Clinical Biomechanics 60 (2018) 60–65

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Adjustable-length loop cortical button versus interference screw fixation in quadriceps tendon anterior cruciate ligament reconstruction – A biomechanical in vitro study

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ARTICLE INFO

Keywords:
ACL reconstruction
Quadriceps tendon
ACL biomechanics
Adjustable loop device
Tibial fixation

ABSTRACT

Background: This biomechanical cadaveric in vitro study aimed to evaluate and compare the dynamic elongation behavior and ultimate failure strength of tibial adjustable-length loop cortical button versus interference screw fixation in quadriceps tendon-based anterior cruciate ligament reconstruction.

Methods: Sixteen human quadriceps tendons were harvested and fixed into porcine tibiae using either biodegradable interference screw (n = 8) or adjustable loop device (n = 8) fixation. An acrylic block was utilized for femoral adjustable loop device fixation for both groups. All constructs were precycled for 10 times at 0.5 Hz and manually retensioned before tested in position and force control mode each for 1000 cycles at 0.75 Hz according to in vitro loading conditions replicating the in vivo ACL environment. Subsequently, an ultimate failure test at 50 mm/min was performed with mode of failure noted.

Findings: Tibial IS fixation showed no statistically significant differences in the initial (−0.46 vs. −0.47 mm; P = 0.9780), dynamic (2.18 mm vs. 2.89 mm; P = 0,0661), and total elongation (1.72 mm vs. 2.42 mm; P = 0,0997) compared to adjustable loop device fixation. The tibial button fixation revealed an increased ultimate failure load (743.3 N vs. 606.3 N; P = 0.0027), while stiffness was decreased in comparison to screw fixation (133.2 N/mm vs. 153.5 N/mm; P = 0,0045).

Interpretation: Anterior cruciate ligament reconstruction for quadriceps tendon graft using a tibial adjustable-length loop cortical button provides for comparable dynamic stabilization of the knee with increased ultimate failure load at decreased stiffness compared to screw fixation.

1. Introduction

The choice of graft and fixation method in the anterior cruciate ligament (ACL) reconstruction surgery still remains a matter of debate. In the present study, ACL reconstruction techniques with an all-soft tissue single-bundle quadriceps tendon (QT) were used. The use of QT in ACL reconstruction was introduced by Blauth et al. and is considered stable, safe, and reproducible graft giving advantages over commonly used double-bundle hamstring tendon grafts, especially in revision cases (Blauth, 1984; Crall and Gilmer, 2015; Lee et al., 2004; Slone et al., 2015; Wirth and Kohn, 1996).

Despite several advantages, the QT autograft remains the least commonly used option among surgeons today. Using a central quadriceps free tendon can eliminate the described risk of patella fractures due to bone block harvest, leading to a reduction in operative time and easier postoperative rehabilitation with reduced anterior knee pain. However, this technique involves a larger suprapatellar incision (Lund et al., 2014; Theut et al., 2003).

Several options are available for tibial graft fixation; however, previous studies comparing the various techniques have provided controversial results (Kousa et al., 2003). Biodegradable interference screws allow for achieving high initial fixation strength with early osseous integration and accelerated postoperative recovery (Ettinger et al., 2014; Weiler et al., 1998). Graft slippage is a typical mode of

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https://doi.org/10.1016/j.clinbiomech.2018.10.001
Received 3 April 2018; Accepted 1 October 2018

failure within the screw–tendon–bone interface; thus, fixation strength is highly dependent on correct screw insertion angle and bone quality. Further possible adverse effects are graft damage, bone impaction, and screw fracture during insertion as well as compromised biological tendon integration due to a reduced graft–bone interface (Konan and Haddad, 2009).

Another reliable and popular option is the use of adjustable-length loop cortical button devices (ALDs). While first-generation ALDs were designed for femoral fixation, second-generation ALDs are also effective for tibial use (Lubowitz et al., 2011). Reverse tension devices are more commonly used due to the advantage that tensioning is possible from both sides of the graft at any degree of extension (Fabbri et al., 2017). Minimally invasive ACL reconstruction with ALDs allows for bone-saving tunnel preparation, graft retensioning after primary fixation, maximum graft–bone interface, and increased ultimate failure strength compared to screw fixation (Mayr et al., 2015; Milano et al., 2006).

Currently, however, biomechanical and clinical data with these configurations are very limited, especially in combination with ACL reconstruction using QT.

Therefore, this study aimed at evaluating and comparing the dynamic elongation behavior as well as ultimate failure strength of tibial ALD versus interference screw (IS) fixation in QT-based ACL reconstruction in a comprehensive biomechanical cadaveric in vitro study. A non-inferiority study design was used. It was hypothesized that tibial screw fixation would have less graft elongation during cyclic loading with lower ultimate failure loads compared to tibial ALD fixation (H_1). Our null hypothesis stated that no significant difference would be observed between both fixation methods (H_0).

2. Methods

2.1. Testing groups

An all-inside ACL reconstruction technique using human QT was tested and compared to a configuration with tibial-sided screw fixation (Fig. 1) using a biodegradable IS (Biocomposite, Arthrex Inc.). All other fixations were performed using an ALD (TightRope RT, Arthrex Inc.). The femoral fixation was the same for both groups, using an ALD. For each testing group, eight test samples were used, resulting in a total of 16 tests performed.

2.2. Specimen preparation

Fresh porcine tibias (age 8 months) were collected and prepared by removing all the soft tissue from the bone. The tibias were cut were 12 cm distal to the joint line. All obtained specimens showed no sign of previous injuries or diseases. Porcine tibias were chosen because of previously reported similarity to young adult humans (Aerssens et al., 1998). Embedding was carried out in line with the tibial tunnel axis using RenCast, a bicomponent embedding material (Huntsman Advanced Materials, Basel, Switzerland). To allow sufficient space for adjustable loop tensioning and screw insertion, a custom-made jig was used to embed 2 cm distal to the predetermined exit of the tibial tunnel axis. To ensure a constant tunnel length of 40 mm, a caliper and bone saw were used to measure and cut the lateral plateau perpendicular to the tibia tunnel axis. The embedded bones were stored at −20 °C and thawed at room temperature overnight before biomechanical testing.

Overall, 16 QTs were harvested from fresh frozen human cadaveric knees (7 male and 9 female cadavers), with an average age of 69.1 years. Those specimens that were affected by degenerative joint diseases or severe knee injuries were excluded and replaced. Tables 1 and 2 shows the donor-specific data.

All grafts were harvested in 90° flexion, giving full tension to the knee extensor apparatus [I]. After a vertical incision above the 60% medial line of the QT, the graft was removed superperiosteally from the patella using a Quad Tendon Graft-Cutting Guide and a Quad Tendon Stripper/Cutter (Arthrex Incorporation, Naples, FL, USA). The proximal cut of the QT reached the transition zone of muscle and tendon with at least a graft length and a diameter of 80 mm and 8.0–9.5 mm, respectively.

2.3. Graft preparation

After the removal of the grafts, the tendons were cleaned and sized to the desired length (screw group, 80 mm; button group, 70 mm). All tendons were free of damage. Eight specimens were prepared in the

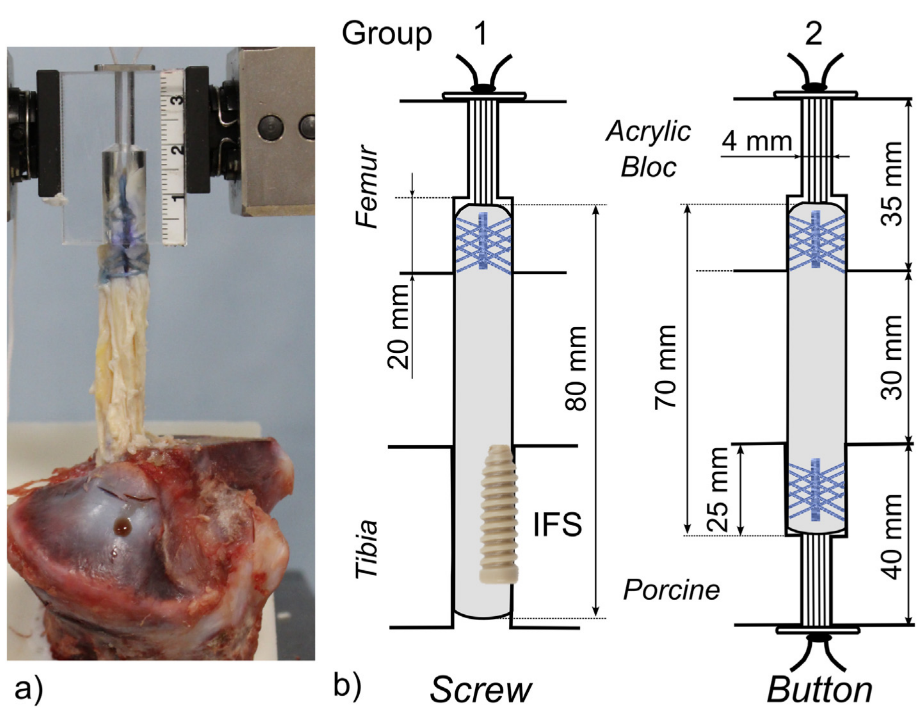

Fig. 1. Experimental setup showing the tibia with attached quadriceps tendon (a). Schematic illustration of bone tunnel and graft-related definitions (b).