INTRODUCTION: Acute post-traumatic pain and a subsequent degradative disease, such as osteoarthritis (OA), are complications associated with joint trauma. To help understand the etiology of the chronic disease process, our laboratory has developed a small animal model. The model consists of a single subfracture, blunt impact to the flexed patellofemoral joint of Giant Flemish rabbits, administered via a gravity-dropped impactor mass. The studies have documented chronic surface fissuring of retropatellar cartilage, and a significant decrease in its elastic modulus and increase in its permeability compared to controls at 12 months post-insult. The model also and a significant decrease in its elastic modulus and increase in its permeability compared to controls at 12 months post-insult. The model also

METHODS: Thirty mature Flemish Giant rabbits (4.9 ± 1.2 kg; 6-8 months old) were utilized in this study. Twenty-four animals were used for the chronic aspect of the study. Eight rabbits were used as unimpacted controls. Eight rabbits received a single blunt insult to the right patellofemoral joint with a high rate of loading (~5 ms to peak). The loads were administered using a 1.33 kg mass with a flat, rigid 25.4 mm diameter impact interface onto the right hyperflexed (120°) hind limb. Eight animals received a blunt insult to the right patellofemoral joint with a low rate of loading (~50 ms to peak). The impact protocol was similar to the high rate of loading, but the joints were impacted using a servo controlled hydraulic testing machine (Model 1331, Instron Corp.). During the impact all the animals were maintained at a surgical plane of anesthesia (2% Isoflurane). All chronic animals were exercised daily and sacrificed 12 months post impact. Immediately after sacrifice, the patellae were excised for mechanical indentation tests on the retropatellar cartilage. The patellae were stained with India ink to highlight surface lesions and photographed. Six additional animals were sacrificed for the acute aspect of the study. Pressure sensitive film was inserted into the patellofemoral joint prior to the impacts to document patellofemoral joint and anterior patella contact pressures and areas in low and high rate of loading experiments. For the chronic animals the decalcified patella was sectioned and stained with Safranin O-Fast Green and the thickness of the subchondral bone plate was measured using existing methods. Paired t-tests were performed to evaluate differences in mechanical properties, total length of fissuring, subchondral bone thickness and average depth in the traumatized retropatellar cartilage compared to the contralateral unimpacted limb. ANOVAs with SNK post-hoc tests were performed to evaluate the differences in these parameters between the two rates of loading and controls. Signed Rank tests and ANOVA on ranks were used to detect differences in the number of fissures between limbs and the two rates of loading. Significant statistical differences were reported for p<0.05.

RESULTS: There were no significant differences in peak load, time to peak, or contact duration between acute and chronic animals for either rate of loading experiment. The average peak impact load was not statistically different between the low and high rate of loading experiments. Analysis of the pressure film from the acute animal experiments indicated that there were no significant differences in the anterior and patellofemoral contact area or the average contact pressure between the high and low rate of loading experiments. There were no statistical differences in the material properties of traumatized retropatellar cartilage between the high and low rate of loading experiments 12 months post-impact. There was significantly more thickening of subchondral bone for the traumatized limbs at each location for the high rate of loading experiments compared to the low rate of loading impacts, and versus controls (Table 1). Examination of the traumatized retropatellar cartilage indicated that the high rate of loading experiments resulted in more fissures compared to the low rate of loading experiments, and compared to unimpacted controls (Table 2). Total fissure length determined from photographs indicated that the high rate of loading resulted in greater fissure length in traumatized retropatellar cartilage compared to the contralateral unimpacted side, and compared to the low rate of loading experiments, and unimpacted controls.

DISCUSSION: The results from this study document more surface fissuring on the retropatellar cartilage 12 months after a single blunt impact at a high versus low rate of loading. These data suggest that experiments with a gravity dropped impactor may overestimate the extent of chronic change occurring in a more clinical joint trauma setting. On the other hand, Radin et al. have shown that a difference of a few milliseconds exists in the rate of loading during heelstrike between patients having knee pain, and assumed preosteoarthritic, versus a non-pain control group. The results from the current study are also similar to a previous study that cyclically loaded hindlimbs of rabbits at two rates. Yang et al. document that high rates of loading result in fibrillation and loss of cartilage with the formation of osteophytes. In contrast, comparative experiments with a low rate of loading do not demonstrate any gross changes in the knee joint. One possible explanation for the results of the current study may be due to the fast relaxation behavior of the solid phase of cartilage. These investigators suggest that the viscoelastic solid would carry a larger percentage of the impacting load in a high versus a low rate of loading scenario. The corresponding larger stress developed in the solid phase for a high versus low rate of loading may generate relatively more surface fissuring. Interestingly, the current study also documented more thickening of the underlying subchondral bone following high versus low rates of loading. A possible explanation for the current results may involve the biphasic nature of bone. Zhang et al. suggest a characteristic relaxation time constant for the lacunar-canaliculinar porosity of approximately 5 ms. Impacts of duration 5 ms versus 50 ms might then create differential states of stress in surrounding bone, possibly resulting in more microdamage in high versus low rate experiments. Microdamage has previously been suggested as a basis for the subsequent remodeling of bone underlying traumatized cartilage.

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