The role of the anteromedial, intermediate and posterolateral bundles of the anterior cruciate ligament in goats

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Introduction: The goat knee is a widely used animal model for basic research on the anterior cruciate ligament (ACL). Detailed biomechanical investigations were carried out in goats with the ACL seen as a single bundle [Oster 1992], however it has now been reported, the presence of several bundles in the goat ACL. During anatomical dissection an anteromedial (AM), intermediate (IM) and posterolateral (PL) bundle can be seen. Therefore, the aim of this study is to describe the biomechanical function of the different bundles of the goat ACL and to evaluate the use as an animal model for double bundle surgery.

Materials and Methods: Fourteen knees of seven adult goats were used for biomechanical testing. Animals with congenital anomaly or arthritis were excluded. A CASPAR Stäubli RX90 robot (Orto MAQUET, Germany) was used to manipulate the joint. A universal force/moment sensor (UFS-Model 4015; JR3 Inc. Woodland, CA) was used to measure the forces and moments for 6-degrees-of-freedom. Anterior tibial translation (ATT) [mm] and in situ forces [N] in response to anterior loading of 50N at full extension, 30°, and 60° of flexion were recorded. Full extension was about 30° between the anatomical axis of the tibia and femur. In order to observe the influence of the three anatomical bundles of the goat ACL on biomechanical stability during ATT, the three bundles of the ACL were cut in sequential order before re-testing the same criteria. After testing the intact knee, the intermediate bundle of all knees was transected. Next, either the AM bundle (group I, n=7) or the PL bundle (group II, n=7) was transected. In the final step, the remaining fibers of the ACL were transected. After each cut, the ATT and in situ forces were measured for the three flexion angles.

Statistical analysis for differences in ATT and in situ forces was done using repeated measurements 2-way ANOVA with Bonferroni post-test to compare differences between the various knee conditions (intact, IM-deficient, IM-/AM-deficient, IM-/PL-deficient and rupture) at the three flexion angles (0°, 30°, 60°). Statistical significance was assumed to be p<0.05. All statistical calculations were performed using Prism software (GraphPad Software; San Diego, CA).

Results: Minimal increase in ATT at all tested flexion angles was observed with IM-bundle cut (p>0.05). In group I (IM-/AM-deficient bundles) the ATT increased considerably from 0° to 60° flexion (p<0.05). In contrast, the ATT of group II (IM-/PL-deficient) increased slightly at 0° of flexion and decreased to normal values at 60°. When all bundles were cut, a huge anterior translation took place (p<0.001, see figure 1).

When calculating the in situ forces for 0° degree of flexion, it was found that both the AM and the PL bundles share most of the load with minimal contribution of the IM bundle. At higher flexion angles (30° and 60°), most of the load is transmitted through the AM bundle.

Discussion: The aim of this study was to characterize the biomechanical functions of the bundles within the goat ACL in order to serve as an animal model for basic research on double bundle ACL reconstruction. Three bundles were clearly evident in every specimen analyzed, with the IM-bundle being the smallest bundle. This is confirmed biomechanically, where the IM-bundle plays only an inferior role compared to AM- and PL-bundles. The PL bundle mainly stabilizes the knee in extension, with less function during flexion. By contrast, the AM bundle is more important in flexion, where it takes almost all load during ATT. These results are comparable to the human ACL.

Based on the biomechanical results, the big AM- and PL-bundles have comparable function to the human knee. This model can be used in basic research to approach some topics like tendon-to-bone healing or graft-tunnel-motion in single vs. double bundle ACL reconstructions.