Biomechanical evaluation of anatomic double-bundle anterior cruciate ligament reconstruction using the anatomic ACL guide system: Comparisons among 3 different procedures

Introduction: Single-bundle anterior cruciate ligament (ACL) reconstruction is the standard surgical option to treat ACL-deficient knees. However, biomechanical studies have shown that normal rotational laxity cannot be restored with single-bundle reconstructions [1]. Recently, anatomic reconstruction of the anteromedial (AM) and posterolateral (PL) bundles has been introduced [2]. Most recently, several prospective clinical trials have been conducted to compare the clinical results between anatomic double-bundle and single-bundle procedures [3-5]: their anatomic double-bundle procedures were significantly better than their single-bundle procedures concerning the pivot-shift test and/or the anterior laxity. However, it remains controversial whether the anatomic double-bundle procedure is superior [6,7]. Biomechanical studies have found that the experimental double-bundle procedure in cadaveric knees can achieve better results in both anterior and rotatory laxity than the single-bundle procedure [8,9]. However, it is possible that tunnel positions created with clinical double-bundle procedures in patients are different from those created with experimental double-bundle procedure, because it is not always straightforward to create tunnels using a specific device in the clinical setting. To address this, a biomechanical comparison of the various clinical double-bundle procedures with single-bundle procedures, using cadaveric knees is required. However, such studies have not yet been performed. The aim of this study was to test the hypothesis that using a commercially available aiming device designed for clinical use, significantly better rotational stability can be achieved with double-bundle reconstruction compared to the single-bundle procedure. Noting that clinical studies found that residual rotational instability was reduced if the single-bundle graft was placed laterally in the intercondylar notch, it was also hypothesised that this change would restore normal laxity better than a single-bundle graft placed high in the notch.

Methods: Eight fresh-frozen cadaveric knees were used. The knee was mounted in a 6 degree of freedom rig and laxity testing was performed using: 90° anterior tibial loads, 5-Nm internal and external tibial torques, and simulated pivot-shift test (50N-iliotibial tract loading, 5-Nm valgus moment, and 1-Nm internal tibial torque). Knee kinematics were recorded with an active optical tracking system (Polaris, NDI, Canada) for the intact, ACL-deficient, anatomic double-bundle reconstructions (DB), conventional single-bundle reconstructions (CSB) and laterally placed single-bundle reconstructions (LSB). ACL reconstruction was performed three times in each knee by filling the tunnels with polyester resin using the same hamstring tendon graft. In the DB, the 4 tunnels that passed through the anatomical attachment of the AM and PL bundles on the tibia and the femur, respectively, were created using the anatomic ACL guide system (S&N). In the CSB, the tibial tunnel that passed through the posterior aspect of the normal ACL attachment was created. Then, the femoral tunnel was drilled into the center of the AM bundle attachment. In the LSB, the tibial and the femoral tunnel were created at the center of the normal ACL insertions between AM and PL bundles. The graft was simultaneously fixed at 20° of knee flexion, applying a total initial tension of 60 N, while a 40N posterior tibial load was applied. Each graft was secured with endobuttons (S&N) on the femur and with screws (DSP plate, S&N) on the tibia. The kinematic data were analyzed by using a two-way repeated-measures analysis of variance. Significance was set at p<0.05.

Results: The anterior translation-versus-flexion curves were significantly different among the ACL-deficient, DB, CSB and LSB (p<0.0001) (Fig. 1). The anterior translations in DB, CSB and LSB were significantly less than in the ACL-deficient knee. There were no significant differences among DB, CSB and LSB. Tibial internal rotation increased significantly (p<0.0182) after the ACL was sectioned, from 6° to 110° knee flexion. The internal rotation-versus-flexion curves were significantly different among the ACL-deficient, DB, CSB and LSB (p<0.0001) (Fig. 2). The internal rotational laxities in DB and LSB were significantly less than in CSB (p=0.0375, and p=0.0006, respectively). There were no significant differences between the ACL-deficient and CSB. Transection and the reconstructions of the ACL did not cause significant changes in tibial external rotation laxity. Under the simulated pivot-shift test, tibial anterior translation increased significantly near extension after the ACL was sectioned. The anterior translation-versus-flexion curves were significantly different among the ACL-deficient, DB, CSB and LSB (P<0.0005) (Fig. 3). The anterior translation was significantly less in DB, and LSB than in CSB (P<0.0001, and P<0.0001, respectively).

Discussion: This study showed that internal rotational laxity under tibial torque and anterior translation laxity under pivot-shift loading were significantly less after DB and LSB than after CSB. However, there were no significant differences between the three procedures with anterior translation load, or tibial external rotation torque. In addition, there were no significant differences between DB and LSB with all loading conditions. Although the present study showed promising results of the DB procedure, further clinical studies, including quantitative evaluation of the effects on the rotatory stability and long-term survival of the graft functions, are needed to establish the clinical utility of the DB for the ACL-deficient knee. This study did not find any significant differences between DB and LSB, where the tibial and the femoral tunnel were placed at the center of the anatomical attachment area. This might suggest that there is no justification for using the more complex double-bundle method, and so further understanding of the clinical and biomechanical performance is required.