

Biomechanical Studies of the Canine Stifle Joint

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The biomechanics of the canine stifle joint can be done using several strategies, including passive physical measurements (goniometer, torsionmeter or other device), *in vivo* measurements (strain gauges, electromyography), *in vivo* imaging (fluoroscopy, kinetic or kinematic analysis), *in vitro* (cadaveric) testing, testing of limb replicas, and computer modeling. These testing methods vary greatly in complexity and cost and each has distinct advantages, drawbacks, and limitations. The purpose of this presentation is to review the published biomechanical studies of the canine stifle joint and comment on future research needs, as they relate to cranial cruciate ligament (CrCL) disease in dogs. The references listed are not an exhaustive list of all references pertaining to canine stifle joint. Rather, these references are representative of the spectrum of evaluation methods used to investigate the biomechanics of the canine stifle joint.

Assessment methods

A search of the terms “stifle” OR “knee” AND “biomechanics” AND “dogs” at PubMed yielded 54 references. These references cover *in vivo* and *in vitro* studies of the mechanics of the canine stifle joint.

***In vivo* studies** include passive physical measurements assessing the motion or stability of the canine stifle joint subjectively or objectively, using a goniometer, torsionmeter or other device. Surprisingly few studies have investigated the motion of CrCL-deficient stifle joints in dogs. One study evaluated the detection of cranial drawer in CrCL-deficient stifle joints.¹ In that study, cranial drawer was more likely to be detected when dogs were anesthetized than when dogs were awake. *In vivo* measurements have been collected using electromyography or strain gauges. A delay in hamstring activation in dogs with CrCL-deficient stifle joints was documented using surface electromyography.² This process is non-invasive. *In vivo* strain in the dog’s stifle ligaments has been reported.^{3,4} However, this process is more invasive: it requires the surgical implantation of strain gauges.

In vivo imaging has been used to assess the dog stifle joint. The shape of the femur and tibia, as seen on radiographs, have been evaluated in normal dogs⁵⁻⁷ and in dogs with CrCL rupture.^{8,9} Standing tibial plateau angle before and after corrective osteotomy (TPLO) has been assessed using radiographs.¹⁰ Non-weight bearing tibial translation resulting from a load delivered by a custom device has been assessed using *in vivo* radiography.¹¹ *In vivo* two-dimensional (uniplanar sagittal) fluoroscopy has been used to assess tibio-femoral subluxation after CrCL rupture and after surgical stabilization using one of four methods.¹² Computed tomography has also been used to assess the shape of the canine femur or tibia *in vivo*.¹³

Kinetic analysis using a force plate or pressure sensitive walkway has been used to assess dogs at risk of CrCL injury,^{14,15} dogs with CrCL injury or surgical CrCL transection or radiofrequency energy application,¹⁶⁻²⁰ and dogs after surgical stabilization of the stifle joint.^{18,21,22} Kinematic gait analysis has been used to assess the stifle joint of normal dogs performing activities of daily living.²³ Gait analysis has also been used to assess dogs at risk of CrCL injury, dogs with CrCL injury,^{24,25} and dogs that underwent surgical stabilization of CrCL-deficient stifle joints by use of extracapsular stabilization,²⁶ TPLO,¹⁸ or TTA.²⁷

In vitro studies have been used to evaluate the biomechanics of the canine stifle joint. Conventional radiographs of cadavers have been used to assess the shape of the tibia²⁸ and the mechanical axis of the pelvic limb.²⁹ The length of the CrCL in dogs with and without rCrCL rupture has also been evaluated using radiography.³⁰ Radiostereometry has been used to assess cadaver limbs placed in a simulated weight bearing stance. The limbs were measured before CrCL damage and after TPLO.^{31,32} Three-dimensional kinematic analysis of the stifle joint has been used in cadaveric limbs to assess the impact of extracapsular stabilization and TPLO.³³ Magnetic resonance imaging (MRI) has also been used to assess sagittal tibio-femoral subluxation (cranial drawer / tibial thrust) in cadaveric dog limbs.³⁴

In vitro testing of cadaveric limbs by use of a materials testing machine is routinely performed to evaluate the impact of CrCL transection³⁵ and the impact of specific surgical procedures, including extracapsular stabilization,^{36,37} meniscal alterations or repair,³⁸⁻⁴² or corrective osteotomies of the tibia.^{30,40,43-49} Pretensioning of the quadriceps has been shown to influence sagittal tibio-femoral subluxation during testing.⁵⁰ Robotic simulation of motion of the canine stifle has been used to assess tibio-femoral subluxation at various stifle joint angles.⁵¹

Polymer replicas have been used to compare the geometry or mechanical properties of the canine tibia after corrective osteotomy.^{52,53} Replicas of the dog pelvic limb have been developed to teach palpation of the stifle joint.⁵⁴

Mathematical or computer modeling has been used to develop models of the canine pelvic limb.^{55,56} One model was used to assess the impact of changing tibial plateau slope or condylar size, the impact of TPLO, and the impact of TTA on stifle biomechanics.⁵⁷⁻⁵⁹

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