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Original article

Postoperative outcome is affected by an intraoperative combination of each graft tension change pattern in a double-bundle anterior cruciate ligament reconstruction

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Abstract

Background: The purpose of this study is to evaluate the intraoperative tension change pattern of each anteromedial (AM) graft and posterolateral (PL) graft and to investigate the optimal femoral tunnel position in double bundle (DB) anterior cruciate ligament reconstruction (ACLR) by comparing postoperative outcomes with each combination of graft tension change pattern.
Methods: Eighty-four unilateral primary DB ACLR cases from 2006 to 2008 with a follow-up of 24 months or more were analysed. The tension change pattern of each AM and PL graft after graft fixation was recorded during DB ACLR, and divided into over-the-top (OTT; tension at $0° > 120°$) and reverse OTT (graft tension at $0° < 120°$) pattern. The combinations of these patterns were then categorized into four groups and the postoperative results were analysed. The femoral tunnel position was measured by a modified quadrant method. The relationship between the femoral tunnel position and the tension change pattern of each graft was evaluated.
Results: The cases that presented reverse tension change pattern of native anterior cruciate ligament (ACL) performed most poorly in postoperative knee laxity among the four groups. In this group, the femoral tunnel of the AM bundle was placed significantly higher in flexion.
Conclusion: This study suggests that the least effective method for knee stability recovery is for the ACL to be reconstructed with the reverse tension change to the native ACL. It is necessary to refrain from placing the femoral tunnel for the AM bundle in a high position in knee flexion in DB ACLR.

Keywords: double-bundle anterior cruciate ligament reconstruction; femoral tunnel placement; graft tension change pattern; stability recovery

Introduction

Anatomic double-bundle (DB) anterior cruciate ligament reconstruction (ACLR)[1] attracts attention from ligament surgeons because of the theoretical advantages and the superiority of stability recovery compared with those of single-bundle reconstruction.[2,3] Anatomic DB reconstruction using medial hamstring tendons reportedly reproduces the normal tension change pattern of each anteromedial (AM) bundle and posterolateral (PL) bundle.[4,5]

A relatively high rate of clinical failure of ACLRs has been also reported.[6,7] The cause of failure is multifactorial, such as the amount of preoperative knee laxity, limb malalignment, graft materials, rehabilitation protocols, etc. Additionally, it was reported that 22−80% of reconstruction failures were thought to be due to technical errors, with the most common findings being incorrect tunnel position.[8−10]

Although there is no clear consensus on the knee flexion angle and the force of initial graft tension at graft fixation

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during DB ACLR, it has been reported that femoral tunnel position of the AM bundle and the PL bundle affects reciprocal tension change during knee flexion and extension more significantly than the tibial tunnel position.[11,12] Previous *in vivo* and *in vitro* studies suggest that graft tension and tension change pattern are correlated with the clinical outcome.[13–15] Although there have been a number of articles about ACLR, few reports have analysed the effects of the initial tension change pattern at the graft fixation during surgery on the postoperative outcome. However, controversies still remain regarding the optimal femoral tunnel position and anatomic placement. Detailed analyses are lacking regarding the optimal femoral tunnel placement in a DB ACLR in order to achieve better recovery of knee stability.

The first aim of this study was to compare the initial tension change pattern of the grafts and the femoral tunnel position. The second aim was to compare the combination of the intraoperative tension change pattern of each AM graft and PL graft, and the postoperative clinical results in DB ACLR. The first hypothesis underlying this study was that there were some anatomical rules in each AM and PL femoral tunnel position which lead to the tension change pattern of each graft. The second hypothesis was that there would be some appropriate initial tension change pattern which would give better clinical results. As a final goal, the results will suggest the anatomical concept of femoral tunnel creation for the best clinical outcome in DB ACLR.

Materials and methods

Patients

A cohort study was conducted for patients with anterior cruciate ligament (ACL) injuries who underwent DB ACLR at our institution between January 2006 and December 2008. The inclusion criteria were primary ACLR with an autologous semitendinosus tendon. The exclusion criteria included a history of injury to the ipsilateral knee and a history of ligamentous injury to the contralateral knee. During this period, 116 reconstructive surgeries were performed by a senior surgeon (T.M.) or by fellow doctors with the assistance of the senior surgeon. Out of 116, 84 patients (average age at surgery ± standard deviation: 24.6 ± 9.7 years) with follow-up for at least 24 months after surgery were included in this study. This study was approved by the Ethical Committee of Tokyo Medical and Dental University, and all the patients provided informed written consent.

Operative procedures of a DB ACLR

The anatomic ACLR advocated by Yasuda et al[1] was performed with a transtibial approach using a four-strand semitendinosus tendon. The anatomic bony landmarks of ACL tibial attachment were touched and felt with the tip of the tibial drill guide. Two tibial guide wires were inserted from the AM surface of the tibia at the tibia tubercle level with anatomic landmarks of the anterior wall of the anterior intercondylar notch, medial intercondylar tubercle, ruptured ACL remnant, and posterior cruciate ligament. These guide wires were placed in the remnant tissue with an angle of 65° for the AM bundle and 45° for the PL bundle from the joint line in the frontal view.[16] The femoral drill hole procedure was performed in a figure-four position with arthroscopic observation from the AM portal. The centre of the femoral drill hole for the AM bundle and the PL bundle was aimed at 1:30 and 3:30, respectively, on the intercondylar clock of the left knee in the deeper area of the resident's ridge in knee flexion position.[17] Graft fixation was performed in the same manner as before,[16] except for the initial tension and fixation angle. First, the PL graft was fixed to an anchor staple at 20° of knee flexion. Applied tension to the PL graft was adjusted to be equal per cross sectional area on a basis of 30 N per 6 mm in diameter. Then, the initial tension of the AM graft was determined by probing in order to equalize to the PL graft at 20° of knee flexion. The AM graft was fixed to the anchor staple by a pull-out method. Before passing grafts to the tunnels, two grafts were tensioned by 10 N for more than 20 minutes on the GraftMaster (Smith & Nephew Inc., Andover, MA, USA).

Tension change pattern recording

The tension change pattern was recorded after the AM graft and PL graft were finally fixed. The surgeon felt the graft tension carefully with a standard probe during passive knee motion from full extension to 120° flexion. If the graft tension increased during knee extension with the tension in near full extension greater than that at 120° flexion, it was recorded as an "over-the-top (OTT) pattern". When it was the opposite, with the tension in near full extension less than that at 120° flexion, it was a "reverse OTT pattern". Based on the combination of the tension change pattern of the AM graft and the PL graft, each patient was categorized into four groups (Table 1). All measurements were performed by the same surgeon, and performed three times to minimize the intrarater variability. Accuracy of the manual tension measurements was validated by comparing with the Stress Equalization (SE) Graft Tensioning System (Linvatec, Largo, FL, USA) as a gold standard.[18–21] The grafts were provisionally fixed to the SE Graft Tensioning System (Linvatec) with sutures at the tibial site after the grafts had been passed through tunnels and fixed at the femoral side with the EndoButton CL-BTB (Smith & Nephew Endoscopy; Smith & Nephew Inc.). The SE Graft

Table 1
Patients' grouping.[a]

	Group 1	Group 2	Group 3	Group 4
AM tension change	OTT	OTT	ROTT	ROTT
PL tension change	OTT	ROTT	OTT	ROTT
No. of patients	29	14	19	22

AM = anteromedial; OTT = over-the-top; PL = posterolateral; ROTT = reverse over-the-top.

[a] All patients were categorized into four groups according to the combination of AM and PL graft tension change patterns.