The Knee 21 (2014) 471–476

Contents lists available at ScienceDirect

The Knee

Biomechanics of single-tunnel double-bundle anterior cruciate ligament reconstruction using fixation with a unique expandable interference screw

Hua-yang Huang [a,1], Yong-liang Ou [a,b,1], Ping-yue Li [a], Tao Zhang [a], Shuai Chen [a,b], Hong-yuan Shen [a], Qing Wang [a], Xiao-fei Zheng [a,*]

[a] Department of Orthopaedics, General Hospital of Guangzhou Military Command of PLA, Guangdong 510010, China
[b] Bioenginering Laboratory, Department of Orthopaedics, General Hospital of Guangzhou Military Command of PLA, Guangdong 510010, China

ARTICLE INFO

Article history:
Received 28 May 2013
Received in revised form 18 October 2013
Accepted 25 October 2013

Keywords:
Anterior cruciate ligament (ACL)
Biomechanics
Single-tunnel double-bundle
ACL reconstruction
Expandable interference screw

ABSTRACT

Background: Single-tunnel double-bundle (STDB) anterior cruciate ligament (ACL) reconstruction can restore biomechanical function and anatomic structure, but existing methods of graft fixation are not adequate. The aims of this study are to examine knee biomechanics after STDB reconstruction using a unique expandable interference screw for fixation.
Methods: The biomechanical parameters of six pairs of human cadaveric knee specimens were measured with the ACL intact, after ACL removal, and after STDB reconstruction using the interference screw or single-tunnel single-bundle (STSB) reconstruction. Anterior tibial translation under 134 N anterior tibial load in a neutral position as well as in 15° and 30° internal and external knee rotation and the internal tibial rotation angle under the rotatory load (5 N · m internal tibial rotation) were measured.
Results: Anterior tibial translations at each degree of knee flexion in the STDB group were significantly less than in the STSB group (all, $P < 0.05$). The internal rotation angles in the STSB group at five flexion angles were significantly higher than in the ACL intact group, whereas there were significantly less than those of the ACL absent group ($P < 0.05$). Under rotatory loads in the neutral position, the tibial internal rotation angles of the STDB group were significantly lower than in the STSB group at all flexion angles (all, $P < 0.05$).
Conclusions: STDB ACL reconstruction with the expandable interference screw provides better anteroposterior and rotational stability than STSB reconstruction.
Clinical relevance: The technique provides the advantages of double-bundle reconstruction using a single-tunnel technique.

1. Introduction

The ACL is generally considered to include two functional bundles; the anteromedial and the posterolateral bundles [1–4]. The anteromedial bundle and the posterolateral bundle provide anteroposterior and rotational stability to the knee joint [5–7]. The goal of ACL reconstruction is to recover anteroposterior and rotational stability. However, there is debate whether arthroscopic ACL reconstruction should be performed with single-tunnel single-bundle reconstruction or double-tunnel double-bundle reconstruction [8,9].

It has been reported that single-tunnel single-bundle reconstruction can restore anteroposterior stability, though it cannot completely restore anatomical function and is relatively poor for restoring rotational stability [10,11]. Double-tunnel double-bundle reconstruction can improve anteroposterior and rotational stability [12]. However, a double-tunnel double bundle reconstruction is difficult to perform, and requires a long operative time, tunnel positioning is prone to error, there is risk of fracture of the lateral femoral condyle and bone bridge fractures, and performing revision surgery is difficult [13,14]. For this reason, some surgeons have explored a single-tunnel double-bundle reconstruction with the goal of restoring the anatomical double-bundle structure of the ACL within a single tunnel. This technique overcomes the shortcomings of both double-tunnel double-bundle and single-tunnel single-bundle reconstruction (i.e., restores anteroposterior and rotational stability without the drawbacks of double-tunnel double bundle reconstructions) [15–17]. However, implants used to secure the femoral end of the ligament in single-tunnel double-bundle reconstruction may not provide satisfactory fixation strength [18]. A similar problem is not encountered with the tibial tunnel because the method of fixation is different. To overcome this

* Corresponding author at: Department of Orthopaedics, General Hospital of Guangzhou Military Command of PLA, No.111, Liu Hua Road, Guangzhou, Guangdong 510010, China. Tel.: +86 20 88654540, +86 13889904894; fax: +86 20 88653539.
E-mail address: doctorzhengxiaofei@hotmail.com (X. Zheng).

[1] These authors contributed equally to this work.

0968-0160/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.knee.2013.10.014

problem, we developed an expandable interference screw with increased fixation strength that exactly divides and fixes the two bundles in the tunnel in relatively anatomical locations.

The purpose of this study was to compare the biomechanical parameters of knees in which the ACL was reconstructed with standard single-tunnel single-bundle reconstruction with those of knees in which the ACL was reconstructed using a single-tunnel double-bundle technique with the expandable interference screw. Our hypothesis was that using the expandable interference screw in single-tunnel double-bundle ACL reconstruction can provide better anteroposterior and rotational stability than single-tunnel single-bundle reconstruction.

2. Materials and methods

2.1. Specimen preparation

This study was approved by the Institutional Review Board (IRB) of the Southern Medical University, Guangzhou, China. Six pairs of fresh frozen cadaver knee joint specimens preserved at −20° (four males, two females; mean donor age, 74 years, range, 56 to 82 y; mean weight, 72 kg, range, 48 to 96 kg) provided by the Department of Anatomy, Southern Medical University, China were used in the current study. Specimens with a history of knee surgery, limitation of joint movement, instability, absence of the meniscus, evidence of osteoarthritis, or with any of the following findings were not used: (1) Joint space narrowing; (2) Subchondral bone sclerosis; (3) Osteophyte formation in the joint margin; (4) Subchondral cystic changes; (5) Bone deformities including flat-bone change of the femoral head and (or) joint subluxation; (6) Varus and valgus deformities. The drawer test, Lachman test, pivot shift test, and varus and valgus stress tests were used to determine stability. The presence of osteoarthritis was determined by anteroposterior and lateral radiographs, and Kellgren and Lawrence grading was used [19]. For all specimens, the femoral shaft, tibia, and fibula were cut off 25 cm from the articular surface. The skin, muscle, ligament, joint capsule and other soft tissue structures 10 cm from the articular surface were preserved.

One knee joint out of each pair was randomly selected for arthroscopic single-tunnel single-bundle reconstruction, and the other received single-tunnel double-bundle. Biomechanical testing was performed with the ACL intact, after ACL removal, and after ACL reconstruction. All procedures and testing were completed the same day for each pair of specimens.

2.2. Biomechanical testing

A Bose® ElectroForce test instrument (Model 3520-AT) was installed in each knee joint, and a robotic system was used to apply force (Fig. 1). The femoral and tibial ends of the specimens were fixed to the device, and computer software controlled the movement of the displacement arm relative to the femur. The sensor in the specimen records and transmits force data to the computer, and the displacement can be read when the target load is reached.

After the specimen was installed, the robotic system was used to identify passive flexion of the knee under a zero load condition [18]. The passive position was defined as the knee position at which the sum of all forces and moments at the knee center are minimal (<5 N and <0.5 N · m, respectively), and thus the error of the measured parameters is also minimal. To minimize the difference between different groups, the motion trajectory with the ACL intact was used as the initial preloading trajectory.

Anterior tibial translation under a continuous stable anterior tibial load (134 N, 10 N/s) at 0°, 15°, 30°, 60°, and 90° of flexion in the neutral position, at 15° and 30° internal and external knee rotation, and the internal tibial rotation angle under a continuous rotatory load (5 N · m internal tibial rotation, 1 N · m/s) with the ACL intact, ACL absent, and ACL reconstructed were measured on each specimen. Subsequently, the anterior tibial translation under 134 N anterior tibial load in neutral position, the internal tibial rotation angle under the rotatory load (5 N · m

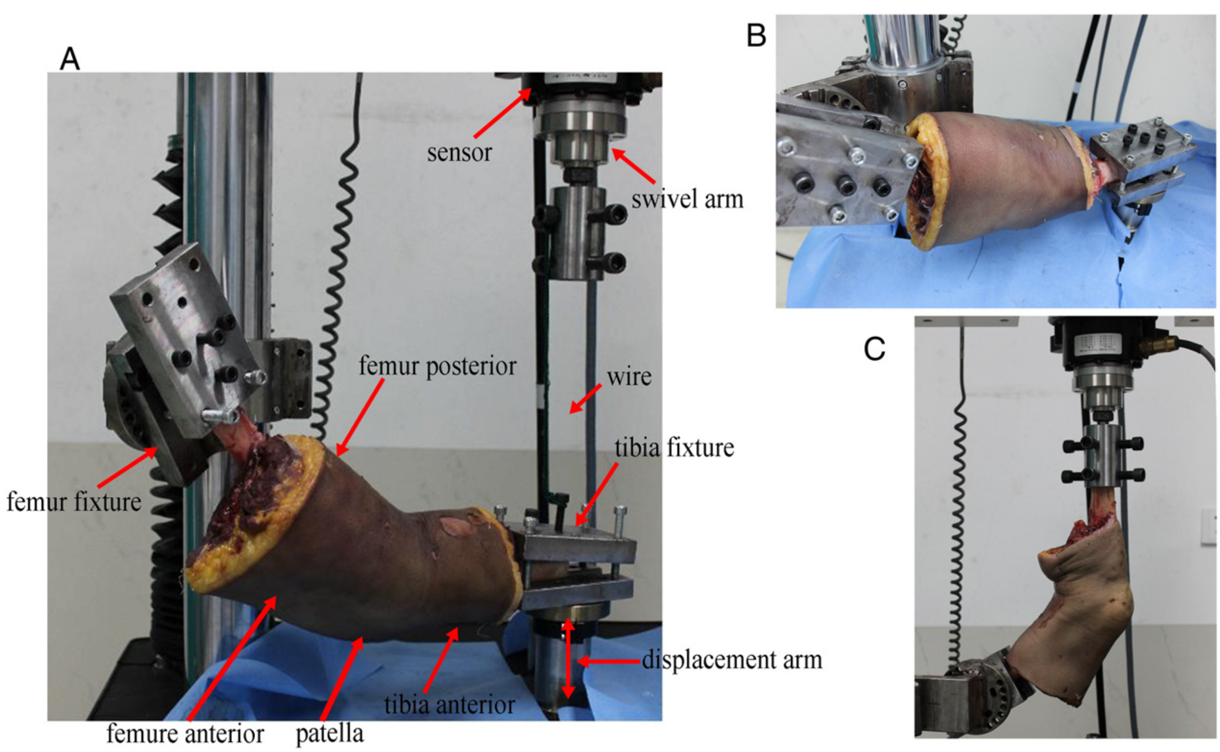

Fig. 1. A) Illustration of the device used to apply force. The femoral and tibial ends of the specimens were fixed to the device, and the displacement arm can move up and down 25 mm. Computer software controls the movement of the displacement arm. The sensor in the specimen records and transmits force data to the computer, and the displacement can be read when the target load is reached. The fixed rotation angle is set by manual measurement. B) Measurement of anterior tibial translation under a 134 N anterior tibial load in the neutral position at 15° knee flexion. C) Measurement of tibial internal rotation angle under a rotatory load (5 N · m tibial internal rotation) in the neutral position at 30° knee flexion.