Influence of Tarsal Joint Flexion on Cranial Tibial Translation in Cranial Cruciate Ligament-Intact and Deficient Canine Stifles

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Introduction

Rupture of the cranial cruciate ligament (CCL) is one of the most common causes of pelvic limb lameness in the dog. Risk factors associated with CCL rupture are myriad and include breed, body weight, sex, stifle conformation, ligament metabolism, and local immune-mediated inflammation. Although rupture of the CCL may sometimes occur due to trauma, the vast majority of cases involve a gradual progression of adaptive and degenerative changes caused by repetitive microinjury that, over time, promote atraumatic ligament failure.

Current theories on CCL injury etiopathogenesis focus on local stifle geometry without consideration for whole limb biomechanics. Recent studies, however, have demonstrated the important role extra-articular structures, such as the hamstrings and quadriceps muscle groups, play in stabilizing the stifle. Yet little research has been performed to date regarding the biomechanical influence that the tarsus, which is linked to the stifle by the gastrocnemius muscle-tendon unit, exerts on the CCL. Though the tarsus’ role in generating cranial tibial thrust is well documented clinically, as demonstrated via the commonly utilized tibial compression test (Figure 1), the tarsal and stifle joint angles at which translation is maximally induced have yet to be elucidated.

Methods and Materials

A repeated measures study design was used to assess the effects of stifle and tarsal joint angles on cranial tibial translation both before and after CCL transection of the stifle in 10 canine cadavers.

- The left limb of each cadaver was mounted to a servo-hydraulic loading system, with the hemi-pelvis and femur fixed in a mid-stance position in order to retain passive components of the quadiceps and hamstring forces. The foot was encased in polymethylmethacrylate (PMMA) distal to the tarsal joint and the foot fixed rigidly to a loading platform (Figure 2).
- The stifle angle was set in 3 different flexion angles (80, 100, and 120°). At each stifle angle, the tarsal angle was then set in 3 different flexion angles (90, 110, and 130°). At each combination of stifle and tarsal angles, the limb was loaded equivalent to the mid-stance of a walk (20% BW).
- Lateralomedial radiographs taken before and after limb loading allowed for assessment of cranial tibial translation and CCL length by measuring the distance between small radiopaque markers (BBs) inserted into the bone at the origin and insertion of the CCL (Figure 3).
- The CCL of each limb was then transected and the protocol repeated.
- The effect of CCL status (intact or transected), stifle angle and tarsal angle on cranial tibial translation (CCL length) was assessed using a mixed effects analysis of variance.

Preliminary Results

CCL-Intact State CCL-Transected State

Figure 2. Lateral view of the left pelvic limb of a canine cadaver mounted to the mechanical testing system. Painted dots were utilized to set joints at specific flexion angles.

Figure 3. Example lateral radiographic views of the left stiffe, tibia, and tarsus of a canine cadaver with a physiologic load applied. A line is drawn connecting radiopaque BBs inserted at the origin and insertion of the CCL.

A scatter plot highlights the relation of CCL length as a function of tarsal angle and the difference between CCL-intact and CCL-transected conditions.

- Tarsal angle has no statistically significant effect on CCL origin and insertion distance in the CCL-intact state.
- However, in the CCL-transected state CCL origin and insertion distance increases as tarsal angle decreases with flexion.

Figure 4. A scatter plot highlights the relation of CCL length as a function of tarsal angle and the difference between CCL-intact and CCL-transected conditions.

- The left limb of each cadaver was mounted to a servo-hydraulic loading system, with the hemi-pelvis and femur fixed in a mid-stance position in order to retain passive components of the quadiceps and hamstring forces. The foot was encased in polymethylmethacrylate (PMMA) distal to the tarsal joint and the foot fixed rigidly to a loading platform (Figure 2).
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- The CCL of each limb was then transected and the protocol repeated.
- The effect of CCL status (intact or transected), stifle angle and tarsal angle on cranial tibial translation (CCL length) was assessed using a mixed effects analysis of variance.

Preliminary Results

Preliminary data support the hypothesis that increased tarsal flexion induces greater cranial tibial translation in CCL-deficient versus CCL-intact canine stifles. Further, this difference is statistically significant only at tarsal flexion angles of 90° when the stiffe is in extension at angles of 100° or 120°. Because the gastrocnemius muscle-tendon unit would be stretched and under greatest tension at these angles, the results support the role of tension in the gastrocnemius muscle-tendon unit in inducing cranial tibial translation.

These results are consistent with clinical observations that dogs with CCL injuries keep their stifles at more acute flexion angles compared to CCL-intact dogs. Maintaining stiffe flexion may therefore be a strategy utilized by dogs with CCL injuries to prevent or limit cranial tibial thrust.

Future applications of this research include the development of orthotic devices for the treatment of CCL injury or prevention (Figure 6). Based on our data, orthoses designed to restrict hock flexion angle may better inhibit cranial tibial translation in CCL-deficient dogs, as well as reduce strain in the CCL and prevent the repetitive microinjury that progresses to ligament rupture in susceptible individuals.

Discussion

Preliminary data support the hypothesis that increased tarsal flexion induces greater cranial tibial translation in CCL-deficient versus CCL-intact canine stifles. Further, this difference is statistically significant only at tarsal flexion angles of 90° when the stiffe is in extension at angles of 100° or 120°. Because the gastrocnemius muscle-tendon unit would be stretched and under greatest tension at these angles, the results support the role of tension in the gastrocnemius muscle-tendon unit in inducing cranial tibial translation.

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Hypothesis

Cranial cruciate ligament-deficient canine stifles exhibit greater cranial tibial translation compared to cranial cruciate ligament-intact stifles as tarsal flexion increases.

Objective

This project aims to determine the effect of tarsal and stiffe joint angles on cranial tibial translation in CCL-deficient and CCL-intact canine cadavers.

Discussion

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References


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Figures 1, 2, 3, 4, 5, 6