RESEARCH PROGRESS REPORT SUMMARY

Grant 01782: Defining the Elements of Successful Cranial Cruciate Ligament Repair

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Research Institution: University of Louisville

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Original Project Description:

Cranial cruciate ligament (CrCL) deficiency affects the canine stifle and is one of the most common orthopedic problems in dogs, having an economic impact of more than $1 billion in the US. In one study, 31,698 of 1,243,681 dogs were diagnosed with CrCL deficiency; a prevalence of 2.55% across all breeds. CrCL deficiency is common in some breeds while unlikely in others; Newfoundlands (8.9%), Rottweilers (8.3%), and Labrador Retrievers (5.8%) have the greatest prevalence. Despite such high prevalence, CrCL deficiency is still poorly understood and is thought to be due to degradation and not the sole result of trauma. Surgical intervention is often employed to stabilize the CrCL-deficient stifle, but no single surgical procedure is supported conclusively by data to suggest long-term success, osteoarthritis prevention or superiority. We propose to investigate commonly employed surgical procedures (tibial plateau leveling osteotomy, tibial tuberosity advancement and extra-capsular stabilization) using our previously developed canine pelvic limb 3D computer model to gain an improved understanding of stifle biomechanics following CrCL-deficient stifle stabilization. We will investigate parameters specific to each surgical procedure using our computer model to further our understanding of their influence on stifle stabilization. Furthermore, we will investigate anatomical characteristics (e.g. tibial plateau angle) to gain an improved understanding of their role in surgical intervention efficacy. Our computer model will be used to compare ligament and stifle structure stresses in the intact stifle vs. surgically stabilized stifles. Our outcome will be a biomechanical, evidence-based assessment of currently used stifle stabilization surgical procedures.

Grant Objectives:

Objective 1. Implement stifle surgical stabilization procedures in our previously developed canine pelvic limb CrCL-deficient stifle 3D computer model and simulate the stance phase of gait. Compare key biomechanical outcomes of surgically stabilized stifles to those of the CrCL-intact stifle and the un-stabilized CrCL-deficient stifle.

Objective 2. Investigate the influence of surgery-specific parameters (e.g. tibial fragment rotation angle, tibial tuberosity advancement (TTA) extent, extra-capsular stabilization (ES) element tension, etc.) on stifle biomechanics following CrCL-deficient stifle surgical stabilization.

Objective 3. Investigate the influence of anatomical characteristics (e.g. femoral condyle shape, body mass, tibial plateau angle, etc.) on stifle biomechanics following CrCLdeficient stifle surgical stabilization.

Publications:

1. Brown NP, Bertocci GE, Marcellin-Little DJ. Development of a canine stifle computer model to evaluate cranial cruciate ligament deficiency. Journal of Mechanics in Medicine and Biology 2013; 13(2):1350043-1350071.

2. Brown NP, Bertocci GE, Marcellin-Little DJ. Evaluation of varying morphological parameters on the biomechanics of a cranial cruciate ligament–deficient or intact canine stifle joint with a computer simulation model. American Journal of Veterinary Research, 2014; 75(1):26-33.

Additional manuscripts in preparation.

Report to Grant Sponsor from Investigator:

Overview

Cranial cruciate ligament (CrCL) deficiency leads to canine stifle (knee) instability. Surgical intervention is often used to stabilize the deficient stifle, but choice of surgical stabilization technique remains debated. Biomechanical evidence that one technique demonstrates superiority is lacking. A 3D computer model of canine gait can aid in comparing the biomechanical outcome of surgical stabilization techniques to further our understanding of the effects of each stabilization technique on the canine stifle joint. We previously developed an anatomically accurate canine hind limb computer model of a healthy Golden Retriever to simulate the stance phase of walking. After CT scanning the dog’s hind limb to allow for accurate model development, we experimentally collected motion capture data and force platform data during walking. Combined with a 3D reconstruction of the hind limb from the CT scan, we used walking data as input to our computer model and simulated the stance phase of walking for this dog having a CrCL-intact stifle. Next we removed (suppressed) the CrCL from modeled stifle. To biomechanically characterize the differences between the CrCL-intact and CrCL-deficient stifle, we determined stifle ligament loading and stability of the stifle joint described as translation and rotation of the tibia, and forces between the femur and menisci. The findings from this effort were reported in a scientific journal.

In our current study, we investigated four common CrCL-deficient stifle surgical stabilization techniques. We implemented the tibial plateau leveling osteotomy (TPLO), tibial tuberosity advancement (TTA), lateral femorotibial suture (LFTS) and TightRope (TR) techniques in our computer simulation model working closely with a veterinary orthopedic surgeon. Caudal cruciate ligament, lateral collateral ligament, and medial collateral ligament loads, translation and rotation of the tibia, and compressive forces between the femur and menisci were compared to the CrCL-intact stifle to determine which stabilization technique(s) most closely returned the CrCL-deficient stifle to normal. Our computer model simulations will provide biomechanical evidence of the efficacy of each stifle stabilization technique.

Tibial Plateau Leveling Osteotomy

Tibial plateau leveling osteotomy modifies the slope of the tibia by cutting the tibia with a surgical saw and rotating the portion of the tibia that interacts with the femur to alter the interaction between the tibia and femur. This technique was represented in our hind limb computer simulation model. Additionally, the extent of tibia fragment rotation, fragment tilt, and fragment cut radius used during surgery were incrementally altered to study the resulting ligament loads and residual tibial movement during walking and characterize the degree of stifle stabilization.

Tibial Tuberosity Advancement

Tibial tuberosity advancement also cuts a portion of the tibia using a surgical saw. In this surgical procedure, the anterior (front) portion of the tibia near the stifle is cut and repositioned further forward. This repositioning changes how the thigh muscles apply force to the stifle. This technique was also represented in the hind limb computer model using two surgical planning methods and resulting ligament loads and residual tibial movement were evaluated during walking.

Extra-capsular Stabilization

Lateral femorotibial suture and TightRope techniques are two common extra-capsular (i.e., outside the joint capsule) techniques that provide stifle stability using sutures that stretch across the stifle joint. These sutures help prevent excessive movement of the stifle. These techniques were implemented in the hind limb computer model using elements that restrain stifle movement. The suture elements wrapped around bony geometry to replicate surgical procedures, and material properties were assigned to match the sutures used during surgery. Resulting ligament loads and residual tibial movement were evaluated during walking. Additionally, the clinical extra-capsular suture material properties (stiffness and tautness) were incrementally altered to study the resulting ligament loads and residual tibial movement during walking and characterize the degree of stifle stabilization as these parameters were varied.

Summary and On-Going Efforts

We are currently analyzing computer model simulation results for each surgical stabilization technique, but we have published findings related to implementation of the TPLO in a veterinary journal. In general, our findings indicate the CrCL-deficient stifle joint was more stable following each technique, but each technique affected the stifle joint somewhat differently. Additionally, we found that TPLO fragment rotation angle and fragment tilt greatly affected stifle biomechanics while TPLO cut radius had little effect on stifle biomechanics. Suture stiffness and pre-tension had less effect on stifle biomechanics compared to TPLO fragment rotation angle and fragment tilt. Body mass had greater effect on stifle biomechanics following TPLO and TTA compared to extracapsular stabilization. In future work we will investigate canine anatomical characteristics for each technique to determine their effects on stifle stability.