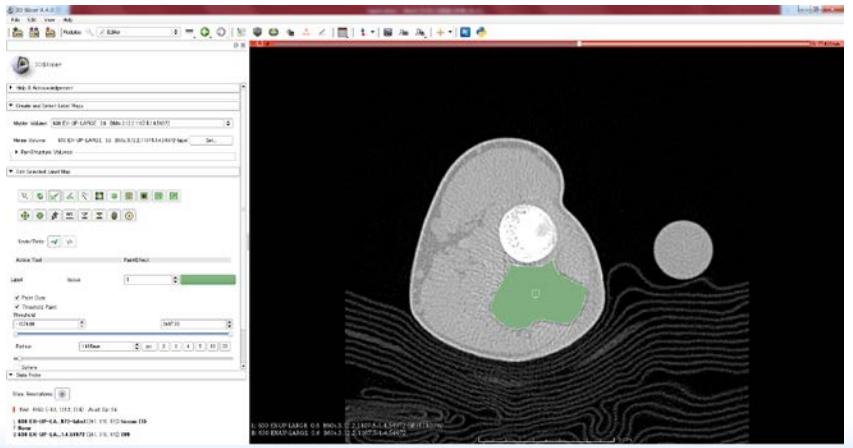


Image Processing

- Check CT data
- Select elbow related data
- Mark out ulna part in the data
- Export CT data of ulna



DICOM Viewer



Slicer

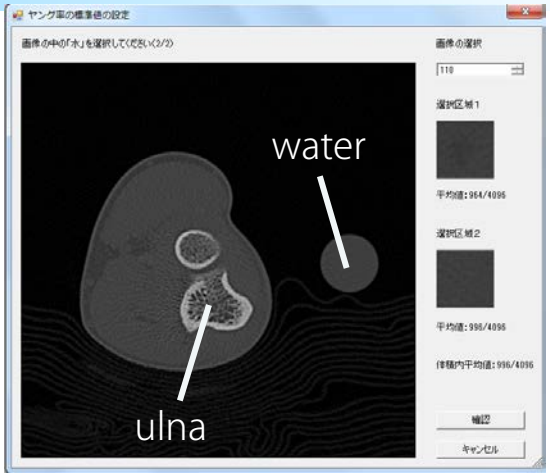
Estimation of Young's modulus

Relationship between CT value(CT),

bone density(ρ) and Young's modulus(E):

$$\rho = a \cdot CT + b$$

$$E = 3.79\ \dot{\varepsilon}^{0.06} \cdot \rho_{app}^{3} \quad \text{(Carter \& Hayes, 1977)}$$



Select region of water

Estimation of Young's modulus:

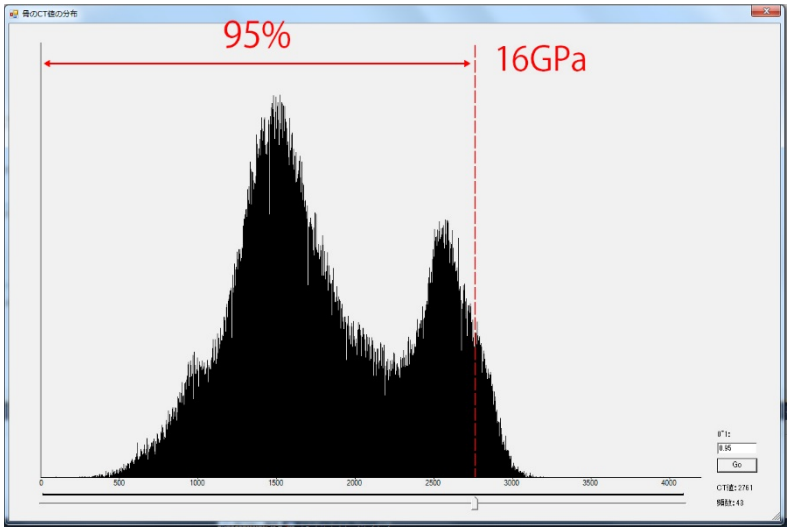
$$\frac{E - E_{\text{water}}}{E_{\text{bone}} - E_{\text{water}}} = \left(\frac{CT - CT_{\text{water}}}{CT_{\text{bone}} - CT_{\text{water}}} \right)^{3}$$

CT_{water} : injector containing pure water included

CT_{bone} : the 95th percentile of CT values

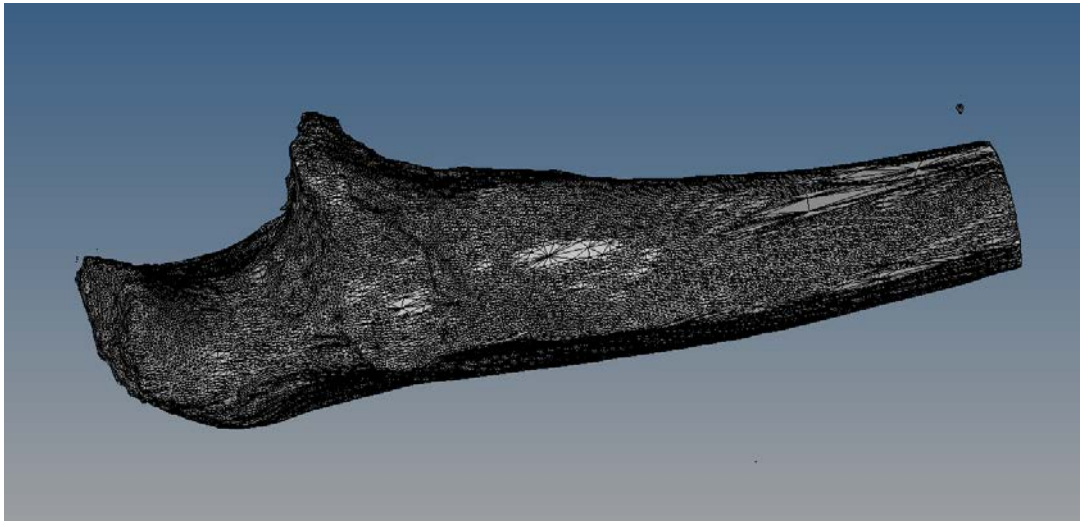
E_{water} : far less than bone → 1MPa

E_{bone} : 16GPa

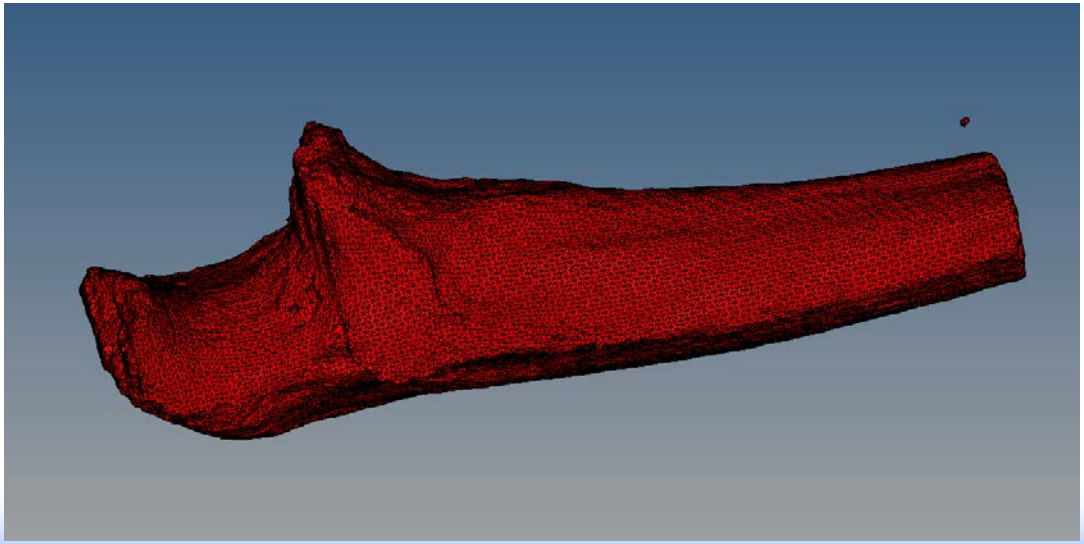


Histogram of CT values of bone

Finite element modeling based on CT data



Extract of bone part from CT data

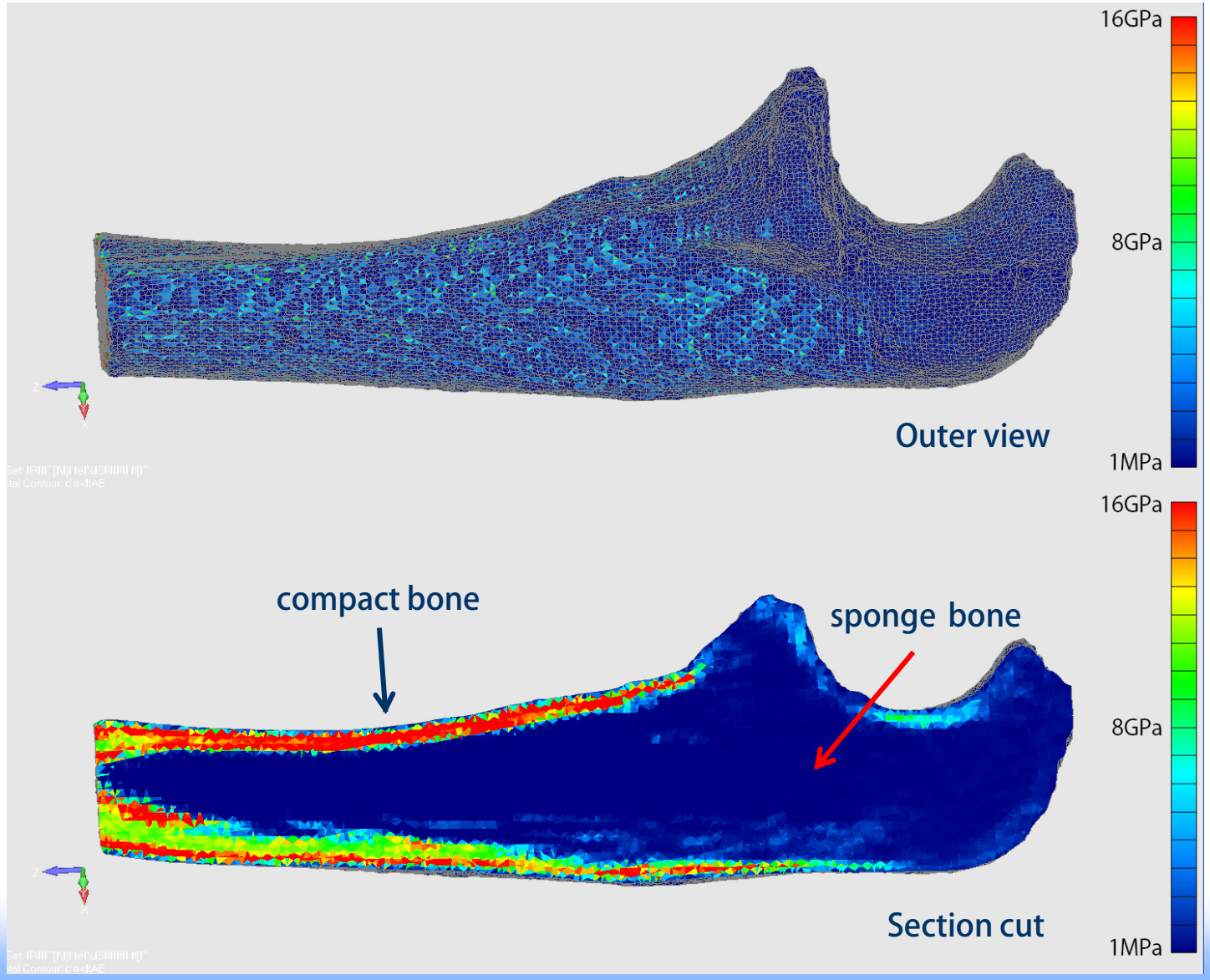


Finite element modeling

Software used:
Altair HyperMesh 13.0

Tetrahedral element
Mesh size: 0.7 mm
Mesh number: 513050
Node number: 111262

Young's modulus distribution based on CT data

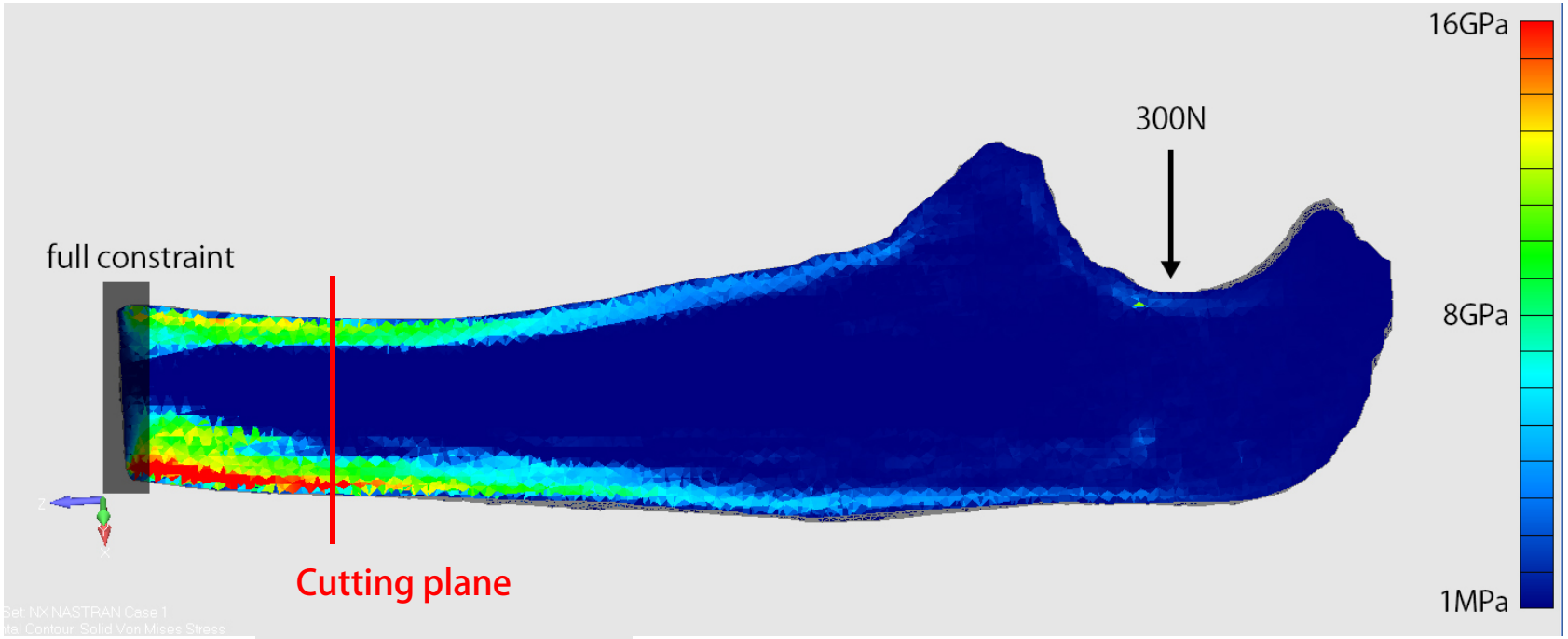


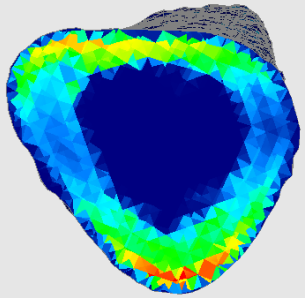
Software used:

Femap with NX

Nastran Version 11.2.0

Trial of stress analysis





Von Mises Stress distribution

Conclusion

- Young's modulus distribution of ulna bone was estimated by patient-specific modeling method.

- Future work:
  Analysis under feasible mechanical conditions

Thanks for listening!