## **Development of FEM-DEM Analysis Methodology to Predict** the Mechanical Damage of Articular Cartilage Caused by Meniscal Injury

Sayo YAMAMOTOa, Yusuke MORITAa and Eiji NAKAMACHIa

<sup>a</sup> Department of Biomedical Engineering, Doshisha University, 1-3 Miyakodani, Tatara, Kyotanabe city, Kyoto, 610-0321 Japan E-mail: dmo0038@mail4.doshisha.ac.jp

### **Objective**

Evaluation of mechanical damage on the articular cartilage caused by meniscal injuries

### 1. Background of the study

- Meniscal Injury
  - · Decline in meniscal function
  - · Concentrated load to the articular cartilage Clarifying the mechanism of OA caused by meniscal injury
- Modeling injured meniscus
- Injured meniscus
- · More large deformation than normal meniscus
- ·Impossible to express the behavior of injured meniscus with FEM
- Multi-physics finite element analysis

Normal part ...Finite element method(FEM)

Denatured part...Smoothed particle hydrodynamics(SPH)

#### Multi-physics finite element analysis

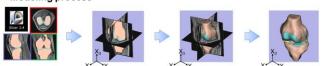
- Collagen fiber orientation
  - · Anisotropy along fiber orientation
  - · A variety of orientation in each layer
- · Meniscal function

Osteoarthritis (OA)

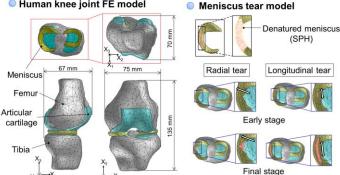
· Meniscal behavior in knee joint

### 2. Modeling

- Finite element model of human knee joint
  - Modeling process



Human knee joint FE model



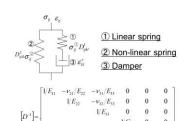
Constitutive equation

 $\dot{\sigma}_{ij} = (D_{ijkl}^1 + D_{ijkl}^2)\dot{\varepsilon}_{kl} - D_{ijkl}^1\dot{\varepsilon}_k^{\nu}$  $\dot{\varepsilon}_{ij}^{\nu} = \frac{3}{2\eta} \sigma_{ij}^{\mathbb{Q}}$ 

Elastic coefficient tensor

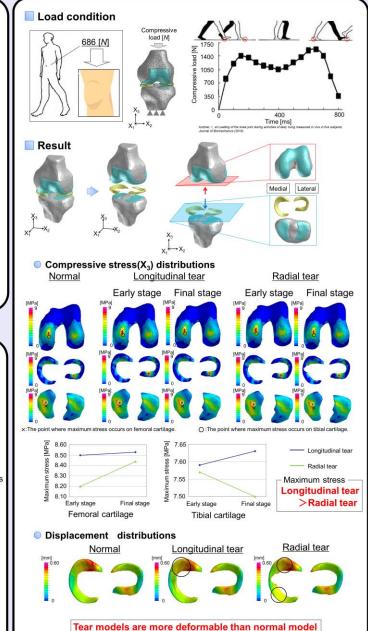
$$D_{ijkl}^{1} = D_{ijkl} \qquad D_{ijkl}^{2} = \tanh\left(\frac{\varepsilon}{A}\right) D_{ijkl}$$

η :Viscosity coefficient :Equivalent stress A :Nonlinearity coefficient



Symm.

# 3. Analysis PAM-CRASH & User's Material Subroutine and SPH-(Murnaghan Equation of State for Slid Element and SPH), ESI Ltd



## 4. Conclusion

- We analyzed walking analysis by using human knee joint models, a normal model, 2 type tear models.
- Maximum stress value in longitudinal tear model is higher than that in radial tear model.
- Menisci in tear models are more deformable than those in normal model.