**Finite Element Analysis to Model the Effects of Osteoarthritis in the Knee**

Francesca Hundall-Saez1, Jessica Z. Liu2, Helen H. Lu2

1Department of Mechanical Engineering, San Francisco State University, San Francisco, CA

2Department of Biomedical Engineering, Columbia University, New York, NY

**Introduction:** Osteoarthritis (OA) of the knee is a degenerative disease that begins with the breakdown of the joint cartilage [2]. The presence of OA in the knee can lead to damage of the cartilage tissue, tendons, synovium and bone, causing chronic pain, swelling, loss of motion, and may lead to excessive stress on the joint [1]. The subchondral bone (SB), calcified cartilage (CC), and articular cartilage (AC) provide the knee with the mechanical strength and support to withstand applied loads. The CC and AC that lies on top of the SB are composed of cells called chondrocytes, which secrete extracellular matrix containing proteins, collagen, and proteoglycans [4]. These proteoglycans are hydrophilic cells, retaining water molecules in CC and AC that give cartilage the mechanical properties necessacery to resist and distribute compressive forces [8]. Pathological processes that affect the joint morphology lead to changes in the biomechanics of the knee, and has been correlated to the presence of OA [1]. Understanding how OA affects the stresses, strains, and load distributions across the SB and CC interface of the knee is integral to engineering cartilage that is capable of replacing damaged tissue. The objective of this study is to use finite element analysis and modeling techniques to identify how the morphology of the knee, and the changes experienced with the presence of OA, affect the stress and strain distributions across the interface.

**Methods:** For this study, we developed both generalized models, and subject specific models, of the SB and CC interface using FEBio, a finite element analysis modeling software. The subject specific models were created using ~~subject specific~~ samples of the osteochondral interface, 3 healthy samples, and 3 OA samples. The samples underwent histological analysis, and the 2D images were generated into 3D models in FEBio. The generalized models were created using characterization data complied from the histology samples. The histology samples were analyzed for their dimensions, along with the shape and frequency of their undulations. Once the characterization data was acquired, it was averaged to determine the dimensions and morphology for the generalized models. The Young’s Modulus, Poisson’s ratio, and density were fixed between both groups. Once the morphology and material properties were determined, FEBio was used to generate the models. After the models were generated, a confined compression test was performed by applying a 4 MPa load to the top surface of each model. After the test was performed, colormap graphs of the strain energy distribution (SED), and max shear stress (MSS) distribution were generated. The stress values at the front interface of the model, and the associated x-positions were extracted from FEBio and imported into Excel where stress vs distance graphs were created for further analysis.

**Results:** The strain energy density colormap showed that strain energy density was the highest at the peak of the undulations in the calcified cartilage in both the healthy and OA groups. The max shear stress colormap distribution showed that stress concentrations occur at the peak of the undulation in the subchondral bone for both the healthy and OA groups. The MSS colormap suggested that the size of the undulation correlates to the magnitude of stress applied to the undulation. The stress vs distance graphs showed that the stress magnitudes were periodically following the shape of the undulations for both the healthy and OA groups.

**Conclusions:** The maximum strain energy density was experienced at the peak of the undulation of the calcified cartilage for both the healthy and OA groups. This suggest that the CC is able to absorb the most energy from the 4 MPa compressional load without undergoing plastic deformation. The maximum shear stress is experienced in the undulations of the subchondral bone for both the healthy and OA groups, suggesting that the SB experiences higher stresses than the CC from the applied load. The stress distribution across the interface of the SB periodically follows the shape of the undulations for both the healthy and OA groups. This suggests that the shape and size of the undulation correlates to the magnitude of stresses experienced in the region. Through analyzing the undulation size and shape, we can conduct critical area analysis to identify the regions that are most vulnerable to failure once a load is applied. Identifying areas that are most prone to failure allows us to engineer cartilage that is capable of withstanding the compressional loads that are applied throughout everyday activity. Further analysis of how fatigue loading affects the stress and strain distributions, and the rate of deformation should be conducted.

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**(Not Included in Word Count) Acknowledgements:** Acknowledgements to funding sources or contributions of individuals not rising to the level of authorship. If it is necessary to include acknowledgements, insert the funding agency and grant number.