# Role of Ligamentous Restraints During Anterior-Posterior Drawer Tests of the Murine Knee

Snehal S. Shetye[1], John S. Bova[1], Andrew F. Kuntz[1], Miltiadis H. Zgonis[1], David L. Butler[2], Nathaniel A. Dyment[1]
[1]McKay Orthopaedic Research Laboratory, Philadelphia, PA, [2]University of Cincinnati, Cincinnati, OH

## Introduction

- Murine models of altered knee loading are frequently employed to study the pathogenesis of osteoarthritis [1].
- They have recently also been used to investigate tendon-bone attachments within the ensuing bone tunnels [2].
- Human cadaveric and large animal model demonstrated that the anterior cruciate (ACL) and posterior cruciate (PCL) ligaments are the primary restraints to anterior or posterior tibial translation, respectively.
- However, the contributions of the cruciate and collateral ligaments to anterior and posterior drawer stability have not been quantified.
- Therefore, the objective of the study was to investigate the role of ligamentous restraints in the murine knee during anterior-posterior loading.
- We hypothesized that the ACL and PCL will be the primary restraints to anterior and posterior drawer, respectively.
- We also hypothesized that the MCL will be the secondary restraint in anterior drawer and the LCL will be the secondary restraint in posterior drawer.

## Materials and Methods

- All animals and procedures were approved by UPenn's IACUC.
- CD1 mice (4 male, 3 female, n=7) 16 weeks of age were assessed for anterior-posterior drawer stability in a custom fixture recently described by our group (Fig. 1).
- Hindlimbs (6 right, 1 left) were isolated, all extraneous soft tissue removed, and all capsule ligaments, including the cruciates and collaterals, along with the menisci left intact.
- The knee was set up at 90 degrees of flexion for all tests.

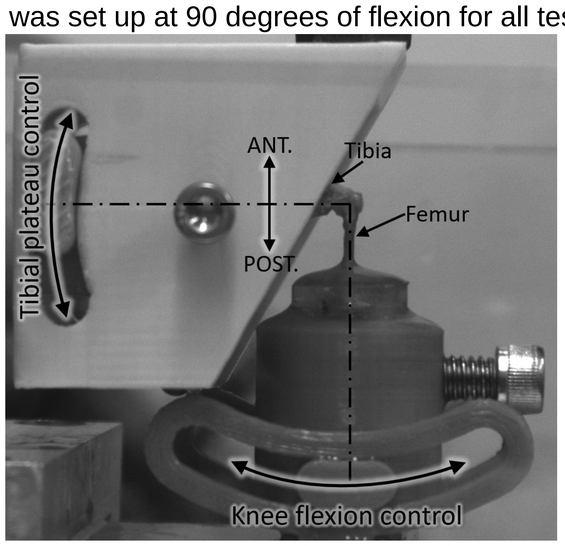


**Figure 1:** Instron setup to quantify the statibity of the murine knee in anterior and posterior drawer at 90 degrees of knee flexion. This setup was used to quantify the contributions of the cruciate and collateral ligaments toward anterior and posterior drawer.

- The baseline knee joint loads were evaluated for anterior and posterior stability by cyclic loading under displacement control between ±0.3mm for 5 cycles and the 5th cycle was used to quantify stability for all cases.
- Following this, a 27G needle was used to carefully cut the ACL with an anterior approach and the stability test was repeated at ±0.3mm to quantify ACL contribution
- Then the PCL was carefully transected, and the stability test repeated to quantify PCL contribution.
- To quantify MCL and LCL contributions, drawer test was modified to reach ±1.0mm, as described previously in cadavers [3].

## Results

**Primary Restraints** (Table 1)

- The peak anterior restraining force for the intact knee was 1.24±0.17N at 0.3mm of displacement.
- The peak posterior restraining force for the intact knee was 0.82±0.1N at -0.3mm of displacement.
- ACL contributed to 95.01±3.30% of the restraining force in the anterior drawer
- Interestingly, ACL transection also reduced the peak posterior load by 14.0±9.8%.
- PCL contributed 89.5±6.9% of the peak restraining force in the posterior drawer.

**Secondary Restraints**

- After ACL and PCL transections, the peak restraining forces at ±1.0mm of displacements were found to be 0.32±0.19N and -0.52±0.31 in the anterior and posterior directions, respectively.
- Transection of the MCL only influenced the anterior peak force whereby the force dropped by 86.13±8.3%.
- Transection of the LCL only influenced the posterior peak force whereby the force dropped by 85.12±11.89%.

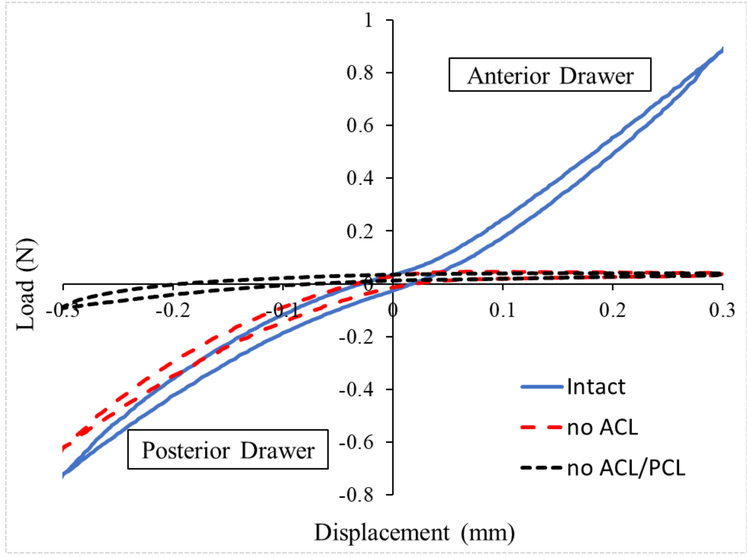


**Figure 2.** Representative sample plots that show the effect of transection the ACL and PCL on anterior andposterior drawer loads.

**Table 1:** *ACL and PCL force contributions at 0.3mm drawer. Values are reported as Mean (S.D.).*

| Anterior Drawer | | | Posterior Drawer | | | |
|---|---|---|---|---|---|---|
| Intact Force (N) | Anterior Cruciate Force (N) | ACL Contribution (%) | Intact Force (N) | Posterior Cruciate Force (N) | PCL Contribution (%) | ACL Contribution (%) |
| 1.24(0.17) | 1.18(0.18) | 95.01(3.3) | -0.82(0.1) | -0.58(0.09) | 86.13(8.3) | 14.0(9.83) |

## Discussion

- To better understand molecular and genetic mechanisms that regulate osteoarthritis pathogenesis in murine models, it is crucial to understand the mechanical stability of the knee joint before and after destabilization and how the joint adapts with time post-injury.
- The data presented here provide a baseline for studies creating these OA models by transecting supporting ligamentous structure involved in knee stability.
- We found that, similar to the human knee, the ACL and PCL are the primary structures providing anterior and posterior stability, respectively, in the murine knee.
- Interestingly, we did see an approximately 14% contribution by the ACL to posterior stability, which has not been observed in humans.
- Further, at a knee flexion angle of 90 degrees, and in absence of the ACL and PCL, the MCL provides most of the stability in the anterior direction and the LCL provides most of the stability in the posterior direction.
- Our data suggest that the menisci did not play a major role in anterior-posterior knee stability since the peak load were close to 0N after transection of these ligaments. This agrees with a previous study that followed a displacement control protocol as presented here [3].
- **This methodology can be applied to murine knee destabilization PTOA models over the time course of OA progression, correlating with biological changes to the joint. In addition, methods to restabilize the knee [2] to attenuate OA progression can be verified.**
- Further studies will investigate the influence of knee flexion angle, compression joint load, and the menisci to anterior-posterior stability of the murine knee.

## References & Acknowledgments

[1] Blaker CL et al., J Orthop Res, 2017 (35)424–439 [2] Kamalitdinov TB et al., J Orthop Res, 2019 [3] Butler DL et al., JBJS, 1980 (62)259-270

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