Introduction

Various anatomical and biomechanical studies indicated that the posterior cruciate ligament (PCL) has two bundles which have different functions. The anterolateral bundle (ALB) is taut in knee flexion and the posteromedial bundle (PMB) is taut in knee extension (1). Recently, some biomechanical studies of double-bundle PCL reconstruction have reported its superiority compared to the conventional single-bundle PCL reconstruction which attached importance to the ALB function (2). On the other hand, some studies reported that single-bundle PCL reconstruction with the innovation of graft fixation or enlargement of the graft size was by no means inferior compared to double-bundle PCL reconstruction (3). However, the majority of previous biomechanical studies were on the non-anatomical double-bundle PCL reconstruction with two femoral tunnels and a single tibial tunnel, therefore the function of the anatomical double-bundle PCL reconstruction (ADBR) with two femoral tunnels and two tibial tunnels in response to external loads remains unclear. The purpose of this study was to evaluate the effect of anatomical double-bundle PCL reconstruction for restraining the posterior tibial translation (PTT) under the posterior tibial load and the rotational tibial torque compared to single-bundle PCL reconstructions which only duplicated the ALB or the PMB.

Materials and Methods

Eight fresh-frozen human amputated knees from patients with an average age of 65.2±5.2 years old were used for this study. Informed consent was obtained from the patients and ethical approval of this study was obtained from the Ethics Committee of our institute. The specimens were mounted on a materials testing machine (Instron 4465; Instron Corp, Canton, MA) with custom-made apparatus without restricting five degrees of freedom except for varus-valgus rotation. The neutral anterior-posterior position of the intact knee was determined and used as a reference position throughout the testing. It was defined as the position midway between the two zero points of the load-displacement hysteresis loop by imposing a ±50-N drawer cycle at 0°, 30°, 60° and 90° of knee flexion. The following external loading conditions were applied to the intact knee: 1)100-N posterior tibial load, 2) 100-N posterior tibial load and 5-Nm external tibial torque at 0°, 30°, 60° and 90° of knee flexion. The PTT in response to each loading condition was recorded. Next, the PCL was transected to simulate an isolated PCL tear. The same loading conditions were also applied to the PCL deficient knee and the PTT were recorded. Three PCL reconstructions were performed in the same knee. The ALB reconstruction (ALR) which reproduced the conventional single-bundle PCL reconstruction, the PMB reconstruction (PMR) and ADBR were performed in randomized order. In this study, two femoral tunnels and two tibial tunnels were created as based on the PCL anatomical footprints. Because the ALB was larger than the PMB, a 9-mm looped semitendinosus tendon and gracilis tendon graft was used to reconstruct the ALB and a 7-mm looped semitendinosus tendon was used to replace the PMB of the PCL. Both of the tendon grafts were tensioned at 88-N as preconditioning. Fixation was achieved on the femoral side with a titanium disc and on the tibial side with a titanium soft tissue screw system (Double Spike Plate) allowing decision of the fixation tensile force (4). The ALB was fixed onto the tibia with the knee at 90° of flexion while a 134-N anterior tibial load was applied to reduce posterior subluxation, while the PMB was fixed onto the tibia with the knee at extension at 134-N anterior tibial load. Both of the tendon grafts were provided with initial graft tension at 40-N. The PTT of PCL-reconstructed knees was determined in the same manner as for the intact knee. The data obtained included the PTT of the intact, PCL-deficient and PCL-reconstructed knees. Multiple comparison procedures with the Tukey HSD test for post hoc test was used to compare these data. The level of significance was set at p<0.05.

Results

In response to 100-N posterior tibial load, the PTT increased significantly following PCL transection when compared to intact knees. With PCL reconstruction, the PTT was decreased from that for PCL-deficient knees. There were no significant differences between the ADBR and intact knee at all knee flexion angles. At 0° and 30° of knee flexion, there also was no difference between the ADBR and the PMR. However, significant differences were detected at 60° and 90° of knee flexion, in which the PTT of the PMR was higher than that of both the ADBR and the ALR (Figure 1). In response to 100-N posterior tibial load and 5-Nm external tibial torque, the PTT also increased significantly by more than 2-fold following PCL transection when compared to intact. Again, PTT was decreased from that for PCL-deficient knees following reconstruction. There were no significant differences between the ADBR and intact knees at all knee flexion angles. When comparing the PTT between 3 reconstructions, there were no differences except that the PTT of the ALR was significantly larger than that of the ADBR at 0° of knee flexion (Figure 2).

Discussion

This study demonstrated that ADBR was more effective than single-bundle PCL reconstruction to restrain the PTT in response to both 1) posterior tibial load, and 2) posterior tibial load and external tibial torque and also restored the PTT to the level of the intact knee at all flexion angles of the knee. Although previous studies showed that the PMB plays a minor role in restraining posterior laxity (5), this study demonstrated that the PMB reconstruction restored the PTT when the knee is near extension in response to posterior tibial load, whereas, the PMB reconstruction could not restrain the PTT at high flexion angles because the PMB is taut in knee extension. Furthermore, in response to posterior tibial load and external tibial torque, PMB reconstruction restored the PTT at all flexion angles, suggesting that the PMB contributes to restraining external rotational instability. Therefore, to restore the complex function of the PCL, not only the ALB but the PMB of the PCL may need to be replicated during PCL reconstruction.

References