Introduction: Dynamic knee instability due to ligament deficiency is a significant clinical problem that has been associated with a high incidence of development of secondary osteoarthritis. The combined role of biological and mechanical factors in the pathogenesis of joint degeneration are not well understood, thus hindering our ability to optimize joint reconstructive surgery aimed at restoring joint integrity.

The ovine stifle joint is a promising in-vivo model for the investigation of joint degeneration and reconstructive surgery. The crucial first step in the development of this orthopaedic model is a detailed and accurate description of joint kinematics in both the intact and ligament deficient joint. This study tracked the in-vivo kinematics of the ovine stifle joint over 20 weeks following collateral ligament transection, and compared these kinematics to those measured in the intact joint. We hypothesized that ligament transection would alter in vivo joint kinematics, and that gross degenerative changes would be evident at 20wks after ligament transection.

Methods: Five skeletally mature trained Suffolk sheep were studied during locomotion on a standard treadmill: level walking at 2.0mph, incline walking at 2.0mph and level running at 3.5mph. The in vivo kinematics were measured in the intact joint, and at 2, 4, 8, 12, 16, and 20 wks following combined transection of the anterior cruciate and medial collateral ligaments. An implantable bone marker system was used to define the 3D position of the tibia and femur during the in vivo motion. Immediately prior to kinematic testing, these markers were surgically inserted into previously implanted bone plates. Bone marker positioning is repeatable to within 0.1mm. Anesthetic was performed using Xylazine (0.14mg/kg), and then reversed following implantation using Yohimbine (0.2mg/kg). Local analgesic (0.2% Lidocaine) was infused subcutaneously in the area of the incision. All animal surgeries and testing were approved and are in compliance with the Canadian Council of Animal Care guidelines.

The 3D spatial positions of the markers during gait were recorded via a high speed (120Hz) video based motion analysis system (Expert Vision, Motion Analysis Corporation, Santa Rosa, CA) utilizing four Falcon hi-res. cameras. Following calibration, the demonstrated accuracy of the spatial reconstruction of the marker positions was 0.15mm. Following euthanasia, the tibia and femur were dissected and bone marker positions were precisely digitized (+/-0.05mm) relative to anatomically based coordinate systems embedded in each bone (Faro Technologies, FL. USA). The 3D marker coordinates were tracked and smoothed (3rd order spline; cutoff 6Hz for level and incline walking, and 12Hz for running), and then normalized to percentages of the gait cycle between successive hoofstrikes. Joint angles and translational positions were calculated using a joint coordinate system. The origins of the tibial and femoral coordinate systems were located at the insertions of the anteromedial band of the ACL into the tibia and femur respectively. For each specimen, the in vivo kinematics of the transected joint at each time point were compared with those of the intact condition, with significance of changes in joint motion assessed using a 2-tailed students t-test (p<0.05).

The tibiofemoral and patellofemoral joints were examined and graded for cartilage degeneration and osteophyte formation. Grades for each ligament deficient joint were compared to its contralateral joint using a nonparametric sign test (p<0.05).

Results: The in vivo kinematics were quantified over the 20 weeks following ligament transection. Immediately following transection (2wks) statistically significant changes in all joint motions were consistently observed for all five animals. In the short term (8wks), all specimens demonstrated increased joint flexion throughout the gait cycle. By 20 wks this flexion angle was restored to within the normal range with small deviations persisting during the swing phase. Although this primary knee motion was restored, significant alterations in coupled joint angles persisted out to 20wks. Ligament transection also resulted in significant tibial shifts in all three directions. The shift in the anterior and superior directions was maintained out to 20wks.

Discussion: Ligament transection consistently produced significant changes in the in-vivo kinematics of the ovine stifle joint for all specimens. Recovery of normal joint flexion was observed over time, however the changes in the coupled joint angles and translations persisted at 20 wks following transection. After 20 weeks of ligament deficiency, severe cartilage degeneration was observed in both the tibiofemoral and patellofemoral joints. This study confirms that the ovine stifle joint is a promising new model in which to study the relationship between dynamic instability and degenerative joint changes.


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Figure 1: Tibiofemoral position in a representative intact and ACL/MCL transected stifle joint during walking (shaded region is ± 2 sd of intact joint).

Figure 2: Articular cartilage of patella of a representative specimen at 20 wks
A) intact contralateral joint  B) ligament deficient joint