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Original article

Excursion of bone-patella tendon-bone grafts during the flexion–extension movement in anterior cruciate ligament reconstruction: Comparison between isometric and anatomic reconstruction techniques

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Abstract

Background/objective: The purpose of this study was to elucidate the biomechanical differences between anterior cruciate ligament (ACL) grafts reconstructed by isometric and anatomic reconstruction techniques, based on their length changes.
Methods: One hundred and thirty-three knees with primary ACL reconstruction using the bone-patellar tendon-bone (BTB) graft were retrospectively identified. Twenty-two knees and 111 knees underwent isometric round tunnel (IRT) ACL reconstruction and anatomic rectangular tunnel (ART) ACL reconstruction, respectively.
Results: After femoral-side fixation of the graft in the surgery, the length change of the graft from 120° flexion to full extension was measured by using an isometric positioner at the tibial side. Both reconstructive techniques showed little length change from 120° to ~20° of flexion, followed by elongation of the graft, until full extension. The amount of length change of the grafts was 1.0 ± 0.7 mm with the IRT technique, and 3.4 ± 0.9 mm with the ART technique. These findings were significantly different, based on the Mann–Whitney *U* test ($p < 0.001$).
Conclusion: The native ACL has an intrinsic length change of 3–6 mm, and therefore the ART technique may more closely replicate the biomechanical function of the native ACL.

Keywords: anterior cruciate ligament reconstruction; biomechanics; isometric; length change

Introduction

Anterior cruciate ligament (ACL) reconstruction is a common surgery to restore knee stability after the rupture of the ACL. A wide variety of surgical techniques have been developed with regard to graft selection, tunnel position, graft fixation, etc. The allograft and autogenous graft are both selectable. However, the hamstring tendon, quadriceps tendon, and bone-patellar tendon-bone (BTB) graft are available for the autogenous graft. The BTB graft especially has the advantage of bone-to-bone healing in the tunnel.[1]

The graft used to be placed in an isometric fashion,[2] based on the findings that isometric graft placement resulted in good anterior stability within 1 mm.[3] In this isometric reconstruction technique, the femoral socket was key in ensuring graft isometry. Previous studies revealed the anterior–superior border of the anatomical ACL footprint as the isometric point[4–6]; however, after overdrilling a guide pin that was inserted at the point, the tunnel aperture occupied mostly the outside of the footprint. Thus, these grafts, which were least

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anatomical and nonphysiological, resulted in several problems such as impingement against the intercondylar notch/wall or the posterior cruciate ligament,[7−9] and poor control in rotational stability because of vertical graft orientation.[10−12]

Several recent studies on the anatomy of the ACL revealed the location of the true anatomical ACL footprint.[13−15] After these findings, techniques on ACL reconstruction have changed toward an anatomy-oriented approach.[16−20] Anatomic ACL reconstruction have clinically shown favourable outcomes.[21−23] However, there is one concern in anatomic reconstruction: anatomically-reconstructed grafts may be exposed to excessive tensile stress during knee motion because of their reduced isometricity. In fact, studies using image analysis show that the theoretical length change of anatomically-reconstructed grafts was 3−6 mm.[24,25] In a clinical setting, Yonetani et al[26] compared the length change of the grafts of the isometric bi-socket technique and the length change of the low socket−two tunnel technique, which were performed during the transitional period from isometric to truly anatomic ACL reconstruction. Yonetani et al[26] found no significant difference in the length change between the two techniques, although the low socket−two tunnel technique showed a slightly greater length change. Therefore, increased concern for the grafts in anatomic reconstruction has remained unsolved.

Based on these facts, the length change of the grafts reconstructed by the current truly anatomical technique should be clarified to better understand the limitations and the potential for more improvements of the current reconstruction techniques. For this reason, this study compared the length change of the BTB grafts in two reconstruction techniques: (1) the isometric round tunnel (IRT) technique and (2) the anatomical rectangular tunnel (ART) technique. In the IRT technique, a femoral tunnel is created in a so-called isometric point in the conventional round shape. In the ART technique, tunnels are rectangular and created within the anatomical femoral and tibial footprints.[18,20] Our working hypothesis was that the length change of the grafts would be greater in the ART technique than in the IRT technique.

Materials and methods

Patients

One hundred and thirty-three knees that had undergone primary ACL reconstruction with BTB autogenous graft from 1996 to 2009 were retrospectively identified as the study subject. There were 107 males and 26 females, and their mean age was 21.5 years. At the ACL reconstruction, 63 patients had a lateral meniscal tear and 39 patients had a medial meniscal tear. Among patients with a lateral meniscal tear, 17 knees underwent meniscectomy and 46 knees underwent a meniscal repair. Among patients with a medial meniscal tear, 11 knees underwent meniscectomy and 28 knees underwent a meniscal repair.

With regard to the technique of ACL reconstruction, the IRT technique was performed between 1996 and 2001 on 22 knees, and the ART technique was performed after 2002 on 111 knees (Table 1). The mean age, male/female ratio, or meniscal intervention was not significantly different between the two groups.

Isometric round tunnel ACL reconstruction

After debriding the torn ACL remnants to provide clear visibility, a 2.4-mm guide pin was inserted from the medial tibial cortex to the centre of the anatomical ACL footprint with a tibial drill guide system (Smith & Nephew Inc., Endoscopy Division, Andover, MA, USA). The guide pin was overdrilled using a 10-mm cannulated drill. A 2.4-mm guide pin was thereafter inserted through the tibial tunnel at the 1-o'clock or 11-o'clock position (i.e., the so-called isometric point located at the superoanterior border of the anatomical ACL footprint and on the lateral wall of the intercondylar notch. The pin was overdrilled with a 9- or 10-mm cannulated reamer to 25 mm in depth, and further overdrilled to the anterolateral femoral cortex with a 4.5-mm drill bit to create a socket 25 mm deep.

A 10-mm-wide BTB graft was harvested from the central portion of the patellar tendon with 15-mm-long bone plugs on both ends. The graft, which included the bone plugs on both ends, was folded longitudinally. Two No. 3 braided polyester sutures were passed through the tibial bone plug and the EndoButton fixation device (Smith & Nephew Inc., Endoscopy Division), and were tied according to the length of the femoral tunnel. On the other side of the graft, two No. 3 braided polyester sutures were also passed through the bone−tendon junction. The graft was passed from the tibial tunnel to the femoral socket, and fixed with the EndoButton device at the femoral side. To evaluate notch impingement, the graft was arthroscopically investigated for any interference by the notch roof during the flexion-extension motion of the knee. There was no notch impingement on the graft in any patient; therefore, notchplasty was not performed.

Anatomic rectangular tunnel ACL reconstruction

The ART technique is precisely described in published articles.[18,20] In brief, after removing the ACL remnant, two 2.4-mm guide pins were inserted in parallel at a 5-mm distance at the anatomical femoral ACL footprint through the far anteromedial portal with the knee in deep flexion, and overdrilled with a 5-mm canulated reamer. A 5 mm × 10 mm

Table 1
Demographic data of the patients.

	IRT technique	ART technique
Patients	22	111
Mean age, y	23.7 (14−45)	21.1 (13.9−44.4)
Sex ratio, male/female	20/2	87/24
MMX	4	7
MMR	4	24
LMX	2	15
LMR	9	37

Data are presented as *n* or *n* (range) unless otherwise indicated.
ART = anterior cruciate ligament; IRT = isometric round tunnel; LMR = lateral meniscal repair; LMX = lateral meniscectomy; MMR = medial meniscal repair; MMX = medial meniscectomy.