Magnetic particle translation as a surrogate measure for synovial fluid mechanics
Yash Y. Shah, Lorena Maldonado-Camargo, Ph.D., Neal S. Patel, Adam H. Biedrzycki, D.V.M., Ph.D., Elena G. Yarmola, Ph.D., Jon Dobson, Ph.D., Carlos Rinaldi, Ph.D., Kyle D. Allen, Ph.D.

1Department of Materials Science and Engineering, University of Florida, Gainesville, FL, 2J. Crayton Pruitt Family Department of Biomedical Engineering, University of Florida, Gainesville, FL, 3Department of Chemical Engineering, University of Florida, Gainesville, FL, 4Department of Large Animal Clinical Sciences, University of Florida, Gainesville, FL

Introduction: Synovial fluid mechanics vary with osteoarthritis progression. These changes are difficult to quantify in a clinical setting due to synovial fluid’s complexity as a Non-Newtonian fluid and by limited sample volumes. This work will introduce a novel technique, termed magnetic particle translation, to measure synovial fluid mechanics using magnetic nanoparticles.

Materials and Methods: Polystyrene microspheres embedded with superparamagnetic iron oxide nanoparticles are distributed through a 100 µL synovial fluid sample. Then, a 1 mm NdFeB magnet inside a protective sheath is inserted into the sample. While the magnetic collection tool is submerged, particles translate toward the collection tool and aggregate on the surface of the sheath. Then, the collection tool is removed from the synovial fluid sample and the percentage of magnetic particles collected by the magnet in a given time is quantified via fluorescence intensity. To validate this relationship, magnetic particle translation was demonstrated in three phases. First, magnetic particle translation was assessed in glycerol solutions with known viscosities. Next, the relationship between magnetic particle translation and synovial fluid viscosity was assessed using bovine synovial fluid that was progressively degenerated via ultrasonication. Finally, magnetic particle translation was used to assess differences between healthy and OA affected joints in equine synovial fluid.

Results and Discussion: Figure 1A demonstrates that as the fluid viscosity of the glycerol solutions increased, magnetic particle translation decreased. Figure 1B demonstrates the magnetic particle translation in degenerated synovial fluid. Here, particle collection in a given amount of time increased as fluid degenerated, demonstrating the relationship between particle collection and fluid mechanics holds in non-Newtonian synovial fluid. Finally, Figure 1C demonstrates how particle collection in a given time was higher in OA joints relative to healthy horses (p < 0.001).

Conclusion: Combined, these data demonstrate potential viability of magnetic particle translation in a clinical setting to evaluate synovial fluid mechanics in limited volumes of synovial fluid sample.

Acknowledgements: This research was supported by the National Institute of Health (R21AR064402 and R01AR068424).

Figure 1: A) Empirical correlation between magnetic particle translation and water:glycerol solutions. B) Relationship between magnetic particle translation and synovial fluid viscosity. C) Magnetic particle collection in healthy and disease equine synovial fluid samples.