Cartilage disease- such as osteoarthritis- is a significant health issue that affects millions of patients of all ages. There are currently methodologies to replace damaged tissue or joints, yet there are few interventions to prevent or slow the disease progression. As mechanical wear is an important component of cartilage disease, the primary objective of this project was to investigate the wear characteristics of articular cartilage and factors that may improve or reduce the tissue’s wear resistance. More specifically, the project was broken into 4 studies with the following objectives: (1) develop tests parameters and investigate different methodologies to quantify cartilage wear, (2) determine a semi-automated indentation protocol to measure changes to the mechanical properties of cartilage, (3) quantify the effect of genipin crosslinking treatments on the modulus, coefficient of friction and wear factor of cartilage, and (4)
determine whether genipin crosslinking can reverse the effect of a single traumatic impact on the stiffness of articular cartilage.

In developing test parameters for cartilage wear, two different cartilage surface geometries were compared: smaller specimens had a flat surface while larger ones made contact in the center but not at the edge due to the curvature of the articulating surface. The cartilage wear of the two geometries was compared using three different techniques. A modified wear factor was considered to be the most accurate assessment of cartilage wear, but surface damage measurement with India ink was an effective, inexpensive and quick technique to evaluate potential implant materials. To interpret the experimental results, maximum shear stresses were evaluated with sliding contact finite element models. Flat specimens showed excessive wear at the edges due to a non-physiologic stress concentration, while the larger specimens wore more uniformly across the surface.

To identify mechanical changes due to cartilage treatments, a semi-automated indentation protocol for repeatable material characterization of the tissue was developed. The technique incorporated a small preload to detect the tissue surface, followed by a stress relaxation test at a defined indentation depth. The protocol was then used to measure the increase in cartilage stiffness due to ribose-induced collagen crosslinking.
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The effect of artificially crosslinking collagen with genipin, a naturally occurring crosslinking agent, on the modulus, coefficient of friction and wear factor of cartilage was quantified. It was found that the concentration and the duration of exposure to genipin could both be varied to alter the cartilage modulus. Artificially crosslinking bovine cartilage in genipin solutions also decreased the wear factor in a dose dependent manner. Crosslinking in 2 and 10 mM genipin for 15 minutes increased the stiffness by 16 and 62% and decreased the wear factor by 43 and 71%, respectively. There was no change in the frictional coefficient with either treatment.

Finally, it was found that a single traumatic impact decreases the stiffness of cartilage by 23%. Immunohistochemistry demonstrated that this may have been due to damage in the collagen matrix. Crosslinking the impacted cartilage reversed the loss of the modulus and left the tissue 37% stiffer than it was initially.