Knee kinematics and kinetics at the axial plane after ACL Reconstruction during a High Demand Activity: Single Bundle vs. Anatomical Double Bundle

Introduction:
The native anterior cruciate ligament (ACL) is composed of two distinct bundles, the anteromedial (AM) bundle and the posterolateral (PL) bundle. Traditional single-bundle (SB) ACL reconstructions have focused on reproduction of the AM bundle. Although most patients can return to their pre-injury activity level after SB reconstruction, some patients still feel instability even though their reconstructed knee is stable as measured by the Lachman test and the KT-1000 arthrometer. Recently, in-vivo studies revealed that SB reconstruction techniques were insufficient to control rotational loads that mimic the pivot-shift test and recommended reproduction of both the AM and PL bundles [1]. Clinical outcomes between double-bundle (DB) and SB reconstruction methods have been controversial; whereas some studies have reported better results with the DB technique [2, 3], others have reported similar results [4]. Thus, it is necessary to investigate further the rotational stability quantitatively after ACL reconstruction using in-vivo methodology. Therefore, the purpose of our study was to compare the rotational stability after an anatomical DB ACL reconstruction with that after a SB ACL reconstruction during a high demand activity.

Methods:
Twenty-eight patients were divided into two groups: DB group (7 female and 7 male patients; mean age: 21.4 yr; mean weight: 59.0 kg; mean height 166.4 cm) and SB group (7 female and 7 male patients; mean age: 22.6 yr; mean weight: 57.2 kg; mean height 164.9 cm). The time interval between the operation and data collection was more than 6 months and less than 12 months (mean: 9 months.). At the time of data collection, all patients had resumed their activities of daily living and returned to their previous level of sports activities. The study design was approved by the institutional review board of the University of Tsukuba, Japan, and all subjects provided written informed consent. Subjects were evaluated during a drop landing and cutting. For the task, subjects stood on one leg and dropped from a 30 cm high platform onto the center area (400x200 mm) of a force plate, which was 30 cm away from the platform. Subjects landed on their ipsilateral leg and pushed off onto the contralateral leg to make a cut at an angle of 45°. Subjects continued for five steps after the cut. Measurements were continued for three successful trials for both the ACL-reconstructed and intact legs.

Kinematic data were collected three-dimensionally by a 9-camera VICON 612 motion analysis system (Oxford Metrics Ltd., Oxford, England) at 250 Hz, and ground reaction forces (GRF) were recorded at 1000Hz using a 600 x 900 mm force plate (Kistler Japan Co., Ltd., Tokyo, Japan). For each subject, 31 reflective markers of 9 mm diameter were secured to the lower limb. The markers were used to implement the Point Cluster Technique (PCT) as described by Andriacchi et al. [5]. Knee kinematics and kinetics were calculated using the joint coordinate system proposed by Grood and Suntay [6]. Using the PCT for each trial, the angular displacements of external-internal tibial rotation were calculated. Knee joint moments at the axial plane were obtained by solving the Newton-Euler equation using an inverse dynamic technique. The reference position for these measurements was obtained during a static trial. The maximum range of tibial rotation and the maximum external rotation-moment from initial foot contact with the force plate until takeoff of the ipsilateral leg was analyzed. The dependent variables were calculated for each trial and then averaged across the three trials. Group means for the dependent variables were calculated for the intact and ACL reconstructed legs. The ratio of the average of the ACL reconstructed leg to that of the intact leg was calculated for the two different operative groups. To compare between the DB reconstruction group and the SB reconstruction group, an unpaired student’s t test was performed on the kinematics data. Significance was set at p < 0.05.

Results:
For the mean maximum range of tibial rotation during the identified evaluation period, no differences could be found in the ratio of the ACL reconstructed leg to the intact leg between the DB group (0.89±0.29) and the SB group (0.91±0.24) (Fig. 1). For the mean maximum external rotational-moment, no differences could be found in the ratio of the ACL reconstructed leg to the intact leg between the DB group (1.02±0.39) and the SB group (1.47±0.87) (Fig. 2).

Discussion:
Some in-vivo studies have reported that SB ACL reconstruction, though restoring anteroposterior tibial translation, does not restore tibial rotation to previous physical levels during a high demand activity [7]. Although these studies showed that SB reconstruction did not restore normal knee kinematics during a high demand activity, the studies did not evaluate an anatomical DB reconstruction technique. The purpose of this study was to compare the kinematics and kinetics, especially tibial rotation and knee joint moment at the axial plane, of an anatomical DB reconstruction with a SB reconstruction by hamstring grafts during a high demand activity. Based on the results of previous in-vitro studies, we hypothesized that rotational stability in the anatomical DB reconstructed knee would be restored more normally than the SB reconstructed knee when compared with their intact contralateral knee. But the results of this study could not prove our hypothesis. The main limitation of this study is the number of subjects participating was small. Although the effects of age, sex, graft type, meniscal injury, surgery/testing timing, or functional scoring were minimal, the sample size and statistical power were insufficient. As this study is ongoing, it may be possible to investigate the influence of these factors as data from more subjects becomes available. In conclusion, we found that anatomical double-bundle ACL reconstruction did not restore rotational stability more than single-bundle ACL reconstruction during this high demand activity.

References: