The Effect of Tunnel Position on In-situ Force Vector Direction in Single Bundle and Double Bundle ACL Reconstruction

INTRODUCTION

Recent studies have examined the magnitude of the in-situ force carried by replacement grafts in ACL reconstruction as well as the in-situ force of the native ACL. The magnitude can offer some insight into the force carrying capabilities of the replacement graft and how it matches up to that of the native ACL. However, to fully restore native ACL functionality, the in-situ force vectors should not only match in magnitude but also in direction. The purpose of this study is to investigate the direction of the in-situ force vectors in four single bundle ACL reconstruction techniques with different tunnel positions and double bundle ACL reconstruction and compare those to that of the native ACL.

METHODS

Sixteen fresh frozen cadaveric knees were used. Eight (n = 8) were used for the following techniques: 1. Anteromedial bundle reconstruction (AM-AM), 2. Posteriorlateral bundle reconstruction (PL-PL), 3. Classical vertical SB reconstruction (PL-HighAM), 4. Double bundle reconstruction (DB). The other eight (n = 8) knees were used for anatomical middle position SB reconstruction (MID-MID). A robotic/universal force-moment sensor (UFS-Model 4015; JR3 Inc., Woodland, CA) testing system was used. The robotic system was capable of controlling the displacement and the force/moment applied to the knee in all 6 DOF based on a mathematical description of knee kinematics and kinetics via a personal computer and a custom MATLAB program with a multitask operating system (Math Works Inc., Natick, MA, USA). The robot arm has repeatability of motion within ± 0.02 mm at each joint. The universal force/moment sensor (UFS) has reliability within ± 0.2 N and ± 0.1 Nm according to the manufacturer.

Each specimen was rigidly secured to the robot via custom Aluminum cylinders and an epoxy compound. An anterior load of 89N was applied (KT) to the intact knee and the anterior tibial translation (ATT) was recorded at 0, 15, 30, 60 and 90 degrees of flexion. The knee was then removed from the robot and the ACL was carefully transected arthroscopically. The knee was then secured back to the robot and the kinematics of the intact state were repeated. An in-situ force vector composed of three dimensional force components in the anterior-posterior, medial-lateral, and superior-inferior directions was then determined. A positive value was used for medial and negative for lateral. A similar protocol was used for each of the five reconstructed techniques to obtain the 3-D force components of the in-situ force vector of the replacement grafts. Once the intact and replacement ACL in-situ force vectors were determined, the 3-D angle between the two vectors, termed here the deviation angle, was determined and illustrated in Figure 1.

RESULTS

The deviation angle data for intact, AM-AM, PL-PL, PL-HighAM, MID-MID and DB reconstructed knees were analyzed by using a two-factor repeated-measure analysis of variance. Statistic analysis for differences in deviation angle was performed using the Friedman test and the Wilcoxon Signed Ranks Test was used for pair-wise analysis. It was assumed that there was statistical significance when p < 0.05 for the Friedman test and p < 0.02 for the Wilcoxon Signed Ranks test (Post-hoc analysis with a modified Bonferroni approach). All statistical data were calculated using a statistical software package (SPSS version 17.0).

DISCUSSION

In the present study, a deviation angle from the intact in-situ force vector was used as a quantitative measure to compare the effectiveness of various ACL reconstruction techniques. PL-HighAM, DB and MID-MID reconstruction have lower deviation angles in all flexion angles than AM-AM and PL-PL reconstructions. It is important to note however, the in-situ force vector has a magnitude and direction and the present study did not take magnitude into account. Also, the present study only determined deviation angles for simulated KT. Although, the ACL’s primary role is to resist ATT, recent studies have shown that the ACL also may provide rotationally stability. In the future it may be of interest to examine the in-situ force vectors for simulated pivot shift and determine which tunnel position compares best with the intact ACL.

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REFERENCES